

WALT DISNEY PICTURES AND WALDEN MEDIA PRESENT
A JAMES CAMERON FILM

The search
for life beyond
begins below.

ALIENS OF THE DEEP

EDUCATOR'S GUIDE

Dear Educator,

All my life, I have wondered what lay beyond the horizon – and below it. When I had the chance to travel to the ocean floor, to see the extraordinary creatures that thrive there, and to search for clues about the potential for life on other planets, I couldn't wait to go.

The movie I made about this journey, *Aliens of the Deep*, uses the dramatic sweep of the large-format screen to tell the story of an expedition to one of Earth's deepest, most extreme and unknown environments in search of the strange and alien creatures that live there.

Aliens of the Deep is the result of visually stunning expeditions to hydrothermal vent sites in the Atlantic and the Pacific. These are violent volcanic regions where new planet is literally being born and where the interaction between ocean and molten rock creates plumes of super-heated, chemically-charged water that serve as oases for animals unlike anything seen elsewhere. There, six-foot-tall worms with blood-red plumes, blind white crabs, and an inconceivable biomass of shrimp capable of “seeing” heat all compete to find just the right location in the flow of the super-heated, life-giving

water – or fry trying. These ecosystems are as close to alien as anything ever imagined, and provide one possible blueprint for life that might exist beyond our world.

Of course, I did not go alone. With me was a team of scientists from NASA and the National Science Foundation. We considered how the life forms we observed represent life that may one day be found in outer space – not only on distant planets orbiting distant stars, but also within our own solar system.

Aliens of the Deep is a compelling teaching tool. Watching this film and participating in the thought-provoking activities in this Guide will engage and motivate your students. Both deep-ocean and space research are interdisciplinary, as are the topics presented here, all linked to national education standards. This Guide will lead your class to greater insight into the mysteries of life in extreme environments and the potential for discovering life in outer space.

Enjoy the adventure!

James Cameron



ALIENS OF THE DEEP

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HOW TO USE THIS GUIDE:

The activities in this Guide are designed for students in grades 5–8. The Guide may be used before or after viewing the film. Activities and material in this Guide may be reproduced for use in the classroom.



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Photograph on p. 4 of *Deinococcus radiodurans* © Drs. Michael J. Daly and Alexander I. Vasilenko, Dept. of Pathology, Uniformed Services University of the Health Sciences, Bethesda, MD.

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Some activities in this guide were adapted from *Life on Earth... and Elsewhere?* an Educator’s Guide from the NASA Astrobiology Institute.

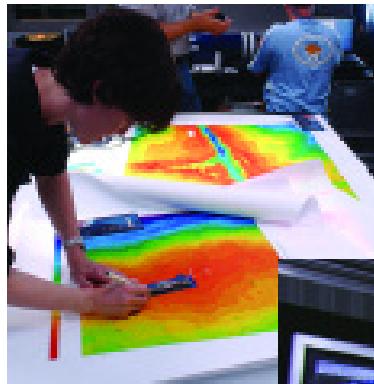
ABOUT THE MOVIE

MEET THE EXPLORERS

In *Aliens of the Deep*, Academy Award®-winning director, deep-ocean adventurer, and space-exploration visionary James Cameron invites you to join him and a team of space and ocean scientists on a journey to the depths of the ocean. You will travel to seafloor hydrothermal vents in the Atlantic and Pacific oceans to see some of the most amazing rock formations and strangest life forms on our planet.

Aliens of the Deep provides a first-hand look into James Cameron's passion for exploration, the extreme machines that allow humans to explore the deep, and the possibilities that lie both below and beyond the horizon. The expedition team helps us consider the connections between life under water and life we may one day find in space.

Scientists from many fields joined James Cameron's expedition. The crew included **astrobiologists**, **marine biologists**, **planetary scientists**, and **geophysicists**.



Mission scientists (left to right) Dijanna Figueroa, Maya Tolstoy, Pan Conrad, Kevin Hand, Kelly Snook, and Tori Hoehler, at work during the *Aliens of the Deep* expedition.



Astrobiologists use many different disciplines and technologies to try to answer such questions as: "Does life exist elsewhere in the universe?" and "What is life's future on Earth and beyond?"

For the first time in human history, advances in the biological sciences, space exploration, and space technology will make it possible for us to answer such questions.

PAN CONRAD is a Senior Astrobiologist at NASA. "I think if we're going to try to get evidence of life on another planet, we've certainly got to look for evidence of life on our own first," she says. "It's the only sample we've got. Every kid who grew up loving science fiction as I did has the idea that there should be a point-and-shoot device that you could take to another planet that would say 'Aha! There's life over there.' So we set about trying to come up with that device."

TORI HOEHLER is a researcher on the NASA Astrobiology Institute Lead Team at the NASA Ames Research Center. He wants to understand how living organisms affect the

chemistry of their environment. "The chemistry and biology of Earth's deep-sea vents help us understand what life could be like on other worlds. In many ways, a trip inside a research sub must be like a trip inside a spacecraft: cramped and tight; surrounded by electronics upon which your very life depends; descending through blackness with only a tiny window on the outside world; and yet, at the very end, the reward of seeing things from a completely new perspective."

Marine biologists study marine organisms, especially their behavior and interaction with their environment.

DIJANNA FIGUEROA is a marine biology graduate student at the University of California at Santa Barbara. She studies how deep-sea mussels adapt to their harsh environments. On the *Aliens of the Deep* expedition, Dijanna focused on mussels' uptake of oxygen and different nutrients and tried to learn more about what makes vent mussels different from their shallow-water cousins. "I think I have one of the coolest jobs," she says. "I get to go to the bottom of the ocean, see these animals, and figure out how they work."

Geophysicists study the structure and composition of the Earth. Using complex instruments to measure the Earth's properties, they work to better understand how our planet is put together.

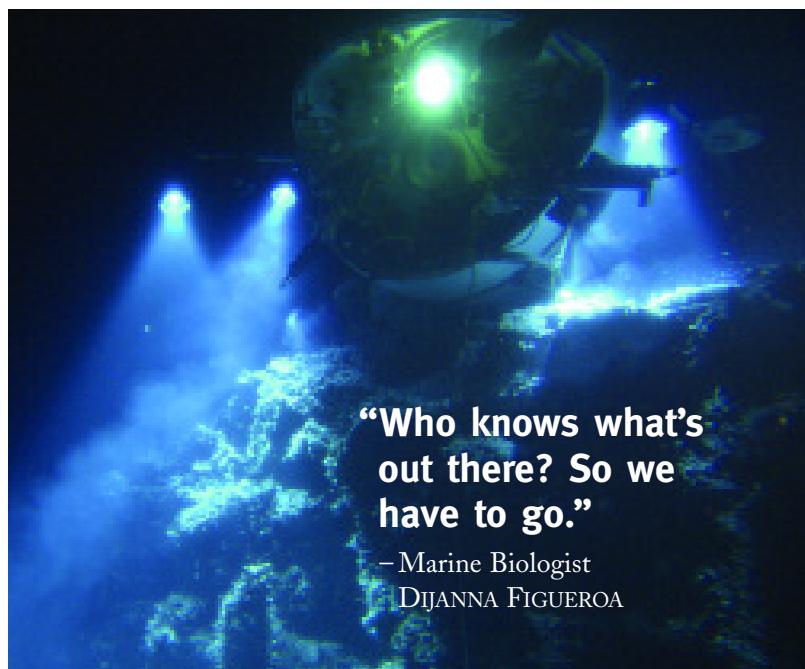
MAYA TOLSTOY is a geophysicist and marine seismologist at Lamont-Doherty Earth Observatory in New York. Maya usually stays on the surface when she goes to sea, sending down instruments to study earthquakes on the ocean floor – a key to determining how the Earth's surface was formed. On the *Aliens of the Deep* expedition, Maya was able to travel to the seafloor for the first time. "For me, the opportunity to dive was fantastic. It was the opportunity for the astronomer to become an astronaut."



Planetary scientists study the origin and evolution of our sun's family of planets and of solar systems in general.

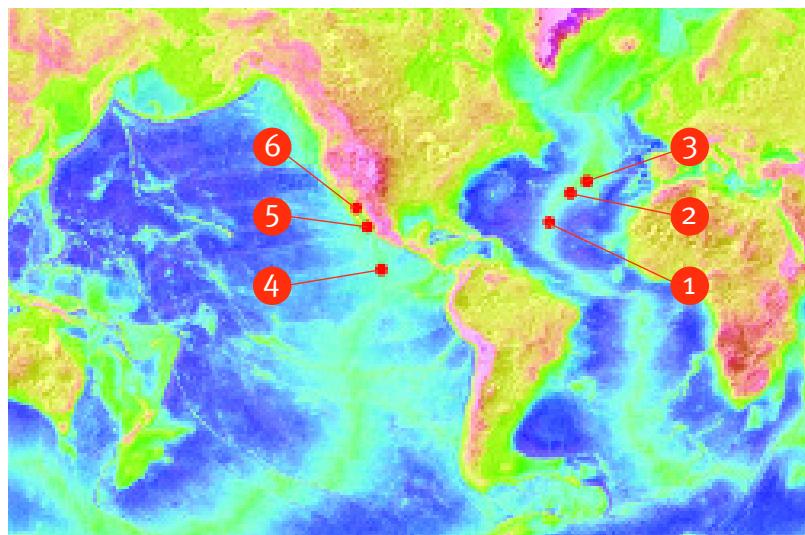
KEVIN HAND is a graduate student in geology at Stanford University in California. His research focus is on the possibility of life on Europa, one of Jupiter's moons. His dives with the *Aliens of the Deep* expedition gave him his first view of the seafloor and helped him consider the possible connections between Earth's deep-sea vents and the life-supporting processes of other planetary bodies. "Diving in the Rovers is an absolutely incredible experience," he says, "because you see EVERYTHING around you."

KELLY SNOOK is a planetary scientist at NASA's Johnson Space Center in Houston. She develops programs that study the Earth and the Moon to prepare for the eventual exploration of Mars. On the *Aliens of the Deep* expedition, Kelly kept dive records and discussed dive results via satellite phone with her NASA colleagues in Houston, as if she were in space and they were in "Mission Control" on Earth. Kelly's goal is to "learn how to explore space without leaving the Earth." To her, the submersible is like a vehicle on Mars, so "we were using this as an opportunity to learn lessons about space."



"Who knows what's out there? So we have to go."

— Marine Biologist
DIJANNA FIGUEROA



Tracking the Exploration

If you looked at the Earth from space, and could make the ocean invisible, you'd see huge ridges running like zippers along the floor of the Atlantic and Pacific oceans. These are chains of underwater volcanoes where the Earth literally spreads apart at the seams as magma presses up from deeper within the crust to form a new seafloor surface.

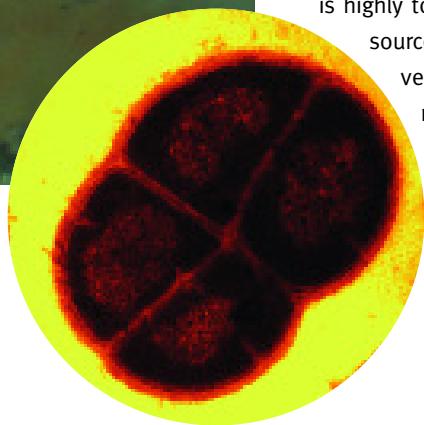
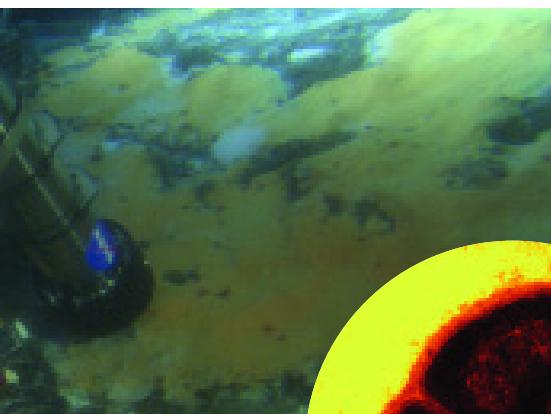
Dives during the *Aliens of the Deep* expedition took place at several volcanically-active areas. In the Atlantic Ocean, dives were made at Lost City (1), Snake Pit (2), and Menez Gwen (3). In the Pacific Ocean, dives were made at 9°N (4), at 21°N (5), and at Guaymas Basin (6).

ABOUT THE MOVIE

MEET THE ALIENS OF THE DEEP

Before scientists first traveled to hydrothermal vent sites in person in 1977, they thought these areas were lifeless. How could a living thing possibly survive — miles beneath the surface, in total darkness, under immense pressure, and near super-heated, poison-filled water that reaches more than 345° Celsius (650° Fahrenheit)? Yet hydrothermal vents and the areas around them are full of life. Vent creatures survive in one of the most hostile environments on the planet. It is their ability to survive under seemingly impossible conditions that makes these organisms so fascinating, not only to marine scientists, but to planetary scientists and astrobiologists as well.

Meet some of the strange and amazing organisms of the hydrothermal vent world.



MICROBES drive the vent food chain. A “mat” of microbes, the orange-white coating on the seafloor, is shown at left; the example below is magnified 500 times. Vent microbes grow by using the chemicals in vent fluids (like hydrogen sulfide, which is highly toxic to humans) as an energy source. Some microbes survive in very high-temperature environments — up to about 121°C (250°F) — hot enough to boil an egg in a few minutes! — so they can live closest to the vent fluid source, which may reach 350°C (662°F).



VENT MUSSELS (*Bathymodiolus thermophilus*) are usually found at vent openings where seawater and vent fluid mix. Mussels can “farm” bacteria inside their own bodies, or filter bacteria from surrounding water. This dual feeding method may help them survive longer than other organisms do if venting stops at a site.

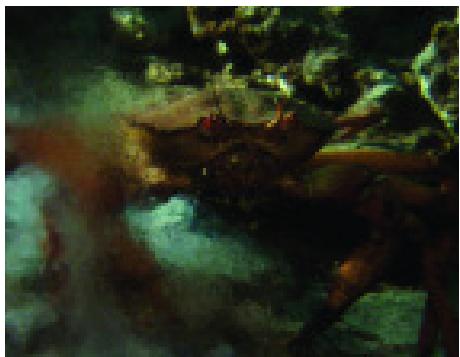
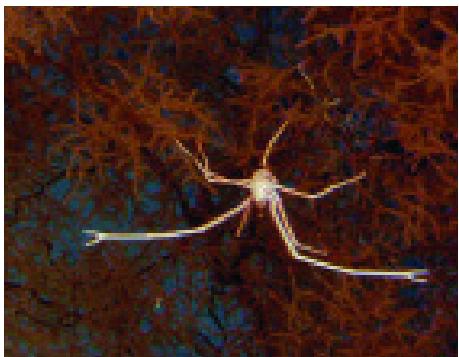
VENT SHRIMP (*Rimicaris exoculata*) swarm on and near smoker chimneys. Each shrimp has a light-sensitive patch on its back that might lure it toward the very, very faint glow hydrothermal vents give off. Vent shrimp like this have not been found in the Pacific Ocean to date.

“They are as close to alien life as anything seen on Earth — a clue to what might exist elsewhere.”

— James Cameron



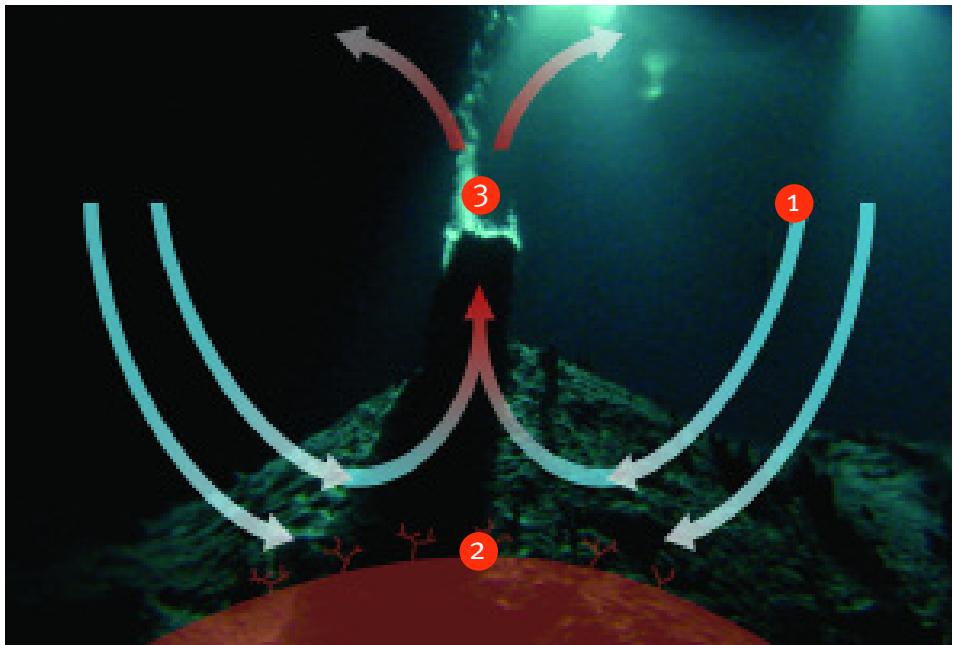
TUBEWORMS (*Riftia pachyptila*) may grow as tall as a person. They are found in places where both cold, oxygen-rich seawater and warm hydrogen sulfide-rich vent fluid flow past. Their red plumes take in oxygen from seawater and hydrogen sulfide from vent fluid. Tubeworms have no stomachs or mouths. They take in nutrition by “farming” bacteria inside their own bodies, which in turn live on hydrogen sulfide present there. *Riftia pachyptila* were found during the Pacific Ocean portion of the *Aliens of the Deep* expedition. Different species of tubeworms have been found at many hydrothermal vent sites around the world. But no tubeworms have been found so far at any of the hydrothermal vents on the Mid-Atlantic Ridge.



CREATURES OF THE DEEP (moving clockwise) such as this **SPIDER CRAB**, **DEEP-SEA CRAB**, **ANGLERFISH**, **BRISINGID STARFISH**, and **VENT ANEMONE** are sometimes found living near vent communities. Because of all the food produced by bacteria at the vents, many deep sea animals may live near, or visit the vents to feed.



How does a hydrothermal vent form?



1. Cold sea water passes down through cracks in the Earth's crust.
2. The water is heated by underground plumes of hot magma. The superheated water carries chemicals and minerals. Now it is hydrothermal fluid.
3. The superheated and now buoyant hydrothermal fluid rises back up through other seafloor cracks. As it rises, it mixes with cold bottom water, deposits minerals, and chimneys form.

Hydrothermal vents are found at volcanically-active areas on the seafloor where water seeps down through cracks. The water goes through a series of chemical reactions with subsurface rocks. This creates hydrothermal fluid, a mixture of water, chemicals and minerals, which vents upward through seafloor cracks. When hydrothermal fluid mixes with cold bottom water, mineral particles form and it looks like smoke is coming out of the chimneys. The chimneys are formed from these particles, deposited as the water rises from the sea floor.

Hydrothermal vents are home to an array of bizarre rock formations and life forms. Most organisms on Earth live off energy from the sun. But the energy driving these communities is in the toxic chemicals of the hydrothermal fluid. Some scientists believe that hydrothermal vents may hold clues to the history of life on Earth and could provide a blueprint for life we may one day find on other planets.

EDUCATIONAL ACTIVITIES

The activities in this section will help you and your students explore some of the scientific concepts presented in the film. You may want to reproduce a few sets of these pages for the class to read together. When reviewing “Meet the Explorers” (pages 2–3), focus with your students on the various scientists’ specialties. Students may want to do further library research to learn more about these different fields of research. “Meet the Aliens of the Deep” (pages 4–5) might prompt students to do further library research on the various organisms described. “What Does Life Need to Live?” (page 7) will help you prepare students for the series of investigations presented in the rest of this guide. “Is There Life on Other Planets?” (pages 8–9) invites students to imagine the types

of organisms that may someday be found elsewhere in the universe. “What Can Life Tolerate?” (pages 10–11) introduces students to the research techniques that astrobiologists and planetary scientists use. These researchers look for environments on Earth that match the extreme conditions that may be found on other planets. “The Goldilocks Planet: What Makes a Planet Habitable?” (pages 12–13) helps students explore the qualities that may make a planet “just right” to host life. Finally, “Breaking News: A New Space Discovery” (pages 14–15) is an interdisciplinary activity that invites students to combine their research and their imaginations to create “news articles” about the future discovery of life in space.



Vent crabs scavenge around tubeworms.

Standards and Correlations

All lessons correlate to national standards taken from the National Science Education Standards (NSES) or those developed by the National Council of Teachers of English and the International Reading Association (NCTE/IRA).

	WHAT DOES LIFE NEED TO LIVE?	IS THERE LIFE ON OTHER PLANETS?	WHAT CAN LIFE TOLERATE?	THE “GOLDILOCKS” PLANET	BREAKING NEWS
NSES					
SCIENCE AS INQUIRY	●	●	●	●	●
LIFE SCIENCE	●	●	●	●	
EARTH AND SPACE SCIENCE	●	●		●	
PHYSICAL SCIENCE				●	
NCTE/IRA					
COMMUNICATION STRATEGIES					●
EVALUATING DATA					●

WHAT DOES LIFE NEED TO LIVE?

GRADE LEVEL: 5–8

SUBJECT: Science

NATIONAL STANDARDS: NSES: Science as Inquiry, Life Science, Earth and Space Science

MATERIALS: None

DURATION: 45 minutes



A Guided Classroom Discussion

Begin by asking students, “What do living things need in order to live?” Create a list of the students’ ideas. The list should include requirements such as water, an energy source (e.g., light, chemicals and food, including carbohydrates, fats, or sugars), other nutrients (e.g., minerals, vitamins, gases, and chemicals, including substances found in seawater, soil and fertilizer), and a habitat (e.g., livable suitable temperature range, protection). Ask students, “Where would organisms get these types of materials?” Again, create a class list. The list should include sunlight, chemicals, food and other organisms for energy; and soil, lakes, oceans, air, food, and other organisms for nutrients.

Discuss with students the strengths and weaknesses of the argument that if all life on Earth requires energy, raw materials, and water, then extraterrestrial life must require the same things.

Additional Classroom Activity

Have the students work in groups of four and produce the information described above in a chart. On the left side, students should list what every living thing needs (water, energy source, nutrients). Then, on the right side, students should identify where an organism might get these things.

Science Background – Is Water Necessary for Life?

Scientists have agreed to search for life only where they think liquid water is likely to exist now or to have existed in the past. The insistence on liquid water is because water has a very unique set of properties that make it a good solvent for the kind of chemistry needed for life. Liquid water is an important vehicle for transporting and delivering dissolved chemicals to all parts of a living organism. It is also an important chemical reactant in its own right.

Scientists believe it is unlikely that the complex chemistry required to form living organisms could occur when molecules are locked in ice. Although some scientists have considered a few other solvents such as ammonia or a silicon-based solvent, most scientists agree that life in our solar system would likely be akin to the carbon-based life here on Earth and therefore require liquid water. Scientists note that over 80% of our own bodies consist of water, and that water is incompressible – it does not shrink much under pressure. This is important for animals living under high pressure.



Vent scenes captured during the filming of *Aliens of the Deep* include: a Pacific vent chimney (left); tubeworms (center); and a rock, plus crab, being sampled by a submersible's robotic arm (right).

IS THERE LIFE ON OTHER PLANETS?

GRADE LEVEL: 5–8

SUBJECT: Science

NATIONAL STANDARDS: NSES: Science as Inquiry, Life Science, Earth and Space Science

MATERIALS: None

DURATION: 45 minutes

Objective

Students consider the possibility of life – simple to technological – in our galaxy.

Activity

Students create a drawing of an organism that might be found on Jupiter's moon Europa and describe how it is uniquely adapted to that environment.

Classroom Discussion

Here are some suggestions for framing a class discussion about what students think when they hear the term "extraterrestrial."

- Ask: "Do you think Earth is the only place in the universe where life exists? The only place in the solar system?" (*Answers will vary.*)
- Ask: "How far from Earth do you think we would have to go to find the nearest life? The nearest intelligent life?" (*Answers will vary.*)
- Ask: "What sort of life form do you think is most abundant in the universe?" (*Answers will vary.*)

Explain that astrobiology is a branch of science that involves thinking about whether or not there is extraterrestrial life, where it might be, and how we can learn more about it.

Assessment

Can students describe why finding extraterrestrial life and observing its adaptations will be breakthrough discoveries?

Science Background – Adaptations

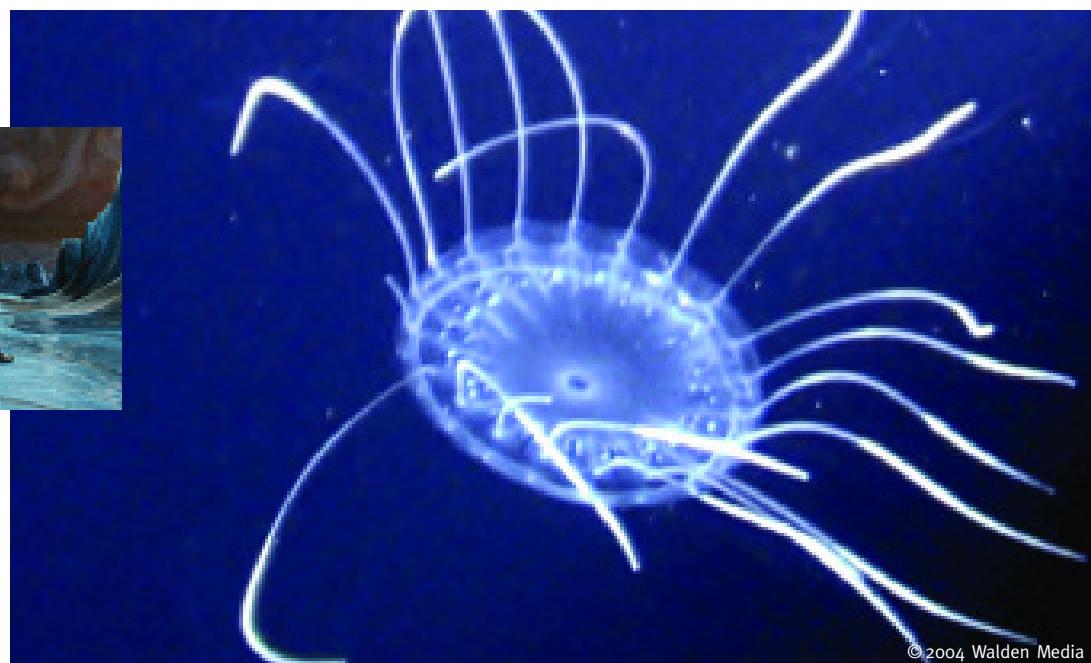
Some scientists feel that studying extreme organisms on Earth is the most effective way to understand the extent to which other planets in the solar system (and beyond) might be considered habitable (i.e., capable of supporting life). All living things are adapted to their environments. Adaptations include any genetic characteristics that allow an organism to survive and reproduce in a given environment. Bacteria have found ways to adapt and thrive in almost every extreme environment on Earth, from caves far beneath Earth's surface to hot springs at near-boiling temperatures. Bacteria have also adapted to conditions deep beneath the surface of the ocean, beyond the reach of direct sunlight. Bacteria near deep-sea vents have no access to sunlight. These organisms have acquired a kind of energy adaptation; they use the energy in chemicals like hydrogen sulfide to make food molecules. Chemicals, not sunlight, provide the primary source of energy that powers the food chain.

Because conditions on other planets may be very different from those on Earth, extraterrestrial organisms may have unusual characteristics, making them less recognizable to scientists. In order to search for such different kinds of life, astrobiologists must be very creative (using everything they have learned about the wide range of unusual organisms on Earth, and then using their imaginations to expand on their knowledge) in considering where to look and what kinds of missions, tools, and evidence might be used to find "extraterrestrial life."

Solissimus jellyfish.



Spacecraft like this may someday explore Jupiter's moon Europa.



IS THERE LIFE ON OTHER PLANETS?

NAME _____ DATE _____

Imagine a remotely-operated vehicle that could explore oceans on other planets or moons. What kinds of living things might it find? Would they be microbes (single-celled creatures) or multicellular organisms? How would they live? In this activity, imagine that a spacecraft landed on Jupiter's moon Europa and found life. Your job is to describe an extraterrestrial creature that might possibly be found on that moon.

Procedure:

1. Do research to learn about Jupiter's moon Europa. (For example, find out what it is made of, whether there are undersea volcanoes, etc.)
2. Based on Europa's conditions and potential habitats for life, begin to imagine a creature that could live there. Describe its habitat and how it survives. Where does it get nutrients and energy?
3. Make a sketch of your creature. Be able to answer the following questions:
 - How does it "eat" (convert energy)?
 - Is it made of one cell or many?

- What type of "support systems" does it have in its body? (Bones? Cartilage? Tissue? Exoskeleton? Other?)
- How does it move?
- How does it protect itself?
- What kinds of senses does it have? (Show structures on your diagram.)

Be able to explain how your creature is adapted to its environment.

4. Create a poster, sculpture, or digital image, and a report about your extraterrestrial.

Invent a Creature

Write a description of your imaginary creature. Be sure to answer all the the questions in Step 3, above.

WHAT CAN LIFE TOLERATE?

GRADE LEVEL: 5-8

SUBJECT: Science

NATIONAL STANDARDS: NSES: Science as Inquiry, Life Science

MATERIALS: None

DURATION: 45 minutes

Objective

To show that organisms living under extreme conditions on Earth can serve as analogs for extraterrestrial life, and can help us understand the limits for those types of environments that can support life and those that cannot.

Activity

In this activity, students look at different extreme environments in which organisms live. Students consider ways in which these environments and the organisms found in them could provide clues for the environments in space in which life might be found.

Classroom Discussion

Have students read the information about extremophiles. Place the following table where students can see it. Have the students refer to the information on the student sheet to complete the table. This table is filled in for your benefit.

Afterwards discuss the following:

- Could humans be considered extremophiles? Explain.
- If you were able to send a test tube of one kind of extremophile in your chart to Mars, which would you choose? Why? If you were able to send a test tube of one kind of extremophile to Europa, which would you choose? Why?

Assessment

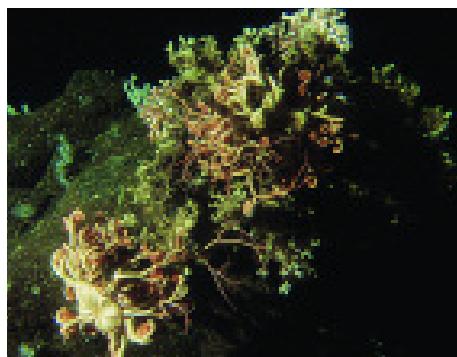
Have students describe how life and conditions on Earth can be used as a model for life on other worlds.

Science Background – Extremophiles

Thanks to advancing technologies, scientists have discovered organisms that live under conditions previously considered extreme and uninhabitable. These bacteria and bacteria-like organisms are called extremophiles. Many of these organisms have adapted ingenious ways to exist in spite of these environmental constraints. For example, organisms that live near hydrothermal vents survive in high-pressure environments, in water with a much higher boiling point than what is found nearer to the surface. Organisms in extremely cold environments may create their own “anti-freeze” and use it to protect their cells. Some microbes reproduce very rapidly, with as little as twenty minutes between generations. Such microbes rapidly pass on genetic variations that increase survivability.

Why are all extremophiles either bacteria or bacteria-like, rather than like cockroaches, plants, or us? Mostly because these microbes have amazing survival strategies that allow them to inhabit many diverse environments.

Environmental Condition	Maximum Known Level Tolerated by Life	Minimum Known Level Tolerated by Life	Typical Level for Human Body
TEMPERATURE	121°C [250°F]	-15°C [5°F]	37°C [98.6°F]
ACIDITY	pH 0 (most acidic)	pH 11 (most basic)	pH 5-8
SALT LEVELS	30%	0%	3.5%
RADIATION LEVELS	5 million rads		



WHAT CAN LIFE TOLERATE?

NAME _____

DATE _____

Some scientists think that life may have begun on Earth in the extreme environments of the hydrothermal vents far beneath the ocean's surface. If organisms on Earth can thrive under extreme conditions, maybe organisms live under similar conditions on other worlds. As we explore the worlds in our solar system, we find many more environments that are "extreme" than we do environments that would be suitable for animal or plant-type life. For that reason, Earth's extremophiles may serve as the best model for life that might exist elsewhere in the solar system.

Extremophiles are microbes that not only tolerate extreme conditions (extreme by human standards, anyway), but they require them! If you put most of them in the kinds of conditions we like, they would die.

Most Extreme Known

HOTTEST	121°C [250°F]	Archaea Strain 121 (first collected at a deep-sea vent off Puget Sound, WA in 2003).
COLDEST	-15°C [5°F]	Cryptoendolithotrophs (Antarctica)
DEEPEST UNDERGROUND	3.2 km underground [approximately 2 miles]	These microbes live between rock grains in Earth's crust and are exposed to high levels of pressure, heat, and radiation.
MOST ACIDIC	pH 0.0	Unclassified microbes that grow in caves. This is about as acidic as battery acid. Most life lives in a pH range of 5 to 8. Very acid conditions are found at hot springs.
MOST BASIC	pH 11	Alkaliphilic microbes are found where large bodies of water have evaporated and left behind layers of alkaline (basic) minerals, such as at Mono Lake, CA.
HIGHEST RADIATION DOSE	5 million rads	<i>Deinococcus radiodurans</i> is a common soil organism. A dose of 1000 rads will kill a person.
LONGEST PERIOD IN SPACE	6 years	<i>Bacillus subtilis</i> living in a NASA satellite that exposed test organisms to extreme conditions of outer space.
HIGHEST PRESSURE	1200 times atmospheric pressure	This was a bacillus living at the bottom of the Marianas Trench, the deepest point beneath Earth's surface.
SALTIES	30% salt	Halophilic organisms live in water with a 30% salt content. Seawater and human blood are 3.5% salt.

THE “GOLDILOCKS” PLANET: WHAT MAKES A PLANET HABITABLE?

GRADE LEVEL: 5–8

SUBJECT: Science

NATIONAL STANDARDS: NSES: Science as Inquiry, Life Science, Earth and Space Science, Physical Science

MATERIALS: None

DURATION: 45 minutes

Objective

Students will assess the possibility of the existence of life on other planets or moons in our solar system.

Activity

Students research the physical conditions on different moons and planets and rank them according to their habitability.

Classroom Discussion

Begin this class by reviewing the key habitability factors (see Science Background) for making a planet or moon a good home for living things. You might review by asking:

- In general terms, what do living things need? (*Living things need energy, nutrients, liquid water, and a clement habitat.*)
- What kinds of things might limit life? (*Extreme temperatures, high levels of radiation, such as ultraviolet radiation, and a lack of food or liquid water can limit life.*)

Students will need reference materials in order to complete this activity.

Assessment

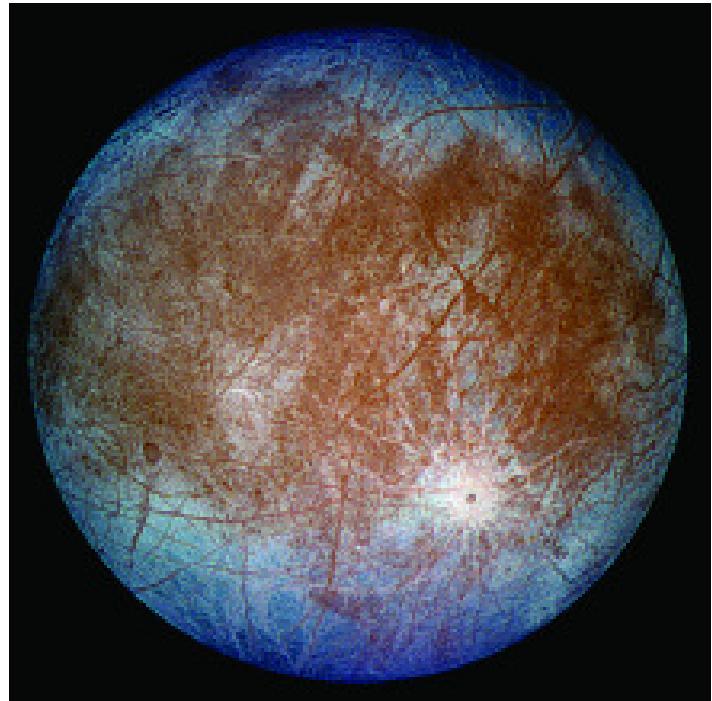
Can students select three candidates for planets or moons on which life might be found? Can students articulate the reasons behind their choices?

Science Background — Key Habitability Factors

Temperature: Life on Earth seems to be limited to temperatures between -15°C and 121°C (between 5°F and 239°F). At 125°C (257°F), proteins, carbohydrates, and nucleic acids start to break down. Cold temperatures cause chemicals in cells to react too slowly to support the reactions necessary for life.

Water: Life as we know it requires liquid water. On a cold planet or moon, there must be internal heat to melt ice or permafrost. On a hot planet or moon, water will boil away or evaporate unless it is far beneath the surface.

Atmosphere: Atmospheres can insulate and protect life from harmful ultraviolet radiation and from small and medium-size meteorite impacts. In addition, an atmosphere can serve as an important source of biochemicals, such as carbon from



Jupiter's moon Europa

carbon dioxide. Atmospheres can also provide an insulating “greenhouse effect.” They act like a blanket that holds a planet’s heat close to the surface. Atmospheric pressure also helps keep water in liquid form.

Energy: Organisms use either light or chemical energy to run their life processes. Microbes that exist where sunlight is unavailable as a direct source of energy can obtain energy by breaking down a broad array of chemical compounds.

Nutrients: The Earth’s geological processes, such as volcanic activity, plate tectonics, and the cycling of liquid water enable the cycling of chemicals like phosphorus, sulfur, carbon, and water to make them readily available to the organisms in the various habitats on our planet. Likewise, other planets and moons would have to have some way of providing these raw materials for organisms if they are to be habitable in ways similar to Earth.

THE “GOLDILOCKS” PLANET: WHAT MAKES A PLANET HABITABLE?

NAME _____

DATE _____

The movie *Aliens of the Deep* presents an ecosystem that gets its energy for life from chemicals and heat. Scientists study vent ecosystems as models to help them imagine habitats on other worlds. But where in the solar system should we begin to look? One way astrobiologists narrow the number of possible “hiding places” for life is to understand what makes conditions on a planet or moon “just right” for habitation. Then they study the habitable places very closely.

In this activity you will rank each planet or moon listed below as a likely, unlikely, or possible candidate for life.

Procedure:

1. Use reference materials to find the physical conditions of each of the planets and moons listed below.
2. Fill in the table.
3. Select three candidates where life might possibly be found and state your reasons for your choices.

PLANET/MOON	Life is Likely	Life is Possible	Life is Unlikely	Why?
MERCURY				
VENUS				
EARTH				
EARTH’S MOON				
MARS				
JUPITER				
JUPITER’S MOON IO				
JUPITER’S MOON EUROPA				
JUPITER’S MOON GANYMEDE				
JUPITER’S MOON CALLISTO				
SATURN				
SATURN’S MOON TITAN				
URANUS				
NEPTUNE				
PLUTO				

BREAKING NEWS: A NEW SPACE DISCOVERY

GRADE LEVEL: 5–8

SUBJECT: Language Arts

NATIONAL STANDARDS: NSES: Science as Inquiry; NCTE/IRA: Communication Strategies; Evaluating Data

MATERIALS: None

DURATION: 45 minutes

Objective

Students will apply knowledge gained from previous lessons to write a news story. Students will also understand the structure of a news story – the five Ws and H.

Activity

Students will review the previous lessons and use the knowledge they have gained to write a newspaper article about a space exploration event that occurs in 2055.

Classroom Discussion

Review with your class the highlights from lessons 1–3.

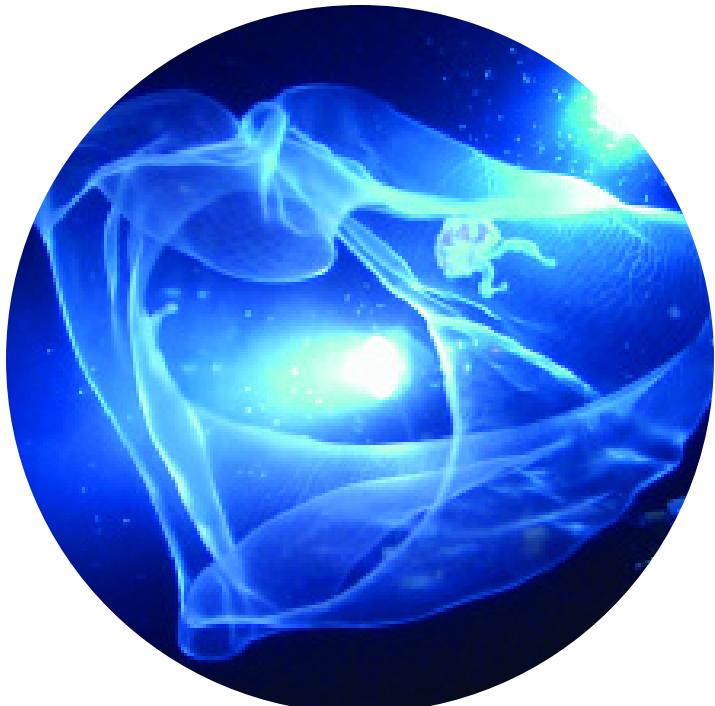
- Exploration 1: What Does Life Need to Live?
- Exploration 2: Is There Life on Other Planets?
- Exploration 3: What Can Life Tolerate?
- Exploration 4: The “Goldilocks” Planet – What Makes a Planet Habitable?

Have students imagine what space exploration will be like fifty years from now, in the year 2055. Could scientists discover new planets and life forms? Will life be found on Europa?

Review with students the elements of a good news story. These include an attention-getting headline, a well-written lead, a story that informs, and details and information that are credited to sources, such as specific documents or individuals. Review the five Ws and H of a news story – who, what, when, where, why and how.

Assessment

Assess students' writing based on their understanding of the five Ws and H of a news story and their comprehension and incorporation of the science objectives covered in the previous lessons.



Animals observed during the *Aliens of the Deep* dives include (top) a jelly animal the explorers called the “Space Bagel,” also known as *Deepstaria enigmatica*, and (bottom) a deep-sea octopus called *Opistoteuthis agassizii* (or “Dumbo” for short).



BREAKING NEWS: A NEW SPACE DISCOVERY

NAME _____ DATE _____

Imagine it is the year 2055. You are a reporter who has been assigned to cover breaking news about the latest space discovery (for example: a new planet, organism, or solar system). Using what you've learned about habitable planets, extremophiles, and the necessities of life, write an article on a separate piece of paper about what has been discovered out in space.

Remember the elements of a good news story: an attention-getting headline; an engaging, well-written lead; a story that informs; and details and information that are credited to sources, such as specific documents or individuals. Use the prompts below to help you plan your story.

1. What is the latest space discovery? Provide details about this discovery.

2. Who made the discovery?
3. Where did the discovery take place?
4. When was it discovered?
5. How was it discovered?
6. What exists on this planet that allows it to be habitable?
7. What organisms have been found? What are they like?
8. How have these organisms adapted to allow them to live in this environment?

Bonus: Add a drawing and a caption to accompany your story, or videotape your news story.

RESOURCES

Books about Underwater Exploration:

Earle, Sylvia. *Atlas of the Ocean: The Deep Frontier*. Washington, DC: National Geographic Books, 2001. An expert exploration of the watery universe that covers the vast majority of our planet.

Haslam, Andrew, and Barbara Taylor. *Oceans*. Chicago: World Book Inc., 1997. With background information on studying oceans, this book also contains numerous experiments suitable for the classroom.

Kaharl, Victoria A. *Water Baby: The Story of Alvin*. New York: Oxford University Press, 1990. The complete story of this remarkable sub's first twenty-five years.

Kovacs, Deborah, and Kate Madin. *Beneath Blue Waters: Meetings with Remarkable Deep-Sea Creatures*. New York: Viking, 1996. Introduces readers to a fabulous series of strange and beautiful open-ocean animals.

Kunzig, Robert. *Mapping the Deep: The Extraordinary Story of Ocean Science*. New York: W. W. Norton, 2000. A beautiful state-of-the-art visual tour of our planet's last frontier.

Madin, Kate. *Down to a Sunless Sea: The Strange World of Hydrothermal Vents*. Austin: Steck-Vaughn, 1999. An account of the discovery and exploration of hydrothermal vents, including many firsthand descriptions.

Van Dover, Cindy Lee. *The Octopus's Garden: Hydrothermal Vents and Other Mysteries of the Deep Sea*. Reading: Addison-Wesley, 1996. Firsthand account by the only Ph.D. marine biologist to become an Alvin pilot.

Books about the Search for Life in Outer Space:

Dick, Steven J. *The Biological Universe: The Twentieth Century Extraterrestrial Debate and the Limits of Science*. Cambridge: Cambridge University Press, 1996. A scholarly examination of the search for life in outer space.

Morton, Oliver. *Mapping Mars: Science, Imagination and the Birth of a World*. New York: Picador, 2002. An in-depth account of our nearest neighbor's history, geology, and human potential.

MacInnis, Joseph, with an introduction by James Cameron. *Aliens of the Deep: A Companion Book to the Large-Format Film*. Washington: National Geographic Books, 2005.
Travel behind the scenes with an eyewitness observer to the *Aliens of the Deep* expedition. Illustrated with spectacular photographs taken directly from the film.

Deep-Ocean Websites:

<http://www.ridge2000.org/>

RIDGE 2000 is an NSF-funded research program to study the Earth's deep-sea vents and oceanic spreading ridge system as an integrated whole. RIDGE 2000 involves scientists from around the country. The Education & Public Outreach section of the site offers links to resources for educators, including expedition websites, classroom materials, and teacher professional development opportunities.

www.ocean.washington.edu/outreach/revel/

The University of Washington's School of Oceanography operates an annual deep-sea research cruise, especially for educators. This website details the educators' direct observations, and describes ongoing research projects.

<http://oceanexplorer.noaa.gov/>

NOAA Ocean Explorer website provides public access to current information on a series of NOAA scientific and educational explorations and activities in the marine environment. The site also provides a platform to follow explorations in near real-time.

www.ocean.udel.edu/deepsea/

In what is probably the most accessible site so far, the University of Delaware provides a look at the results of its deep-sea mission along with easy-to-follow background information. The site's toxic chemicals section details the possible connection to life on places like Europa.

www.divediscover.whoi.edu

Dive and Discover is an interactive distance learning website designed to immerse you in the excitement of discovery and exploration of the deep seafloor. Dive and Discover brings you right on board a series of research cruises to the Pacific and Indian Oceans, and gives you access to the latest oceanographic and deep submergence research as it happens.

Life in Outer Space Websites:

www.astrobio.net

Astrobiology Magazine, an online periodical with daily updates and headlines, contains information about ongoing missions and research in space as well as projects undertaken here on Earth.

<http://nai.nasa.gov>

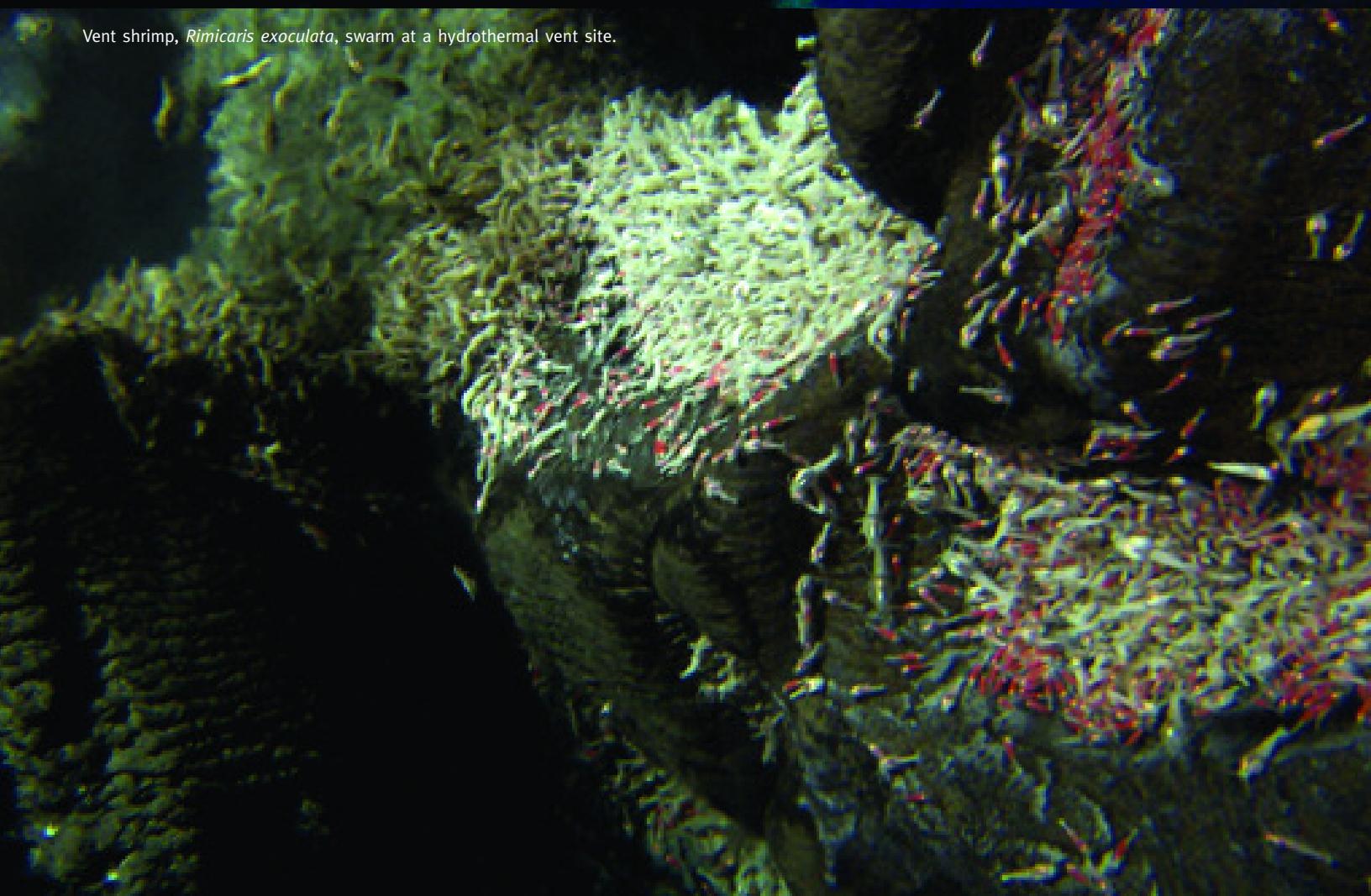
Home base for NASA's Astrobiology Institute. The "For Teachers" section features many classroom professional development resources in astrobiology.

<http://space-science.nasa.gov/missions/prometheus.htm>

This site details NASA's plans for a mission to orbit Jupiter's icy moons, including Europa.



Rover (right) and Mir (left) submersibles explore hydrothermal vents.



Vent shrimp, *Rimicaris exoculata*, swarm at a hydrothermal vent site.

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