Activity Guide

This activity guide is designed to help you introduce astrobiology to your regular science curriculum. It can be used on its own or in conjunction with the NOVA Origins TV show, a four-part PBS series airing September 28 and 29, 2004.

Befitting the multidisciplinary nature of astrobiology, the activities are in three general areas — Life Sciences, Earth Sciences and Applied Sciences/Technology. The final activity in the Applied Sciences/Technology section can be used to integrate all three areas through a simulated mission to another planet.

The Life Sciences section uses bacteria samples to explore the parameters of life and the environments where it may be found, and then uses the results to find life elsewhere in the classroom, helping students gain an understanding of how scientists look for life in the universe. In the Earth Sciences section, students identify rocks and minerals to determine environments that may be conducive to the formation of life, learning which minerals were most likely created from a reaction with liquid water and which rocks may hold evidence of fossils.

In the Applied Sciences/Technology section, students explore technology within the context of a “rover” mission to a distant planet, learning how to use remote sensing — where robots and technology are used in place of human beings — to gather information and send it back to scientists who interpret the data.

In each section, before you begin the described activities, discuss the following:

- “What is astrobiology?”
- “What makes a planet like Earth hospitable to life? What are the conditions that make it possible for life to exist? Is water essential to life?”

For background, use the accompanying article, visit NASA’s Astrobiology Institute website, http://nai.arc.nasa.gov/ or go to the Pacific Science Center’s Origins website, http://www.pacsci.org/origins/.

NOVA Origins
Four-Part Television Series on PBS

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Materials for “Microbial Survival!”
- Petri dishes, prepared with tryptic agar, (2/group)
- Cotton swabs, sterile, (4/group)
- Broth, (6mL/class)
- Test tubes, glass, sterile, with caps (2/group)
- Wax pencil or permanent marker (1/group)
- Safety goggles (1 pair/student)
- Latex gloves (1 pair/student)
- Hot plate (1/class)

Materials for “Looking for Life in the School”
- Petri dishes, prepared with tryptic agar (2/group) — see “Teacher Preparation”
- Cotton swabs, sterile (4/group)
- Wax pencil or permanent marker (1/group)
- Safety goggles (1 pair/student)
- Distilled water (1 L/group)

Teacher Preparation
1. Familiarize yourself with safety guidelines for working with live bacteria! Space does not permit a full explanation of the safety procedures for working with bacteria. You can learn how to work safely with bacteria at [http://www.nwse.pdx.edu/forms/ms_pathogens.pdf](http://www.nwse.pdx.edu/forms/ms_pathogens.pdf), the guidelines for student exhibitors at the Northwest Science Expo. Read them, and have the students read through them too, to set a good climate for safety in the lab. If you have not worked with live bacteria before, you may find it valuable to consult with colleagues who have.

2. Anything that may have been contaminated by bacteria, as well as unused plates of agar, should be sterilized in an autoclave or pressure cooker prior to disposal. Sterilization of materials may also be achieved by soaking them in a 10% bleach solution.

3. Prepare two Petri dishes per group with tryptic agar. You can purchase prepared Petri dishes for between $16 and $20 for 10 dishes at most science-supply companies. You can also purchase agar and Petri dishes separately and prepare them yourself for between $6 and $15 for 20 plates.

4. Put 2mL of broth in three separate sterile glass vials with lids. Inoculate each sample with a different bacteria. You may purchase live bacteria samples from most science-supply companies for between $6 and $12 each. Possible bacteria to choose from are: *Aspergillus niger, Bacillus cereus, Micrococcus luteus, Penicillium notatum*, *Saccharomyces cerevisiae*, and *Serratia marcescens*.

5. As an alternative, you can purchase Ward's Great Microbial Survival Contest Lab Activity for $83.00 and prepare it. This is more expensive (Ward's claims that one kit will supply six groups) but easier. The kit does not include goggles, gloves (or a freezer), but you will probably end up with extra supplies if you use materials wisely. A compromise would be to purchase one kit to get the bacteria samples and most basic materials, then supplement with other supplies purchased in bulk.
Activity: Microbial Survival!

Concepts
➤ Extreme changes in environmental conditions can affect the survival of organisms.
➤ For any particular environment, some organisms survive well, some survive less well and some cannot survive at all.
➤ Most cells function best within a narrow range of temperature, pressure and acidity.

Objectives
Students will be able to:
■ Plan and carry out a controlled experiment
■ Record and analyze observations, then draw conclusions about how well different bacteria survive in different extreme environments

National Science Education Standards/Grades 5 – 8
Content Standard A Abilities necessary to do scientific inquiry; understandings about scientific inquiry
Content Standard C Structure and function in living systems; populations and ecosystems; diversity and adaptation of organisms
Content Standard F Risks and benefits; science and technology in society

Assessment Tools
Assessment tools and tips for this activity are available at http://www.pacsci.org/origins.

Procedure
Day 1 Time: 40 – 50 minutes
1. Groups will choose two kinds of bacteria and select one extreme environment from this list: heat, cold, drying and alcohol.
2. Using sterile pipettes, groups place 10 drops of each of the chosen bacterial broths into separate test tubes and label the test tubes. Gloves and goggles are on for anyone near bacteria, or near supplies that need to be sterile.
3. Other group members label the two prepared Petri dishes by drawing a line down middle of each closed dish, then labeling one side “control” and the other with environment of choice. Petri dishes are then set aside, agar side up to prevent condensation.
4. Group test tubes are then subjected to environment of choice.
   A. Heat Students place lightly-capped test tubes in boiling water for 15 minutes.
   B. Cold Students place lightly capped test tubes in a freezer overnight.
   C. Drying Students dip a swab in a test tube, then place it in a gauze pad overnight.
   D. Alcohol Students add 2 – 4 drops of alcohol to test tube.
5. Teacher makes up a 10% bleach solution and uses it to clean up all surfaces, then soaks contaminated materials in it overnight before disposal.
Day 2  Time: 30 minutes

6. Students retrieve test tubes and Petri dishes. Students dip sterile swab into each experimental test tube. Holding lid open for as short a time as possible, they swab prepared Petri dish on the side labeled with environment in zig-zag pattern.

7. Using sterile swab, students take sample from teacher-prepared broth. They streak the “control” side of the Petri dish in zig-zag pattern. The other halves of the Petri dish should be streaked similarly with a swab from the prepared broth (the teacher will still have some for each bacteria type).

8. Students should record initial observations of the Petri dishes, including time and date.

Days 3 – 5  Time: 15 minutes/day

9. Students record daily observations of changes they see in the dishes. Comparisons should be made between the different bacteria, and between control and experimental setups (cloudy streaks should be seen where the agar was swabbed with broth).

10. At the end of the week the bacteria should be done growing. The students’ final observations should be recorded and the Petri dishes and all test tubes should be cleaned. Use an autoclave, a pressure cooker or soak all materials overnight in 10% bleach solution. See guidelines above.

11. As a class, groups should compare their results. Did certain bacteria survive better in certain environments? Were there instances where no bacteria survived at all? Discuss the implications of the results with regard to what students thought at the beginning that life needed to survive. What might this mean for looking for life elsewhere in the universe?

Activity: Looking for Life in the School

Concepts

➤ Life can exist in many different environments (temperature, pressure, chemical composition) as long as it has liquid water available to it.

➤ Access to nutrients, and freedom from cataclysmic events (janitorial doomsday events) allows life a greater chance of survival.

Objectives

Students will be able to:

■ Develop an hypothesis about where to swab for bacteria in the classroom or school

■ Demonstrate safe and appropriate lab procedures

■ Evaluate their hypothesis in relation to their test results

Assessment Tools

Assessment tools and tips for this activity are available at http://www.pacsci.org/origins.

Procedure

Day 1  Time: 50 minutes

1. Groups decide on four things that would make it more/less likely for bacteria to be found in a spot. Groups pick four small spots (2” x 2”) to look for bacteria. This should include at least one area where the expectations would be high, and at least one where the expectations would be low. This should not include toilets or anywhere that pathogens would be expected! Read guidelines at http://www.nwse.pdx.edu/forms/ms_pathogens.pdf.

2. Groups rank the spots from 1 (high) to 3 (low) using the criteria from step one.
3. Students draw lines across the Petri dishes to divide each dish in half. They number three of the halves from 1 – 3 for the three sites to be swabbed. The fourth half should be labeled “control.”

4. Students wet the end of a sterile cotton swab with distilled water.

5. Students wipe the swab over the area where they most expect to find bacteria (spot #1) making sure to get the whole swab rubbed on the surface.

6. The swab should then be streaked in a zig-zag pattern across the agar on the side of the Petri dish labeled #1. As with activity 1, students make sure to have the Petri dish open only briefly.

7. Students repeat the process with the other two spots and Petri dishes.

8. Students wet the end of one more swab with distilled water and streak this swab across the final Petri dish half labeled “control.”

9. Students put the Petri dishes in a spot where they won’t be disturbed and make initial observations of the bacteria, especially noting anything that could have caused unwanted contamination of a sample (e.g., dropping a swab, leaving a lid open too long, fingers in the dish, etc.).

Days 2 – 5  
Time: 15 minutes

10. As the following days go by, observations should be recorded and data collected. Instead of the cloudy streaks seen in the first activity, there should be isolated spots that gradually spread. These represent colonies of bacteria that began as a single bacterium! Similarly, mold spores will grow in some dishes, distinctive because they will not necessarily be round and will be, well… furry. Students should make a table to clearly record the number of areas of growth (bacterial or mold) observed each day. Different group members should make counts separately to arrive at an average. Encourage rich observations (colors, shapes, sizes of colonies), but if molds are present, students should not smell them. Our bodies deal with mold spores every day, but they can be concentrated when you’re growing them, and for purposes of safety in this experiment, we are assuming that everything could be a pathogen.

11. Students should evaluate their hypotheses and present their evaluations in a group presentation.

Guiding and Evaluating Student Work

For students to get the most out of these activities, it helps to have clear expectations from the start. “Microbial Survival” is a good information-gathering activity, with a discussion as the final product rather than a full report. Before students begin “Looking for Life in the Classroom,” each student in a group can be assigned responsibility for a section of writing, with time on the final day to work on this in groups. Instructional strategies for guiding and evaluating student learning (developing an hypothesis, recording data, making observations and reaching a conclusion) are available at http://www.pacsci.org/origins.

Budgetary Alternatives

Suggested ways to lessen the costs of the Life Sciences activities if resources are short:

- Conduct the “Microbial Survival!” activity so each group of students uses one type of bacteria and tests one environment. Groups then compare results.

- Conduct the “Microbial Survival!” activity as a demonstration by the teacher, with students observing.

- Use just one type of bacteria and study the effects of different environmental tests on just that one type.
Earth Sciences Activities

Materials
- Mineral Identification Worksheet (8/group)
- Mineral identification cards (1 set/group)
- Geology Table Sign (1/group)
- Opal (1/group)
- Fluorite (1/group)
- Fluorite, different color than previous one, acts as mystery mineral (1/group)
- Quartz (1/group)
- Hematite (1/group)
- Copper (1/group)
- Magnetite (1/group)
- Halite (1/group)
- Magnifying glasses (1/student)
- Scratch tiles, black, 1” x 1” (2/group)
- Scratch tiles, white, 1” x 1” (2/group)
- Glass plates, 1” x 1” (small glass mirrors will work) (2/group)
- Magnets, small (2/group)
- Pennies (2/group)
- UV light and either dark cloth or box in which minerals will be viewed under the light
- Pencil

Teacher Preparation
1. Gather the minerals needed for the activity. You can purchase the mineral samples from almost any science-supply company for $5 – $20 for 10 samples. Many local museums and geology clubs have sets they are willing to loan to classrooms for use. Classroom parents may also have rock collections they would be willing to loan.

2. Print out the Mineral Identification Worksheet, Geology Table Sign and the Mineral Identification Cards for this activity at http://www.pacsci.org/origins/. These match the samples (above).

3. The other materials may be purchased at local hardware stores and craft stores very inexpensively. None of the remaining materials should cost more than $12.

Activity: Mineral Identification

Concepts
- Minerals form under specific conditions.
- Some of the conditions under which rocks and minerals form can indicate that an environment conducive to life may have existed.
- The properties of rocks and minerals on other planets can provide evidence of past life on that planet.

Objectives
Students will be able to:
- Identify minerals from their properties
- Learn the conditions under which each mineral formed
- Draw conclusions about whether the minerals indicate if favorable conditions for life once existed
- Evaluate their hypothesis in relation to their test results

National Science Education Standards/Grades 5 – 8
- **Content Standard A** Abilities necessary to do scientific inquiry; understandings about scientific inquiry
- **Content Standard B** Properties and changes of properties in matter
- **Content Standard D** Structure of the Earth system; Earth in the solar system
- **Content Standard E** Understandings about science and technology
Assessment Tools
Assessment tools and tips for this activity are available at http://www.pacsci.org/origins.

Procedure
Time: 50 minutes

1. Students pick a mineral to identify.

2. Students follow all steps on Mineral Identification Worksheet and record the results.

3. Students compare the results to the mineral identification cards to identify their mineral. The mineral identification sheets give examples of the conditions under which minerals form.

4. When they have identified a mineral and learned the conditions under which it formed, students think of what the mineral can tell them about the planet’s past. Did this mineral require liquid water to form? Did the mineral form in a hot volcano?

5. Students keep their sheets for a reference book that will help to identify a mystery mineral and determine the conditions under which it formed to decide if life could have been present.

6. Students pick a new mineral to identify and follow the above steps.

7. Students compare their results with others. Sometimes rock samples include more than one mineral and students may have different results depending upon what part of the sample they test. Students who “debate” a mineral’s identification should be encouraged to find a way in which they can run conclusive tests to resolve the debate.

8. Make sure that each mineral has been identified by at least one person in the group.

9. Students get the mystery mineral from the teacher, identify it using their worksheets and, as a group, decide if life could have been present when it formed.

10. The class discusses the results each group generated. They then discuss the conclusions groups came to regarding whether life may have been present when the minerals formed. On Earth, life has been found everywhere with liquid water and a source of energy. What are the implications for searching for life beyond our planet? What would scientists be looking for? (Answer: the same conditions known to harbor life on Earth; i.e., water and a source of energy.)
Materials
- Gloves and knee pads (pairs), rolling chair, or rolling platform (one for every three students)
- Blindfold (one pair for every three students)
- Paper and pencils
- Open area to perform in

Teacher Preparation
This section may be done as a stand-alone section, or it may be used to integrate and evaluate the other activities in this guide as students perform a simulated mission to another planet in search for evidence of life or the conditions where life might form.

Activity: Remote Sensing and Communication

Concepts
- Remote sensing devices allow us to explore places that humans cannot go.
- When working with a remote-sensing device, careful planning and very specialized communication techniques are needed in order to be successful.

Objectives
Students will be able to:
- Break an action down into a series of simple commands, then group commands together to deliver efficient and effective instructions to a robot (i.e., the rover)
- Analyze and describe the difficulties and limitations of communication with a remote-sensing device
- Develop a plan to send a rover to another planet to perform a specific set of actions

National Science Education Standards/Grades 5 – 8
Content Standard F  Risks and benefits; science and technology in society
Content Standard G  Science as a human endeavor; nature of science

Assessment Tools
Assessment tools and tips for this activity are available at [http://www.pacsci.org/origins](http://www.pacsci.org/origins).

Procedure / Part 1: Training and Testing

1. Students in teams of four choose roles: one is “robot,” one is “operator,” one is “safety,” and one is “recorder.”
2. Blindfolded robot waits for directions on hands and knees. Safety waits next to robot. Safety is in charge of keeping the blindfolded robot safe.
3. Operator draws a small (about one-inch square) box anywhere on a piece of paper, then places paper face up on floor a few feet in front of robot. Places pencil on floor next to paper.
4. Blindfolded robot performs all actions exactly as stated, no more and no less.
5. Operator gives rover step-by-step directions to pick up the pencil and make a check mark in the box on the paper. Just to locate and pick up the pencil, for example, the robot will need to receive a series of commands to move his/her arm up, down, left, or right, when to close fingers, etc.

6. Recorder records number of commands necessary to accomplish goal.

7. Students switch roles within the group. They try to accomplish the same mission in fewer steps. Are there ways to give clearer commands? Are there ways to group commands together? Would it help to train the robot to make sure it understands the commands?

8. Students switch roles within the group again to try to accomplish the same mission in even fewer steps.

9. Teacher may use the record of the trials to assess whether the students were improving their communication skills.

Remote sensing devices explore where humans can’t go.
**Procedure / Part 2: Mission Simulation**

**Days 1 – 2**  
**Time: 50 minutes/day**

10. Teacher sets up one or two cleared areas with random objects and obstacles in a room. Overturned chairs or tables make wonderful obstacles behind which surprise objects may be hidden. The room becomes a simulated planet surface. If the class has participated in the Earth Sciences section, the teacher may choose to place minerals in various locations. If the class has participated in the Life Sciences section, teacher may prepare bacteria collection as noted in that activity. If this is a stand-alone activity, the teacher may locate random objects that may or may not be indicative of life, such as various rocks, water, vinegar, ball bearings, dirt, sculpting clay, a shoe, etc.

11. In teams of four, students take on roles as rover, engineer, radio wave and satellite.

12. Teams are told that they will be given five minutes each to send a robot to the planet’s surface, guide the robot to an area on the surface, collect a sample (rock, bacteria, other item), and return to the satellite. The sample will then be analyzed by the team to determine if it provides evidence that life did or does exist on that planet.

13. The team members survey the area and decide where they would like to send the rover. They should choose an area that they think might have evidence of life and formulate a plan to send the rover to collect and return with a sample. Teachers may choose to make a scaled map of the room and Polaroid photos to simulate satellite images or simply allow students to peek into the room from the doorway. Objects may still be hidden behind obstacles from this perspective.

14. The rover is equipped with all the tools that the team decides he/she will need. For added challenge, the rover may be blindfolded.

15. Student teams will take turns running missions. If the room is large enough, more than one mission may be running at the same time. Two missions running simultaneously would allow a class of 36 students two turns each in a 50-minute class period.

16. The engineer writes commands on small slips of paper, gives them to the radio wave, who in turn gives them to the satellite. This simulates the amount of time it takes for radio waves to travel to another planet. If the satellite determines a command would be unsafe, it can send a message back “unsafe” and not give the command. Otherwise, it reads the command once EXACTLY as written. Safety of the blindfolded student is the satellite’s main task. (In the real missions, rovers have “artificial intelligence” that will override a command that appears unsafe to its program.)

17. The rover must perform the command exactly as stated. For instance, if a command to “turn right” is given, the rover must keep turning right until a command to “stop” is given or the satellite deems the action to be “unsafe.”

18. Other groups should be watching and learning from groups performing missions before them.

19. Once time is up for a group, members should discuss what worked and what did not work. They should make a plan for their next mission. Most groups will not return a sample on their first try, but the mission is not a failure! There is always a lesson learned. In “real life,” only 30% of the mission attempts to Mars so far have been “successful,” but the failures have added knowledge on how (or how not) to do a mission.

*Teams are given five minutes each to send a “robot” to the “planet’s surface,” guide the robot to an area on the surface, collect a “sample” (rock, bacteria, other item), and return to the “satellite.”*
20. After the teams each take their turns, each student will write a short report about what he/she thinks went well, what didn’t, and why. The class should discuss the results together. What was learned? Do the results show conclusive evidence for life?

21. Students review as a class what they learned regarding science, technology and team building. This works well as an open discussion. The results may surprise you!

22. The teacher talks about some of the current and planned missions to Mars, having students imagine the next generation of missions on which they might participate. For background on current missions go to [http://www.nasa.gov](http://www.nasa.gov) and [http://www.jpl.nasa.gov/missions](http://www.jpl.nasa.gov/missions).

**Only 30% of the mission attempts to Mars so far have been “successful.”**
Background Information

Watch the NOVA Origins Series to learn more about what scientists know about the origins of the universe, the origins of our planet, the origins of life on our planet and possibilities of life elsewhere in the universe. The series is scheduled to air on PBS September 28 and 29, 2004, from 8 to 10pm ET/PT.

You can explore some of these websites:

http://www.pbs.org/nova/origins (website for the Origins Television Series)

http://www.ucmp.berkeley.edu/index.html (Berkeley Museum of Paleontology — good stuff on fossil record/bacteria, etc.)

http://www.aai.org/committees/education/Curriculum/bacteria.pdf (procedure for culturing bacteria for common surfaces)

Educational Outreach

Located in Seattle, Washington, the Pacific Science Center (PSC) has created the educational outreach materials to enrich the NOVA Origins television series. It has formed exclusive partnerships for NOVA Origins with ten pre-eminent science centers and museums. The NOVA Origins Outreach Partners will host a range of programs that will bring the core ideas of the television series to life within museums, science centers, schools and community agencies throughout the country.

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NOVA Origins Four-Part Television Series on PBS

Now in its thirty-first year of broadcasting, NOVA is produced for PBS by the WGBH Boston Science Unit. The Origins mini-series is a co-production of Thomas Levenson Productions, Unicorn Projects, Inc. and NOVA/WGBH. Origins: Earth is Born and Origins: How Life Began are Pioneer Film & TV productions for NOVA/WGBH and Channel 4. The director of the WGBH Science Unit and senior executive producer of NOVA is Paula S. Apsell. The Origins Executive Producer is Thomas Levenson. The Origins host and Executive Editor is Dr. Neil deGrasse Tyson.

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