Life: Here? There? Elsewhere?

The Search for Life on Venus and Mars

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Contents

Scope and Sequence
Life in the Universe Curriculum

This scope and sequence is designed to describe the topics presented and the skills practiced in the Life in the Universe series curriculum as they relate to factors in the Drake Equation:

$$(N) = R_{*} \bullet f_p \bullet n_e \bullet F_l \bullet F_i \bullet F_c \bullet L \bullet$$

In this equation, N is an estimate of the number of detectable civilizations in the Milky Way Galaxy that have developed the ability to communicate over interstellar distances. If a civilization has such an ability, it most probably arose from the *desire* to communicate. It follows that such a civilization is probably trying to communicate, just as we are trying. This was the rationale for formulating the Drake Equation, and this is the rationale for the search for extraterrestrial life.

Factors in the Drake Equation	**Related Topics**
R_* = the number of new stars suitable for the origin and evolution of intelligent life that are formed in the Milky way Galaxy each year	*Astronomy, Chemistry, Mathematics*
F_p = the fraction of these stars that are formed with planetary systems	*Astronomy, Mathematics, Physics*
N_e = the average number of planets in each system that can sustain life	*Astronomy, Biology, Chemistry, Ecology, Physics*
F_l = the fraction of life-sustaining planets on which life actually begins	*Astronomy, Biology, Chemistry, Ecology, Geology, Meteorology*
F_j = the fraction of life-sustaining planets on which intelligent life evolves	*Anthropology, Biology, Geology, Meteorology, Paleontology*
F_c = the fraction of systems of intelligent creatures that develop the technological means and the will to communicate over interstellar distances	*Language Arts, Mathematics, Physics, Social Sciences*
L = the average lifetime of such civilizations in a detectable state	*Astronomy, History, Mathematics, Paleontology, Social Sciences*

Life in the Universe Series	**Topics**	**Skills**
Grades 3-4 *The Science Detectives*	• Art • Astronomy • Chemistry • Language Arts • Mathematics • Physics	• Attribute Recognition • Cooperative Learning • Mapping • Measurement • Problem Solving • Scientific Process
Grades 5-6 *The Evolution of a Planetary System*	• Art • Astronomy • Biology • Ecology • Geography • Geology • Language Arts • Mathematics • Meteorology • Social Sciences	• • Problem Solving • Cooperative Learning • Scientific Processes • Mapping • Measurement • Inductive Reasoning • Graphing
Grades 5-6 *How Might Life Evolve on Other Worlds?*	• Art • Biology • Chemistry • Ecology • Language Arts • Mathematics • Paleontology • Social Sciences	• Classification • Inductive Reasoning • Laboratory Techniques • Mapping • Microscope Use • Scientific Process • Cooperative Learning
Grades 5-6 *The Rise of Intelligence and Culture*	• Anthropology • Art • Biology • Ecology • Geography • Geology • Language Arts • Mathematics • Social Sciences • Zoology	• Cooperative Learning • Design • Graphing • Inductive Reasoning • Laboratory Technique • Microscope Use • Problem Solving • Scientific Process
Grades 7-8 *Life: Here? There? Elsewhere? The Search for Life on Venus and Mars*	• Art • Astronomy • Biology • Chemistry • Comparative Planetology • Ecology • Engineering • Language Arts • Mathematics • Physics • Zoology	• Cooperative Learning • Design • Graphing • Inductive Reasoning • Laboratory Techniques • Microscope Use • Problem Solving • Scientific Process
Grades 8-9 *Project Haystack: The Search for Life in the Galaxy*	• Anthropology • Art • Astronomy • Biology • Chemistry • Ecology • Geometry • Language Arts • Mathematics • Physics • Trigonometry • Zoology	• Cooperative Learning • Design • Graphing • Inductive Reasoning • Laboratory Technique • Microscope Use • Problem Solving • Scientific Process

Foreword

Carl Sagan, Cornell University
1934-1996

The possibility of life on other worlds is one of enormous fascination-and properly so. The fact that it's such a persistent and popular theme in books, television, motion pictures, and computer programs must tell us something. But extraterrestrial life has not yet been found-not in the real world, anyway. Through spacecraft to other planets and large radio telescopes to see if anyone is sending us a message, the human species is just beginning a serious search.

To understand the prospects, you need to understand something about the evolution of stars, the number and distribution of stars, whether other stars have planets, what planetary environments are like and which ones are congenial for life. Also required are an understanding of the chemistry of organic matter-the stuff of life, at least on this world; laboratory simulations of how organic molecules were made in the early history of Earth and on other worlds; and the chemistry of life on Earth and what it can tell us about the origins of life. Include as well the fossil record and the evolutionary process; how humans first evolved; and the events that led to our present technological civilization without which we'd have no chance at all of understanding and little chance of detecting extraterrestrial life. Every time I make such a list, I'm impressed about how many different sciences are relevant to the search for extraterrestrial life.

All of this implies that extraterrestrial life is an excellent way of teaching science. There's a built-in interest, encouraged by the vast engine of the media, and there's a way to use the subject to approach virtually any scientific topic, especially many of the most fundamental ones. In 1966, the Soviet astrophysicist I. S. Shklovskii and I published a book called *Intelligent Life in the Universe,* which we thought of as an introduction to the subject for a general audience. What surprised me was how many college courses in science found the book useful. Since then, there have been many books on the subject, but none really designed for school curricula.

These course guides on life in the universe fill that need. I wish my children were being taught this curriculum in school. I enthusiastically recommend them.

PREFACE

Are we alone in the Milky Way Galaxy? Many people think of science fiction stories or tabloid reports about UFO abductions when they hear about the search for intelligent life on other planets. The reality is that many scientists take seriously the possibility of life on other worlds, and some have undertaken the difficult task of finding out if we are the only intelligent beings in our galaxy. Astronomer Frank Drake proposed an equation to estimate the number of civilizations in our galaxy that produce radio waves. We might be able to detect such civilizations with our radio telescopes. The Drake Equation estimates this number using the answers to the following sequence of questions:

1. How many stars are formed in the Milky Way Galaxy each year?
2. What fraction of stars are similar to our Sun?
3. What fraction of stars are formed with a planetary system?
4. What is the average number of planets in such a system?
5. What fraction of planets are like Earth, capable of sustaining life?
6. On what fraction of these planets does life actually begin?
7. On what fraction of life-sustaining planets does life evolve into intelligent civilizations?
8. What fraction of intelligent civilizations develop radio technology?
9. What is the average lifetime of a radio-transmitting civilization?

Scientists pursuing these questions work in many fields, including astronomy, geology, biology, anthropology, and the history of science. Several projects to "listen" for radio signals produced by civilizations on distant planets have been conducted. The most ambitious of these has been undertaken by the research staff at the SETI Institute (Search for Extraterrestrial Intelligence), at first in cooperation with NASA and later using privately donated funds. The SETI team is listening for intelligent signals. The interdisciplinary makeup and highly motivational nature of the search for intelligent life prompted the NSF (National Science Foundation) to support the development of the Life in the Universe Curriculum Project. Designed by curriculum developers working with teachers and NASA and SETI scientists, this program reflects the real-life methods of science: making observations, performing experiments, building models, conducting simulations, changing previous ideas on the basis of new data, and using imagination. It brings into the classroom the excitement of searching for life beyond Earth. This search is a unifying theme that can unleash the imagination of students through integrated lessons in the physical, life, space, and social sciences.

Life: Here? There? Elsewhere? The Search for Life on Venus and Mars engages students in a search for life or signs of life within our solar system. Students learn that “life” is not always intelligent, nor is it always easily recognizable. They “explore” Venus and Mars and learn why these two planets are the only ones in our solar system that could possibly harbor life. Each step of the way, students work in cooperative teams and build on the knowledge of previous activities to help them understand the rich complexity of searching for life or signs of life on other planets. Life: Here? There? Elsewhere? is the first of two teacher's guides designed for grades 7-9. In the second guide, entitled Project Haystack: The Search for Life in the Galaxy, which focuses on SET1 (Search for Extraterrestrial Intelligence), students explore the vast celestial “haystack” in search of a “needle,” the needle being an artificially generated radio signal, which would be a sign of intelligent life. With Project Haystack, students move beyond our own solar system and look to other stars for radio signals that might indicate intelligent life. Each guide can be used independently of the other.

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Mission 13: The *Viking* Search for Life on Mars	Dr. Harold Klein-Santa Clara University; SETI Institute
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Introduction

Learning Objectives

Concepts

Through the activities in this book, students will learn about and be able to apply concepts in the following areas:

- In our solar system, only Earth is ***known*** to have life.
- In our solar system, Mars and Venus are considered to be the most likely places where life as we know it could occur or could have occurred in the past.
- *Scale* is an important consideration in observations of Mars and Venus, and in any search for life.
- Exobiologists study life in harsh environments on Earth to understand how life might survive on other worlds.
- Some Earth microbes can survive in harsh environments and under conditions known to exist on Mars. However, Venus is too harsh to support known Earth life.
- Although a human voyage to Mars within this decade is unlikely, it is possible to send to both Mars and Venus robotic spacecraft and landers that can search for signs of life using remote sensors.
- Water is essential to life on Earth. The presence of water on Mars or Venus would indicate that one necessary ingredient for life was present.
- "Life" is not always obvious and easy to recognize. Some types of life on Earth are microscopic and do not look like familiar plants or animals.
- "Life" is not easy to define. Life can only be *described* by a series of characteristics.
- Microscopic, airborne microbial life may be detected by culturing microbes in nutrient media.
- Dormant life may be activated by water, or by a warm liquid nutrient.
- Life may be detected by observing certain signs of life, such as the presence of complex carbohydrates or proteins, or the slow and steady production of gases.
- The ***Viking*** spacecraft in 1976 performed three life detection tests on Mars. The results at first seemed positive, but scientists eventually concluded that life had not been found.
- Mars spirit and opportunity Rovers found indicators of water on Mars.

Skills

The activities are also designed to help students develop the following abilities:

- Working in teams to accomplish goals.
- Using models and laboratory simulations to understand scientific concepts.
- Conducting experiments.

- Collecting, analyzing, and interpreting data.
- Learning to build equipment that extends the range of human perception.
- Understanding that human values must always be considered in scientific investigations.

The activities are also designed to help students develop the following abilities:

- Working in teams to accomplish goals.
- Using models and laboratory simulations to understand scientific concepts.
- Conducting experiments.
- Collecting, graphing, analyzing, and interpreting data.
- Thinking logically and critically.
- Using equipment that extends the range of human perception.
- Considering the place of human values in scientific investigations.

About Inquiry

It is suggested that the process of ***inquiry*** be given the highest priority. This guide is not simply a series of exercises where students do their best and then the teacher gives them the "correct" answer. Most of the worksheet questions are "thought" questions, which have several possible good answers. Students should be made aware of this. Also, there can be no definitive answers to such grand questions as:

- What is life?
  - What are the signs of life that can be detected?
  - Does life exist "out there" and how would we know?
  - Where might we look in our solar system for intelligent life?
  - What are the physical conditions on other planets? Could any Earth life survive on some other planet? On Mars? On Venus?

- What is the best way to search for life, or signs of life, on other planets?
- What evidence would prove that another planet supports life?
- What things are needed for life to begin and to continue to exist, and how can we determine, at a distance, if those things exist on another planet?
- If life is found on another planet in our solar system, how could the discovery affect our civilization?

In the area of extraterrestrial research, questions often do not have definite yes or no answers. Therefore, all questions are good questions, and all guesses can be treated as possible answers. "How do we know?" and "How can we find out?" are the most important questions of all!

Timeline and Planning Guide

The following time estimates are based on feedback from teachers during trial tests. They do not include time required to read this guide or shop for materials. Actual times will depend on the particular team of students and the time spent extending these activities. Some missions will need to be taught over several class periods, and some may take longer the first time they are presented. Each mission subdivision is designed to take one class period. Teachers may want to take two or even three class periods with some mission subdivisions. Activities such as the observation of microbial cultures in mission 3may overlap later missions.

Mission 1: Comparative Planetology

Mission 1.1: Students watch a video image show that zooms in on Earth, Mars, and Venus; compare the planets' similarities; and search for evidence of life in the video photographs.

Mission 1.2: Students construct an orbital model of Earth, Mars, Venus, and the Sun. Students learn about conditions on the three planets and why the search for life in the solar system is focused on these planets.

Mission 2: There's Power in Numbers! (Phase I)

Mission 2.1: Students explore scale and the powers of 10 with a special deck of ZOOM!Cards depicting Earth. Students journey to "Microworld Earth."

Mission 2.2: Students use the ZOOM! Cards to journey to "Macroworld Earth."

Mission 3: Venus Plates and Mars Jars! (Phase I)

Mission 3.1: Students culture *Penicillium notatum* to observe how this microbe lives on Earth.

Mission 3.2: Students observe the early growth of their *Penicillium notatum* cultures. They simulate the low pressure and low temperature conditions of Mars in an experiment to determine whether *Penicillium notatum* could survive under Martian conditions. Students learn about conditions on Venus.

Mission 3.3: Students observe the continued growth of their *Penicillium notatum* cultures.

Mission 4: There's Power in Numbers! (Phase 11)

Mission 4.1: Students use ZOOM! Cards to journey to Mars. Students see the importance of scale in the search for life on other worlds. They see images of Mars at different scales.

Mission 4.2: Students use ZOOM! Cards to journey to Venus. They see images of Venus at different scales.

Mission 5: Initial Spacecraft and Lander Design

Mission 5.1: Each student designs a spacecraft-lander system to search for life at a specific site on Mars or Venus.

Mission 5.2: Students submit their plans to peer review, cooperate to create a composite spacecraft-lander system ideal for specific landing sites, and share their designs with the class.

Mission 6: Venus Plates and Mars Jars! (Phase 11)

Mission 6.1: Students culture *Penicillium notatum* in seeded soil from their Mars Jars, from seeded soil that has been heated to simulate the conditions on Venus, and from seeded soil that was left under normal Earth conditions.

Mission 6.2: Students use their records of normal *Penicillium notatum* growth on Earth from mission 3 to analyze their results, and to see if it survived the simulated conditions of Mars and Venus.

Mission 7: Water!

Mission 7.1: Students investigate the freezing points of clear liquids to identify water, an essential molecule for the development and presence of life on Earth.

Mission 8: What Is Life?

Mission 8.1: Students explore their ideas about the characteristics of life and then play a game called Five Alive! to refine their definitions of life.

Mission 9: Mission to Planet Earth-Life in Soil!

Mission 9.1: Students play the role of extraterrestrial scientists looking for life in Earth's soils. They examine two dry soils, one with obvious life and one that is apparently lifeless. Students describe what they see and then add water to both soils.

Mission 9.2: Students discover life in the apparently lifeless soil: the water has activated dormant life-brine shrimp eggs. Students realize that it might be necessary to activate a sample from Venus or Mars before it can show signs of life.

Mission 10: Chemical Tests for Life

Mission 10.1: Students learn about the structure of carbohydrates and then test unknown soils and various organic and inorganic substances for the presence of starch, a complex carbohydrate that indicates the presence of life.

Mission 10.2: Students learn about the structure of proteins and then test unknown soils and various organic and inorganic substances for the presence of proteins, complex molecules that indicate the presence of life.

Mission 11: Mission to Planet Earth-Life Trap!

Mission 11.1: Students play the role of extraterrestrial scientists looking for life in Earth's atmosphere. They build Life Traps-nutrient gelatin dishes-to capture microbial life that is present in Earth's atmosphere.

Mission 11.2: Students observe the microbial growth in their Life Traps and estimate how long a Life Trap would need to remain open on Venus or Mars.

Mission 11.3: Students observe further microbial growth in their own Life Traps and analyze the results of each other's Life Traps.

Mission 12: Can You "Gas" What's Happening?

Mission 12.1: Students play the role of extraterrestrial scientists analyzing two unknown Earth soils, one seeded with seltzer and one with yeast. They activate the soils with a hot, nutrient solution and observe their gas production.

Mission 12.2: Students graph the results of their gas production experiment. They discover the different rates of gas production that distinguish nonliving chemical reactions from life processes and realize that this test could be done on alien soils.

Mission 13: The Viking *Search for Life on Mars*

Mission 13.1: Student teams go on a "Mission to the Schoolyard" to gather data. They simulate the ***Viking*** sampling procedures and gain an understanding of the limitations of remote and random sampling.

Mission 13.2: Students review the ***Viking*** mission's experiments to solve two "Mysteries of Mars." Students then propose a new mission to Mars.

Mission 14: Final Spacecraft and Lander Design

Mission 14.1: Students redesign their original spacecraft and landers from mission 5, based upon what they have learned throughout these missions. They are limited to three life detection instruments, so they must choose the ones that give the best information.

Mission 14.2: Students receive simulated data keyed to their landing sites and life detection tests, analyze the results, decide if life is present, and issue a statement about the presence of life at their landing site at a class conference.

Preparation

Worksheets

Life: Here? There? Elsewhere? missions are accompanied by worksheets. Teachers are invited to pick and choose from the selection offered for each mission. It is possible to omit some worksheets and replace them with discussions that cover the same material. Also, teachers might allow student teams to work jointly on some worksheets instead of having each student complete his or her own. We provide the worksheets to keep your options open. These worksheets are challenging; they aim to push students to higher levels of thinking. Each question requires careful thought and analysis. Often, there is no simple "right" answer. Students should be made aware of this so they will expect these opportunities to put down their own thoughts and not think that they "missed" hearing the answers to worksheet questions. Teachers should decide ahead of time which worksheets will be used and then copy them from the provided masters. Where applicable, teacher's keys are included for worksheets.

Keeping a Journal: Portfolio-Based Assessment

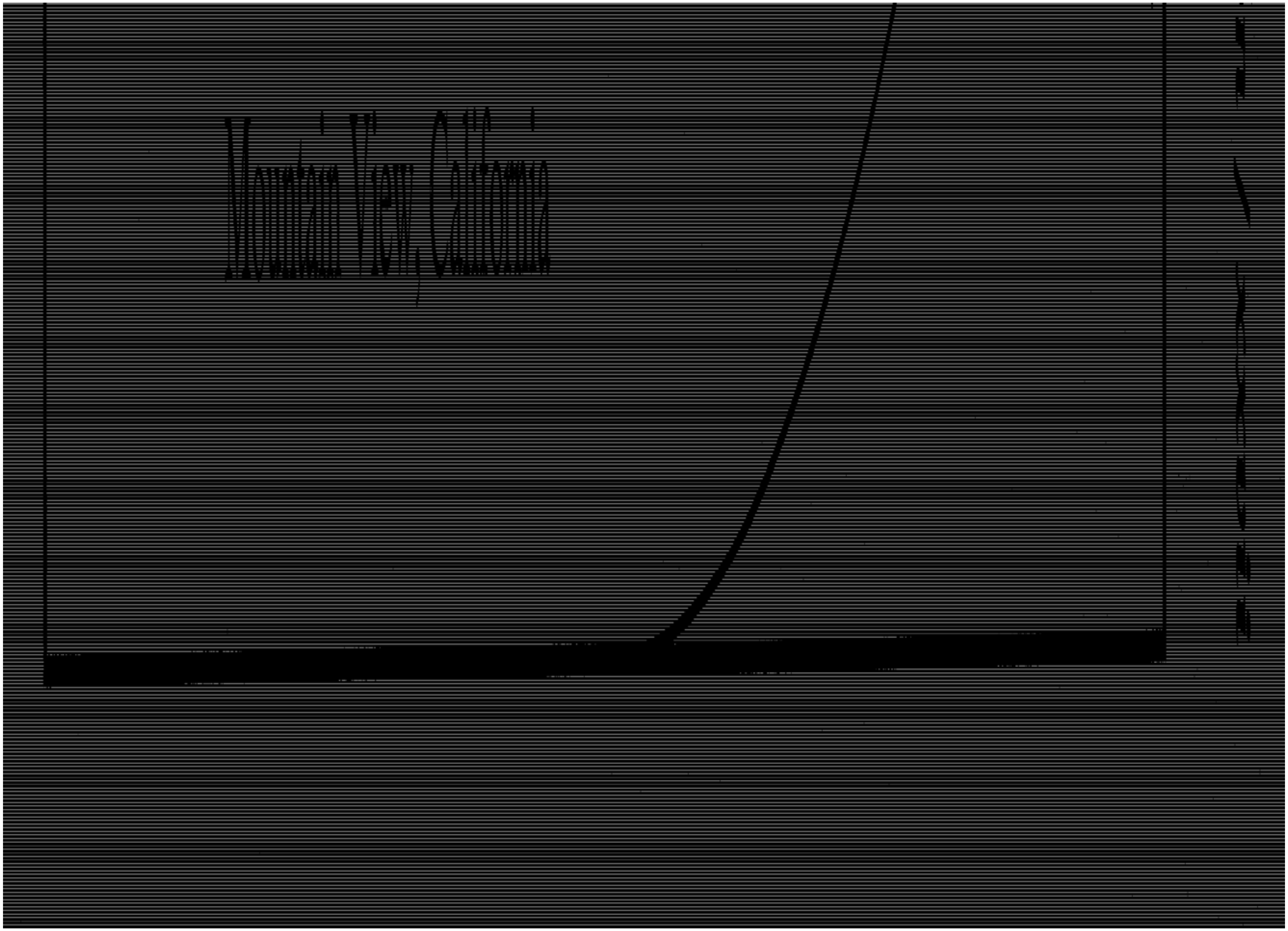
Life: Here? There? Elsewhere? worksheets may be incorporated into a journal, perhaps a "Scientific Laboratory Notebook." This will allow students to keep a personal record of their entire search for life on Venus and Mars. Journals will help students acquire a sense of enthusiasm, a wealth of new knowledge, and perhaps the thought that we might not be alone in the universe. Binders may be used to hold worksheets and other relevant pictures and materials. Or, instead of passing out photocopies of the worksheets, write the questions on the chalkboard for students to copy into their journals. Upon completion of the missions in this book, journals may be used as portfolios to evaluate student performance. Because this book emphasizes thought processes, including both logical and imaginative, rather than a wealth of objective facts, standard objective tests may be inappropriate to assess student progress. You may want to copy the glossary provided at the end of the book and supply it to your students.

Preparation of Special Materials

A list of required and optional materials appears in the appendix. Some of these materials will need to be acquired or ordered well in advance of teaching particular missions. In addition, some of the materials that have been supplied with this guide will need advance preparation. Overhead transparencies can be made from identified pages in this book.

ZOOM! Cards

The ZOOM! Cards that are used in missions 2 and 4 are provided in sheets as part of the kit. They must be cut apart to create decks of cards. If possible, laminate the sheets of ZOOM! Cards before cutting to preserve them for future teachings of *Life: Here? There? Elsewhere?* Clear contact paper also works well. Cut the laminated illustration sheets into individual cards and assemble six complete card decks for Earth, six for Mars, and six for Venus.


Mountain View, California

Mission 1
Comparative Planetology

SETI INSTITUTE

Searching Earth, Mars, and Venus for Signs of Life!

Overview

Mars is the planet in our solar system most like Earth. Both are tilted on their axis of rotation, both have seasons, ice caps, and winds, and both exhibit similar geologic features, some apparently carved out by water. However, Mars is much smaller than Earth, is very cold, and at present has little atmosphere. In the past, its atmosphere was dense, which helped make the surface of the planet much warmer. Venus is about the same size as Earth, but it is a hot, high-pressure planet with a dense cloud cover. Present conditions are quite harsh, but Venus shows evidence of once supporting an ocean and being more like Earth. Earth is the only planet that is known to have life, but our curiosity and the very possibility of life in our solar system require the search to continue! In mission 1.1, students see a video image show of present-day Earth, Mars, and Venus and search for features on these planets that might indicate life. In mission 1.2, students construct an orbital model of Earth, Mars, Venus, and the Sun. Students learn about conditions on the three planets and the relationship of these conditions to some of the requirements for the origin of life as we know it and its continued existence.

Mission 1.1
Materials

For a Class of 30

- *Voyages to Earth, Mars, and Venus* video
- Data Projection and Power point file********************.
- "Voyages to Earth, Mars, and Venus" video script

For Each Student

- "Looking for Life" worksheet
- Pencil
- SET1 Logbook

Getting Ready

1. Set up the VCR and monitor and review the video images and the script.

2. The three video segments (one each for Earth, Mars, and Venus) can all be shown in one class period or one per day to allow more time for discussion. Gauge time accordingly.

3. Copy the worksheet “Looking for Life.”

Classroom Action

1. **Introduction.** Despite what we see in television shows and movies about space travel and extraterrestrials, Earth remains the only planet we know of that supports life. However, there is a great deal of scientific curiosity about life on other planets-some scientists are attempting to detect planets beyond our solar system, some are focusing on planets within our solar system. By participating in the Life: Here? There? Elsewhere? The Search for Life on Venus and Mars activities you will join scientists in searching for life in our planetary neighborhood.

   The most likely candidates with the potential for supporting extraterrestrial life are Venus and Mars. Why? Because they are the most Earth-like planets in our solar system. Both planets have been studied closely. Most of the surface of Venus has been mapped by radar and its atmosphere sampled by Magellan, a United States spacecraft. A Russian spacecraft, Venera, even landed on the surface of Venus and sent back photos of what it saw!

   Mars has been observed even more thoroughly. Like Venus, Mars has been carefully mapped by orbiting spacecraft. Unlike Venus, the surface of Mars was investigated over a long period of time by two NASA spacecrafts, Vikings I and 11, which landed on Mars in 1976. Scientific instruments on board measured the surface temperature, the speed of the winds, the composition of the atmosphere, and seismic activity, and also took pictures of the surrounding area. An on-board suite of instruments tried to detect the presence of life on Mars. While no conclusive evidence for life was found, the results have inspired future generations of scientists to join the search for extraterrestrial life.

   The missions to Venus and Mars raised many questions. Scientific evidence indicates that some of the conditions that led to the evolution of life on Earth also existed on both early Venus and early Mars. Could life have evolved on our neighboring planets? Could it still exist there? In the activities that follow, you will examine and compare Venus, Earth, and Mars. You will study the characteristics of living Earth organisms, learn a variety of methods of testing for life, study the results of the *Viking* life experiments, and finally, devise life-detection experiments that could be carried on some future spacecraft! In the process you will become comparative Planetologists and Exobiologists.

   Write “Comparative Planetologist” on the chalkboard. Ask students to look at the parts of the word *planetologist* to find its definition. Remind students that the suffix *ologist* means “one who studies.” Ask students what a *comparative* planetologist might do. *(Comparative planetologists explore and compare the planets to learn about their composition, formation, and major features. These aspects are important to our understanding of life in our solar system.)*

Write “Exobiologist” on the board. Ask students to look at parts of the word to find its definition. Remind students that the prefix *exo-* means “outside,” or “beyond.” *(An exobiologist is a scientist who studies life outside or beyond Earth.)*

2. **Worksheet.** Hand out the worksheet “Looking for Life.” Explain to students that there will be breaks during the video image show for them to answer the worksheet questions.

3. **Video Image Show.** Explain to students that they are going on three “space voyages” to look at Earth, Mars, and Venus. They will view each planet from a telescope, a spacecraft in orbit, and or images taken at the surface to see if they can tell if there is life on these planets.

   For Earth and Mars, the images will simulate a voyage to the planet, with the proximity of the “camera” getting closer and closer to the surface. For Venus, the images will present the radar mapping data received from the robotic *Magellan* spacecraft. *Magellan* images are created by computers from radar map data.

   Show the video segments for Earth, Mars, and Venus. During each segment, discuss what students are seeing on the planet in the images. Ask them if they can detect the presence of water or the presence of life in the soil or atmosphere. Would they know how to build a spacecraft and lander to survive the conditions on the planet? What do they think caused the major geologic features present on the planet? Suggest these causes: plate tectonics, volcanism, erosion by wind or water, and evaporation.

   While showing the video images, ask students to speculate what they might see at the next, closer level of exploration (the next image). Show students the next image and have them compare what they see with what they expected. This exercise is especially good when observing the images of Mars or Venus because these worlds are unknown to the student audience. Have students discuss how each image reveals new insights and changes their understanding of the planet as a whole.

   After showing all the images, ask students if they think they could look at some other planet very, very closely and tell if there was evidence of life.

Mission 1.2
Materials

For a Class of 30

- “Planet Attribute Cards” (or optional “Blank Planet Attribute Cards”), cut apart (pages 38 and 39)
- Clock with a second hand
- Overhead projector
- “Comparing the Planets” transparency
- “Orbital Model” transparency
- (optional) Three colors of paint and brushes (if clay will dry hard)

For Each Team

- 50 meters of string
- 4 thumb tacks
- Meter stick
- Scissors
- 112 to 1 pound of clay
- Compass
- “Creating an Orbital Model” directions
- (optional) Pencils
- (optional) Piece of cardboard

For Each Student

- “Orbital Model” worksheet
- “Attributes of the Planets” optional worksheet
- Pencil

Getting Ready

1. Divide the clay into approximately equal chunks, one for each team of two students.

2. *(optional)* To save time in class, cut the string into the following lengths, 15 of each: .72 meters, 1 meter, and 1.52 meters. Or, if students will be cutting the lengths, cut the 50-meter length into 15 lengths of 3.24 meters each.

3. Copy the “Creating an Orbital Model” directions for each team and the “Orbital Model” worksheet for each student. Make one set of “Planet Attribute Cards.” Copy the “Attributes of the Planets” optional worksheet for each student if it will be used.

4. Prepare the transparencies “Comparing the Planets” and “Orbital Model.” Set up the overhead projector. (or Data projection and Power point file********.**

Classroom Action

1. **Preliminarily.** Divide the class into teams of two students each.

2. **Transparency**. Show the overhead transparency “Comparing the Planets.” Tell students that they will make models of these three planets with clay.

3. **Activity.** Ask the teams to construct their clay planets. First, the clay will be split into two equal balls. One of these balls becomes the first planet. The other ball should be divided into seven smaller balls of equal size. One of these balls becomes the second planet. The

remaining six small balls should be combined into one to become the third planet. The three clay “planets” are now sized in correct proportion to each other.

Ask students which clay planet they think represents Earth, Mars, and Venus. (Earth is represented by the largest clay ball ,Venus by the slightly smaller ball, and Mars by the smallest ball.) Ask students how many times bigger Earth is than Mars and how many times bigger Venus is than Mars. They should mark the surface of each planet-with the letter V, E, or M-so they can be quickly and positively identified. If the type of clay used will dry hard, have students paint each planet a different color.

4. **Transparency.** Show the overhead transparency “Orbital Model.” Tell students that they will make an orbital model with their three clay planets by following their “Creating an Orbital Model” directions.

   Hand out the “Creating an Orbital Model” directions and materials to each team. Give each team either three pieces of string (one each of lengths .72 meters, 1 meter, and 1.52 meters) or one piece of string (3.24 meters in length). Hand out the “Orbital Model” worksheet to each student.

   First, if the string has not already been so cut, students need to cut their string into the following lengths: .72 meters, to represent a scale average distance from Venus to the Sun; 1 meter, to represent a scale average distance from Earth to the Sun, and 1.52 meters, to represent a scale average distance from Mars to the Sun. These lengths represent the average distance between the Sun and the planet in the orbits of Venus, Earth, and Mars, respectively. (On this scale, 1 meter = 1 Astronomical Unit, or AU, which is 150 million kilometers.) Tell students that the distance scale is not the same as the size scale. Tell students that assuming the string size remains the same, the planets (if made at the same scale as the distances) would be infinitesimal, mere dust motes-thus there are two scales.

5. **Activity.** Have the teams construct their orbital models. Using thumb tacks, students should attach the appropriate string to each planet by pushing it into the clay or by using a tack, and then tie together the ends of the three strings. If possible, the knot where the three strings are tied together should be pinned to a firm surface like cardboard or a notebook. This knot represents the location of the Sun. The cardboard stabilizes the “Sun” in the center of the desk while students manipulate the “planets.”

   Have students use their clay models to discover the arrangements for the shortest and longest possible distances between Earth, Mars, and Venus. Have students use string and meter sticks to calculate how far away these planets are from one another. They should use compasses to draw the planetary orbits on their worksheets.

6. **Activity.** Have students form groups of two teams each for this activity. Each team should remove the central point of their orbital model (the Sun) from the cardboard and pin it to the eraser on a pencil. One student, representing the Sun, should hold this pencil high, so the strings don't get too tangled. Others students will take turns “becoming” Venus, Earth, and Mars, holding their respective planets high.

One student watches a clock with a Second hand to time the other students. First, Earth demonstrates one Earth year by walking counterclockwise around the Sun in 60 seconds. Next, Venus demonstrates one Venus year by walking counterclockwise around the Sun in 36 seconds. Then, Mars demonstrates one Mars year by walking counterclockwise around the Sun in 114 seconds.

Ask groups to demonstrate various scenarios for the class. For example, how many revolutions does Venus make around the Sun in one Earth year? Have one team show only the movement of Venus while a second team shows only the movement of Earth. Both planets should begin at the same compass point and then orbit the Sun for 60 seconds at their appropriate orbital rate. (Earth will make 1complete revolution while Venus makes 1.66 revolutions.) Many other such comparisons can be made.

It is not practical to have three students representing the three planets orbiting one Sun at the same time because the strings tend to get very tangled. A solution is to mark out a chalk circle on the floor for each planet to follow; this way, students can carry the clay planets without the strings attached.

7. **Display.** Attach one of the planetary models to a bulletin board and hang the appropriate planet attribute card under each planet.

   Use the bulletin board to illustrate a discussion of how the distance from the Sun might be critical to whether or not there is a possibility for life to begin and survive on each planet. To get the discussion started, ask students to explain what they know about the evolution of the first life on Earth. What was Earth's early environment like? How might this compare to early Venus and Mars? How has Earth evolved in a way that allows life to thrive but Venus and Mars appear barren? Why are Mercury and Saturn unlikely candidates for life?

   As a wrap up to this discussion, describe the “Goldilocks Model”- the question of life seems to be connected with the question of whether or not liquid water can exist on the surface of a planet. Early in their evolution, Venus, Earth, and Mars all appear to have had liquid water. The changes in their planetary atmospheres have produced what some scientists call the “Goldilocks Model” of the inner solar system. Mars is too cold, Venus is too hot, and Earth is just right-for liquid water.

8. ***Optional Homework.*** Hand out the optional worksheet “Attributes of the Planets.” Give each student a copy of the “Planet Attribute Cards” to use in completing this homework assignment. Have students use the library to find additional information on the planets.

Going Further

Activity: The Rest of the Solar System

Ask students to calculate the scale size of each model planet, and how far away from the model Invite students to use more modeling clay to create an orbital model that contains all nine planets in a system and their major satellites. Provide students with the following algorithm for making scale diameter calculations of planets.

To calculate the size of a model planet:

1. Measure the diameter of your clay Earth in centimeters:

2. Divide 12,756 (actual diameter of Earth, in kilometers) by the diameter of your clay Earth: _____. This number is your scale of how many kilometers each centimeter represents.

3. For any planet, divide its actual diameter (in kilometers) by the scale number calculated in step 2. The answer is the diameter (in centimeters) for a clay model of that planet.

   actual diameter / scale = model diameter

   Sun to place its orbit. Caution: The gas giant planets (Jupiter, Saturn, Uranus, and Neptune) are so big (Jupiter, for example, has a volume 1,323 times that of Earth) that they will require some other material, such as fluffy cotton, to realistically construct them. Have students calculate the diameter of the ball of clay that would represent Jupiter.

Discussion/Research: Goldilocks in Space

Goldilocks found that Papa Bear's porridge was too hot, while Mama Bear's porridge was too cold. However, Baby Bear's porridge was just right. In a similar way, Venus today is too hot for life as we know it, while current Mars is too cold for life as we know it. It may be that only our own Earth is "just right." Have students consider what would happen if Earth was nearer to the Sun, like Venus, or farther away, like Mars. What is the probability that Earth would be at just the right distance from the Sun? How much variation could there be in this distance, while still maintaining the right temperature range for life? Is this range related to the physical properties of water? Have students research why the planets formed at their particular distances from the Sun. Where do planets form within the disk of material that encircles a newborn star? How many planets that form in a system will have orbits that are the right distance (in the "life zone") from a star so as to make them suitable for life?

Discussion: Greenhouses and Global Warming

Discuss the evolution of Earth, Mars, and Venus: Venus: each planet has evolved to become the way it is today. Early Mars was much like early Earth: it had a carbon dioxide (CO_2) atmosphere that trapped heat from the Sun like a greenhouse, and it had liquid water on its surface that carved rivers and channels. Mars was too small to retain its atmosphere, which gradually escaped into space, and the planet cooled down.

Venus once was covered with an ocean, but a dense greenhouse atmosphere gradually heated its surface and boiled away the water. Atmospheric sulfur dioxide (SO_2) oxidizes to form sulfur trioxide ($2S0_3$). Sulfur trioxide combines with the water in Venus' atmosphere to form sulfuric acid (H_2S0_4), an extremely corrosive chemical. Some of the water from the surface of Venus is now in its corrosive atmosphere.

Today, the life-supporting climate of Planet Earth is being threatened by the greenhouse effect. Most scientists fear that our global climate will increase in temperature as modern life-styles and technology produce increasing levels of greenhouse gases, such as carbon dioxide and methane. Some fear a spiraling effect that could leave Earth looking like Venus does today.

Research: Radar, Bats, and Dolphins

The *Magellan* spacecraft's images of Venus were constructed through radar imaging. Ask students to research radar. How does a radar camera work? How does the policeman's radar "gun" work? Does it send an image back to the police car? How is this radar similar to the way that bats, dolphins, and other animals use echo location to "see" where they are going in darkness or water? Can blind people learn to "see" by echo location?

Library Research: Missions to Outer Space

Have students research the Apollo, Venera, Magellan, Viking, and space shuttle missions that gathered data and took pictures on our neighboring planets. How were they taken? Have students research other interplanetary missions like Voyager I and Voyager 11, Pioneer, and Galileo. Were the pictures taken on these missions different? What conclusions have scientists come to by looking at these pictures? Most of these missions were not designed to detect life. Even so, could they do it? What measurement might they take, or what scene might they photograph, that would unequivocally show evidence of the presence of life?

Activity: Truth and the Tabloids

Ask students to bring in articles from various tabloids that "prove" that there is life on other worlds. Have them look for articles about the "Great Stone Face" on Mars, cities on the Moon, and so forth. How do we judge if these stories are truthful? Some students may believe anything they read, while others will automatically disbelieve anything that appears in a tabloid, even if it is true. Try to develop logical strategies for analyzing stories from tabloids or from the daily newspaper. Encourage students to be skeptics!

Arrange a lesson on how easy it is to "fake" photos, especially given the graphics computer technology available today. Many tabloid claims are simply hoaxes based on fake photos. Challenge students to make their own convincing "hoax" photos or videos of UFOs and extraterrestrials! What sort of proof would be enough to believe an extravagant claim, such as that of a flying saucer landing on Earth? Such a "grand" claim would require "grand" evidence. A physical artifact (not a photo of one) that could be tested and shown to be impossible to make on Earth would be "grand" evidence. Or a new fact, one that no one on Earth could possibly know or find out, but could still be substantiated by building a new telescope or other instrument would also be "grand" evidence.

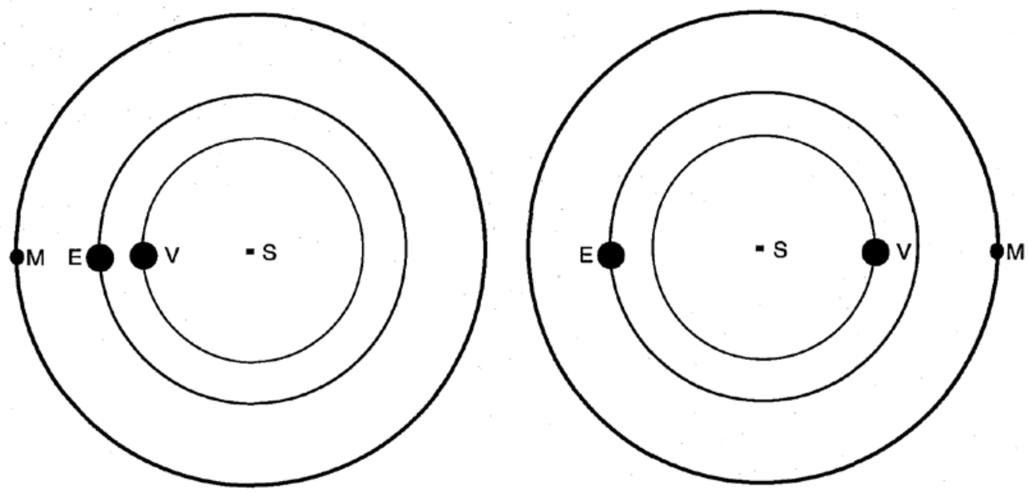
Comparative Planetology
Searching Earth, Mars, and Venus for Signs of Life!

Orbital Model-Teacher's Key

1. On one of the blank orbital pictures below, add Venus and Mars to their orbital paths as close as possible to Earth. Label Venus with the letter V and Mars with the letter M. On the remaining blank orbital picture below, add Venus and Mars to their orbital paths as far as possible from Earth.

   Label the planets again.

Figure 1.1—Orbital Model.



2. If 1 meter on your orbital model represents 150 million actual kilometers, what is the shortest distance that can occur between Earth and Venus? .28 meters x 150,000,000 km = 42,000,000 kilometers Earth and Mars? .52 meters x 150,000,000 km = 78,000,000 kilometers

3. What is the greatest distance that can occur between Earth and Venus? 1.72 meters x 150,000,000 km = 258,000,000 kilometers

   Earth and Mars? 2.52 meters x 150,000,000 km = 378,000,000 kilometers

Script for Video Images

“Voyages to Earth, Mars, and Venus”

Ladies and gentlemen!

We are now going to take three imaginary voyages to three planets. The first is a voyage to Earth, the second is a voyage to Mars, and the third is a voyage to Venus.

We will imagine that we are seeing each planet through the cameras of a tiny spacecraft, which will approach and land to look for signs of life. In each case, the only information we will have about the planet is the information that we can see in the pictures the spacecraft sends back to us. In the case of Earth, it will be harder to imagine this because we live here and we know all about Earth. So, let's pretend that we are extraterrestrial scientists, perhaps exobiologists from a planet that orbits Alpha Centauri. This way, the only information we will have will be the information shown in the pictures.

As you watch the video, your challenge will be to study each picture carefully and see if you can find any evidence that there is life on the planet, or evidence that life was present in the past. If you can't find evidence of life in the pictures, see if you can find features of the planet that might make it a good environment for life. Raise your hands as you get ideas and I'll call on you to share them. Keep track of your ideas and your classmates' ideas on your “Looking for Life” worksheet. Okay, ready? Let's begin.

Voyages to Earth

Image # 1

We're approaching Earth, the third planet out from a G-type yellow star. We're passing the planet's single moon en route to our destination. The Moon is now about 160 kilometers below us; the planet is still about 400,000 kilometers away. We see Earth against the black backdrop of pace. The Sun is straight above us, out of the picture, 150 million kilometers away. Look at the razor-sharp horizon of the Moon; it turns abruptly from brown to black at the edge. This is because earth's Moon has no atmosphere. On a planet with an atmosphere, the horizon is fuzzy and discolored. Let's proceed to the next image and then start looking for signs of life.

Image # 2

We're getting closer. Seen from this distance, Earth is always about half-covered with slowly moving white vapors. The vapors swirl in streams and in huge circular patterns. If we watch long enough, we could eventually map the surface of the planet under the vapor cover. We see that the surface consists of irregular brownish shapes -continents- against a blue background. Toward the southern pole of the planet the surface is white. The brown surface features do not change their shapes during the year. The white surface feature toward the southern pole gets a little bigger in winter, then shrinks again in summer. What are these features? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 3

We're getting closer. If our spacecraft stayed here for a year, it would be easy to see that some of the continents are green in spring, then turn brown during summer and fall, then (near the poles) turn white in winter. Near the equator, the continents stay green all year or (in some areas) only turn brown (but not white) for part of the year. What causes these color changes? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 4

Closer still! From about 160 kilometers up, we see more surface detail. The vertical blue strip through the center of the photo has an interesting feature. Its opposite shores fit together! It looks like the blue strip is a widening crack that was once much narrower. Not much white vapor here. Also, the surface colors are patchy. The dark patches get slightly darker and bigger when there is more vapor here. What are these features? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: The horizon is slightly fuzzy, indicating an atmosphere. As more convincing proof of an atmosphere, there is a dust storm blowing out over the water. No proof yet that the blue stuff is a liquid.]

Image # 5

Our spacecraft is now flying about 160 kilometers over the surface, preparing for its final descent. Below us we see that the surface isn't smooth. There are meandering channels that join and go downhill toward the blue area. The higher elevations have white on them. The white patches get bigger in winter and smaller in summer.

What are these features? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 6

Cowabunga! There is a cloud of something billowing up from the surface of the planet! What can it be?

[Notes: Possibilities are a volcano, something burning on the surface, a dust storm, or a chemical reaction that is creating vapors. In any case, it is clear that there is an atmosphere. If there is a fire, then the atmosphere must contain oxygen.

Image # 7

Suddenly we have a view that suggests that the blue areas consist of some liquid with waves on the surface!

What could it be? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: This image shows clear, faint, geometric patterns on land that would be very difficult to attribute to a nonliving process. Certain fault lines on Earth are very long and absolutely straight, but this view definitely raises the possibility that intelligent life may be at work.]

Image # 8

We're nearing touchdown! We fly by an immense crater! What can it be?

[Notes: The straight lines in this view could be due to faults, but, as in the preceding image, they are probably the work of intelligent beings. From the image, it cannot be determined whether the crater is volcanic or meteoritic.]

Image # 9

This planet has active volcanoes! Our space probe goes flying by one that is actually erupting!

Image # 10

We've landed! There is a huge wave of some liquid surging toward us! We have time for only one reading-air temperature is 12” C -and a quick look through the microscope camera.

Image # 11

There it is! It's round….. it's about four centimeters in diameter.... it's-Our probe has stopped sending pictures!

Stop and Assess What You've Seen on Earth

Rewind the video and take a second look at various images if students want to study them longer. Give students time to answer the following two questions on their “Looking for Life” worksheet.

1. In the images of Earth, did you see any environmental features that could support life as we know it?

(The liquid's temperature of 12” C indicates that it is probably water. An atmosphere is present. Oxygen is present, but only if the class agrees that the cloud in image # 6 was actually smoke.)

2. In the images of Earth, did you see any features that could only have been created by life?

(No. Color changes could be caused by seasonal moistening of the surface by rains. Straight lines could have been caused by geologic faults. Geometric figures could have been caused by huge regional faulting patterns. However, the geometric patterns could also have been caused by intelligent life.)

Voyages to Mars

Image # 12

Our next space voyage in search of life will be to the planet Mars, the fourth planet out from a G-type yellow star. But first, let's re-create a real voyage to Mars. In the 1970s, NASA launched two spacecraft toward this planet. These were called the *Viking* missions. This image shows one of those missions.

Mars is the fourth planet from the Sun. When the first *Viking* spacecraft was launched, Earth was at the seven o'clock position in its orbit and Mars was at the five o'clock position in its orbit. In this view, both planets are going counterclockwise. The *Viking* spacecraft followed this dotted line and intercepted Mars midway between its eleven and twelve o'clock positions. By that time, Earth had passed Mars and was now at Earth's eight o'clock position. When the spacecraft arrived at Mars, it went into orbit around the red planet and detached a landing device. At that time, Earth and Mars were about **225** million miles apart.

To send the spacecraft on a straight-line path to Mars would require a huge amount of fuel. The curved dotted-line path was followed because it required the least amount of fuel. Most of the fuel the *Viking* required was burned at launch. Once the spacecraft had left Earth's atmosphere, it simply coasted along its natural path to arrive at Mars. The remaining fuel was used to slow the lander as it dropped to the planet.

Image # 13

After it detached from the orbiting spacecraft, the *Viking* lander dropped to the surface of Mars using a parachute and retro rockets. The parachute by itself wasn't enough, due to the very thin atmosphere of Mars. From the surface, the lander conducted scientific tests and radioed its findings back to the orbiter. The orbiter then radioed the findings to Earth. In our voyage to Mars to search for signs of life, we will see images that simulate what might have been seen from the *Viking* spacecraft as it approached Mars, and also images that were actually taken by the *Viking* lander.

Image # 14

Seen from Earth by telescope, this is about the best view one can get of Mars. The planet is about 50 million miles away. The view is fuzzy because we are looking at it through Earth's atmosphere. Even at this distance and even with the fuzzy view, we see that Mars has permanent white patches at its northern and southern poles, and irregular dark shapes against a reddish-orange background. Each polar white patch gets bigger during the winter in its hemisphere and' much smaller during summer. The dark patches get bigger during summer and smaller during winter, just the opposite of the white patches.

What could these patches be? Do you see any signs of life? Do you see any signs of an environment that might support life? [Notes: The white patches could be frozen water.]

Image # 15

Our spacecraft is closing in! The view is now clear because we are looking through the vacuum of space and not through Earth's atmosphere. We see a lot of details on the surface that can't be seen from Earth. There are three big craters in a line. Running across the middle of the planet is a huge canyon so gigantic that if it were on Earth it would go from California to New York. We don't see much of the moving white vapor that we saw on Earth from the same distance.

What could these features be? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: The canyon is called the Mariner Valley, or Valles Marineris, after the spacecraft that discovered it. It is also called the Grand Canyon of Mars.]

Image # 16

We're now flying over the surface of Mars about 100 miles up. We see that the surface is quite pocked with circular craters. We also see meandering channels that go downhill and end abruptly along a line of cliffs. From this height we sometimes see the entire surface of Mars become fuzzy and indistinct; some or all of its features disappear for a while, reappearing after weeks or months.

What could this phenomenon be? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: Sandstorms, which are evidence of an atmosphere and winds, are obscuring the view.]

Image # 17

We're over the southern pole of Mars! The white patch below us seems to be piled up in layers. It's summer down there. This is as small as the white patch ever gets. As it shrinks, it leaves islands of white behind it that are separated from the main polar cap.

What could the white patch and white islands be? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 18

Lower! We are flying past a giant volcano! It is bigger than Mount Everest. It is the biggest volcano in the entire solar system! If we were to watch it, we would see that it sometimes has white vapor near its summit. However, the vapor seems to form *outside* of the crater. As another peculiar feature, the volcano is “cut off” around its base. Instead of sloping smoothly to the Martian plain below, its base is formed of huge, nearly vertical cliffs, some of the highest cliffs in the entire solar system.

How did the volcano get that way? Is it active? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: The volcano is named Mount Olympus.]

Image # 19

Lower! It looks like **. . .** like **. . .** a sculptured stone “face”! (Ahhh……. is it Elvis? Is it Nixon?) Nearby we see what appears to be featureless country with craters, big rock formations, and numerous small black dots.

What could this stone “face” be? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: This is the famous “Great Stone Face” from tabloid newspapers. If this were the work of intelligent life, comparable to the pyramids of Egypt, for example, one might expect to see a ruined city surrounding it or some other traces of its builders. Of course, one might claim that all the other traces of the builders have been buried under drifting sand. Virtually all geologists consider this a natural formation, sure to show up by chance among millions of other rocks that do *not* have a familiar-looking appearance.]

Image # 20

Our lander is down! And what do we see? First, a self-portrait. Next…..

Image # 21

This is the surface of Mars as actually seen by one of the *Viking* landers. Unlike our imaginary vehicle to Earth, the *Viking* landers continued to operate for many years after they settled on Mars, sending back pictures and data the entire time. They observed many passages of the seasons. Among other interesting observations, the pictures often showed that the ground was white in early morning. As the sun rose, the white disappeared, lingering longest in the shadows of rocks. At no time did the ground appear to be wet. Pictures of the landers also showed that the sand moved; it blew around and piled up in different ways. Aside from these changes, the views from the landers were exactly the same when they finally stopped working, years after touchdown.

What are the features in this view? Do you see any signs of life? Do you see any signs of an environment that might support life? What would you watch for if you had several years to watch this landscape for the appearance of life?

[Notes: Examples of things to watch for could include tracks in the sand, growth or movement of the rock-like objects-maybe life-forms look like rocks on Mars, growths of lichen-like objects on the rocks, something passing by in the distance, an increase in the number of rock-like objects.]

Image # 22

This object was not seen by the *Viking* landers. It is something from Earth. But what would you think if a microscope on our lander was seeing this object in the Martian soil? Would that be evidence that there is now life on Mars? That life had existed on Mars in the past?

Stop and Assess What You've Seen on Mars

Rewind the video and take a second look at various images if students want to study them longer. Give students time to answer the following two questions on their "Looking for Life" worksheet.

1. In the images of Mars, did you see any environmental features that could support life as we know it?

   (The sinuous channels on Mars suggest that water was once present. The numerous asteroid craters suggest that there has been no water action or erosion for a long time. The fact that the surface never appears wet suggests that the white substance must be evaporating rather than melting, which suggests that at least some of it may be frozen carbon dioxidedry ice-rather than frozen water. The vapors seen forming around Mount Olympus and other high elevations are clouds; this indicates a very thin atmosphere is present.)

2. In the images of Mars, did you see any features that could have been created by life?

   (No. Reasons for the color changes are unknown, but they could be caused by a nonliving process-perhaps vapor-laden air from the melting polar caps spreads and freezes each night, roughening the Martian surface; or perhaps lighter-colored sand blows over darker material and then blows away again, seasonally. The long watch of landscapes at the two Viking *lander sites revealed absolutely nothing that would indicate the presence of life.)*

Voyages of Venus

Image # 23

Venus is the second planet out from a G-type yellow star-our Sun. Venus is our closest neighbor in space. From Earth, Venus appears mysterious, mantled in creamy yellow "clouds."

What could the clouds be made of? What might be hiding underneath these clouds? A swamp full of tree-size ferns and fighting dinosaurs? A dry, barren desert of swirling sand? A thriving alien civilization? What are these clouds? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 24

In this composite photographic view, we can see that Venus and Earth are almost twins in size, and both planets orbit close to the same star. Could Venus and Earth be identical twins? From Earth, it is difficult to tell. Although the clouds on Venus change and swirl, they never break apart to reveal the surface of Venus. Probes from Earth have shown that the cloud layer on Venus is very thick, and that the clouds are not made of water vapor, but of sulfuric acid, which is water combined with sulfur dioxide. Sometimes, drops of acid begin to fall toward the surface, but they never arrive there. They evaporate because of the intense surface heat.

Do you see any signs of life on either planet? Do you see any signs of an environment that might support life?

Image # 25

We're invited to view the pictures sent back from the *Magellan* mission to Venus! (In 1989, NASA's space shuttle *Atlantis* launched the *Magellan* spacecraft toward Venus.) This spacecraft did not land on Venus, nor did it drop off a lander. Landers don't last long on the surface of Venus. The Russian lander *Venera* was crushed after about 20 minutes on the surface by an atmospheric pressure of 1,260 pounds per square inch, which is 90 times the atmospheric pressure on Earth! Instead the *Magellan* spacecraft orbited Venus for years, sending back information to Earth. The *Magellan* sent back radar mapping data and atmospheric data until October 12, 1994, when it was sent into the planet's atmosphere to do a few last atmospheric tests before crashing on the surface of Venus. It was a kamikaze spacecraft!

Image # 26

This was the *Magellan* spacecraft. Because of the thick cloud cover on Venus, *Magellan* didn't just take photographs using visible light. Instead, *Magellan* used a synthetic aperture radar to map the surface features. Radar waves penetrate the clouds, bounce off of the surface, and return to the spacecraft.

Based on the time it took a radar signal to bounce back to *Magellan* we can tell how far the surface of Venus is below the spacecraft (whether it reflects off a tall mountain or the bottom of a deep valley, for example). On-board computers translate the radar data into striking “pictures” of the surface of Venus.

Image # 27

Suddenly the once-hidden surface of Venus fills the entire screen! We are seeing the surface of Venus, as it appears beneath the mantle of creamy yellow clouds. This is a composite view of one hemisphere of Venus, made by combining the data from many, many radar images. Over 98 percent of the planet's surface was mapped by *Magellan.*

What do you see in this composite view? What is the surface of Venus really like? What could the light and dark areas be? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 28

The next image from Magellan's orbit shows the Northern Hemisphere drifting into view. There are more light and dark areas visible, in different patterns. But there are no polar ice caps; Venus is much too hot for that! Sensors reveal that the surface of Venus is above 460º C, which is hot enough to melt lead! No wonder the rain (sulfuric acid) evaporates before it reaches the surface!

Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 29

Are we getting closer? In a way, we are. We are magnifying our image and looking at a much smaller portion of the planet. This is like using a zoom lens on a camera. All the radar images from Magellan appear in black-and-white as in this picture, though it is possible to have the computer color the image.

What makes the black-and-white pattern? What is the huge circular feature near the center of the picture? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: The circular feature is the volcano Sapas Mons.1

Image # 30

This is the same area as the last picture, at the same magnification, although the circular feature seems to be revealed in more detail. This picture is a “false-color” image. Scientists had the computer print the picture in color. The orange colors were chosen because the Russian lander Venera was able to send back a few color photographs of the surface of Venus before it was crushed by the tremendous atmospheric pressure. The Venera lander saw a red-orange world, dimly lit, as Earth is on an overcast day.

What could the circular feature be? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 31

It's amazing what a computer can do with a little data! This is another false-color image of the same circular area interpreted according to the height of the features. This is called a perspective view, because it lets us see what the terrain looks like from another perspective. This is just as the surface would look from an airplane flying over the surface of Venus but beneath the cloud cover. The sky is not really black; scientists left the image black because there is no radar data for the sky. (Radar can only image surface features.) The sky would also be orange in a photograph taken from the surface of Venus. Also, the little bump on the horizon and all the vertical features have been exaggerated 10 times so they are easy to see. (Venus is a very flat world. Mountains are only about half as high as those on Earth.)

What could the terrain be? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 32

This is a false-color perspective view of another area. Even with 10-times exaggeration, most of the terrain appears flat, but there are some bumpy formations near the horizon. Most of the surface of Venus appears to be covered by volcanic rocks. Ancient lava flows appear to form vast, flat plains. What could the bumpy formations be? Hills? Mountains? Volcanoes? Venusian monsters? Could the flat area be an ancient ocean bed? A dry desert? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: The bumpy formations are volcanoes: the larger is Sif Mons and the smaller is Gula Mons.]

Image # 33

This is another false-color perspective view of the two bumpy formations near the horizon. They are mountains! They are also volcanoes! One is 2 kilometers high; the other is 3 kilometers high. Only 15 percent of the surface of Venus is mountainous today.

What might the surface of Venus have been like in the past? What do you think the brightly colored lines are? Why do you think so? Do you see any signs of life? Do you see any signs of an environment that might support life?

Stop and Assess What You've Seen on Venus

Rewind the video and take a second look at various images if students want to study them longer. Give students time to answer the following two questions on their "Looking for Life" worksheet.

1. In the images of Venus, did you see any environmental features that could support life as we know it?

   (No. The clouds may look promising, but they do not hold any liquid water; life as we know it requires liquid water. The water in the clouds is combined with sulfur dioxide to make sulfuric acid, which is corrosive to living things on Earth. The high temperature and extreme pressure do not look promising either. The most likely place for life on Venus might be in the upper atmosphere, which is cooler and under less pressure. But the upper atmosphere is mostly carbon dioxide.)

2. In the images of Venus, did you see any features that could have been created by life?

   (No. There is nothing that even appears promising.

Comparative Planetology

Searching Earth, Mars, and Venus for Signs of Life!

Looking for Life-Teacher's Key

Answers to student questions:

Earth

1. Yes. A temperature of 12° C indicates that the liquid is probably water, which is vital to life. The slightly fuzzy horizon is evidence that an atmosphere is present that contains oxygen if it was smoke that was seen in image # 6. As more convincing proof of an atmosphere, there was a dust storm blowing off out over the water in image # 4.

2. No. The color changes could be caused by seasonal moistening of the surface by rains. The smoke could be a volcano, something burning on the surface, a dust storm, or a chemical reaction that is creating vapors. Straight lines might have been caused by geologic faults, and geometric figures might have been caused by regional faulting patterns. Still, geometric patterns on land would be very difficult to attribute to a nonliving process. Certain fault lines on Earth are very long and absolutely straight fault lines are present on Earth, but image # 7 definitely raises the possibility that intelligent life may be at work.

Mars

3. Yes. The channels on Mars suggest that water was once present. The numerous asteroid craters suggest that there has been no recent water action or erosion. Because the surface never appears wet, the white substance must be evaporating rather than melting, which suggests that at least some of it may be frozen carbon dioxide-dry ice-rather than frozen water. The vapors seen forming around Mount Olympus and other high elevations are clouds; this indicates a very thin atmosphere is present. Sandstorms can also be seen occurring in the atmosphere.

4. No. The color changes could be due to a nonliving process-perhaps vapor-laden air from the melting polar caps spreads and freezes each night. The long watch of landscapes at the two *Viking* lander sites revealed nothing that would indicate the presence of life. Also, *Viking* scientific tests for life were negative. Geologists consider the famous “Great Stone Face” on Mars to be a natural formation, sure to show up by chance among millions of other rocks that do *not* have a familiar-looking appearance. If this were the work of intelligent life, one might expect to see a ruined city surrounding it or some other traces of its builders.

Venus

5. No. The clouds may look promising, but all the water they contain is combined with sulfur dioxide to form sulfuric acid; life as we know it requires liquid water. The clouds are made of sulfuric acid, which is corrosive to living things on Earth. The high temperature and extreme pressure do not look promising either. The most likely place for life on Venus might be in the upper atmosphere, which is cooler and under less pressure. But the upper atmosphere is mostly carbon dioxide.

6. No. There is nothing that even appears promising.

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Mission 1
Project Profile

Welcome to the SET1 team! In ***Life: Here? There? Elsewhere? The Search for Life on Venus and Mars*** you will be learning how to conduct a search for life on Venus and Mars. To accomplish your missions, you will undertake 14 missions to learn about life on Earth and about the planets Venus and Mars. It may be useful for you to jot down your initial impressions and responses to the following questions before starting the missions. Do you think your ideas will change?

Mission 1: Comparative Planetology

Can you find evidence of life on Earth, Mars, and Venus? What are these planets like?

Mission 2: There's Power in Numbers! (Phase I)

What is the effect of scale? Can you tell if a planet has life on it by looking at the entire planet? Can you tell if a planet has life on it by looking at microscopic samples of its soil?

Mission 3: Venus Plates and Mars Jars! (Phase I)

Can life as we know it survive in the conditions found on Mars and Venus today?

Mission 4: There's Power in Numbers! (Phase 11)

What would Mars and Venus look like at different scales? Would you recognize life at different scales?

Mission 5: Initial Spacecraft and Lander Design

What are the major components of a spacecraft and lander designed to search for life on another planet? How are the landing site characteristics incorporated into the design?

Mission 6: Venus Plates and Mars Jars! (Phase 11)

Did our terrestrial life survive through hostile environmental conditions similar to those on Venus and Mars?

Mission 7: Water!

How can you tell if a liquid on another planet is water? Why would you want to know?

Mission 8: What Is Life?

What are the main characteristics of life? How can you tell when something is not alive?

Mission 9: Mission to Planet Earth-Life in Soil!

Is it possible to detect life in a soil sample from Earth or from another planet? How?

Mission 10: Chemical Tests for Life

How can you test for the chemicals that indicate life?

Mission 11: Mission to Planet Earth-Life Trap!

Is it possible to detect life in a planet's atmosphere? How?

Mission 12: Can You "Gas" What's Happening?

Can you test for the presence of life by analyzing a soil sample's release of gases?

Mission 13: The Viking Search for Life on Mars

What was found by the Viking spacecraft during its search for life on Mars? Are any of the tests that were conducted by this spacecraft similar to the tests that you have conducted in your missions?

Mission 14: Final Spacecraft and Lander Design

How would you design a spacecraft and lander to detect life on another planet?

Comparative Planetology
Searching Earth, Mars and Venus for Signs of Lfe!

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Looking for Life—Worksheet

Name: ________________________________ Date: _________________________

Please answer the following questions:

Earth

1. n the images of Earth, did you see any environmental features that could support life as we know it? Describe these environmental features.

2. In the images of Earth, did you see any features that could only have been created by life? What else could account for these features?

Mars

3. In the images of Mars, did you see any environmental features that could support life as we know it? Describe these environmental features.

4. In the images of Mars, did you see any features that could have been created by life? What else could account for these features?

Venus

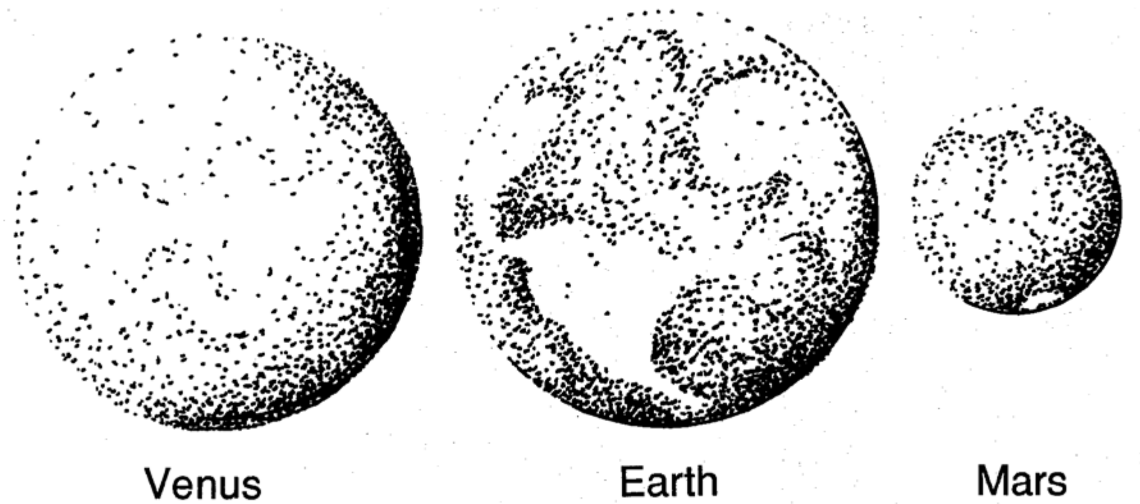
5. In the images of Venus, did you see any environmental features that could support life as we know it? Describe these environmental features.

6. In the images of Venus, did you see any features that could have been created by life? What else could account for these features?

Comparative Planetology
Searching Earth, Mars and Venus for Signs of Life!!

Comparing the Planets--Transparency

Figure 1.2-Mars, Venus, and Earth.



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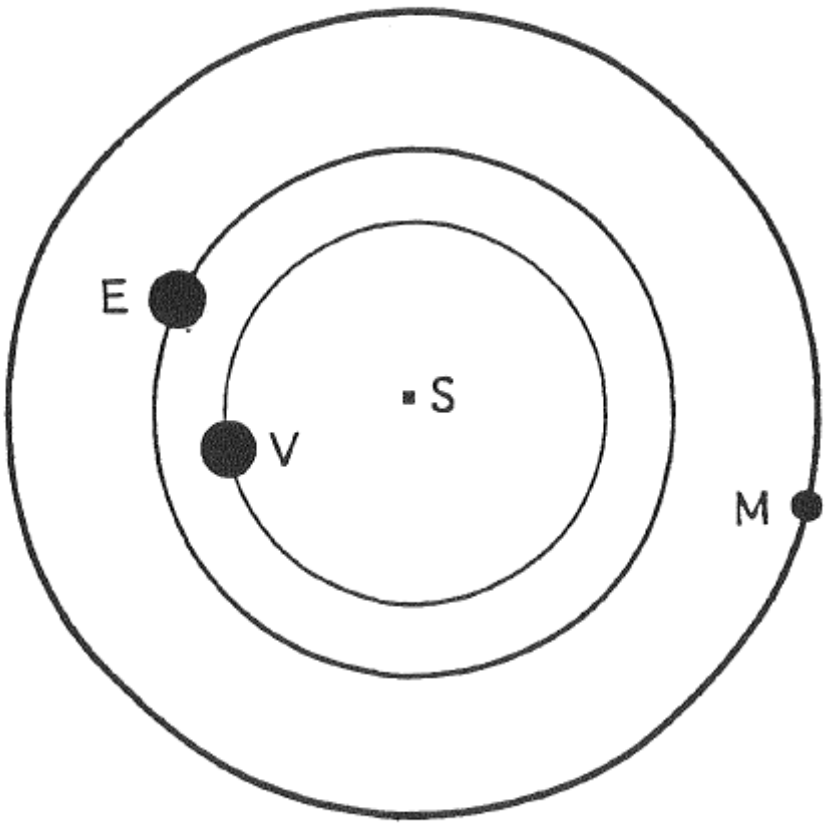
Orbital Model—Transparency

Figure 1.3—Orbital Model



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Creating an Orbital Model—Directions

Making the Planets

1. Split your clay into two equal balls. Choose one of these balls to be your first planet and set it aside.

2. Divide the other ball into seven smaller balls of equal size. Select one of these smaller balls to be your second planet and set it aside.

3. Combine the remaining six small balls to form your third planet.

4. Determine which planet is Earth, which is Venus, and which is Mars. Check with your teacher to make sure you are correct. Mark the surface of each planet with the letter V, E, or M.

Making and Using an Orbital Model

1. Cut (or make sure you have) strings of the following lengths: .72 meters, to represent a scale average distance from Venus to the Sun; 1 meter, to represent a scale average distance from Earth to the Sun, and 1.52 meters, to represent a scale average distance from Mars to the Sun. These lengths represent the average distance between the Sun and the planet in the orbits of Venus, Earth, and Mars, respectively.

2. Tack the end of each string into its appropriate planet. Tie together the ends of the three strings.

3. Tack the knot where the strings are tied together to a piece of cardboard. This knot represents the Sun.

Comparative Planetology
Searching Earth, Mars and Venus for Signs of Life!!

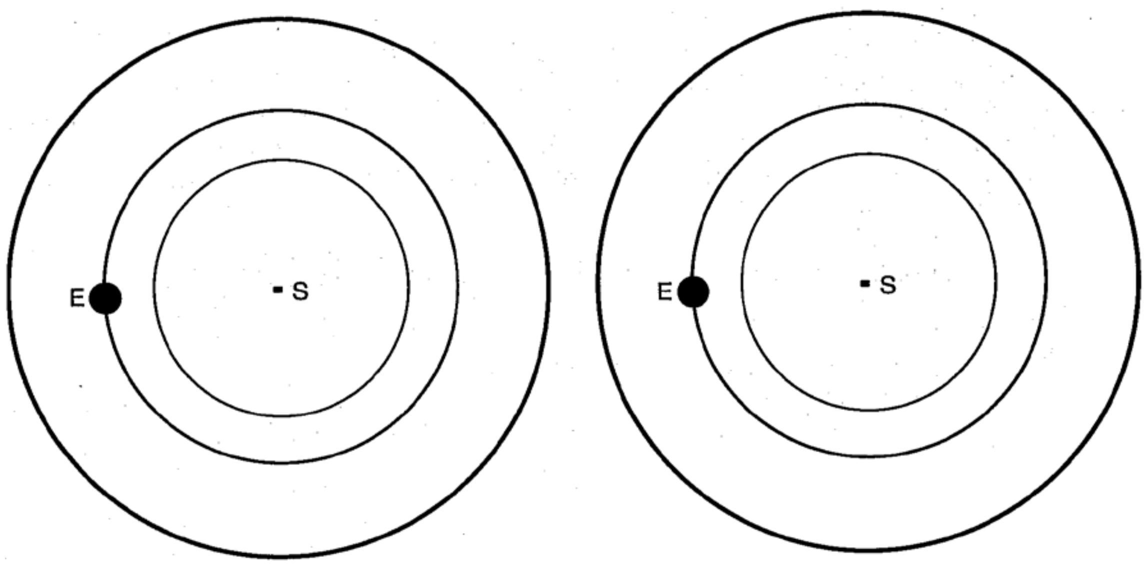
Creating an Orbital Model—Directions

Name: ________________________________ Date: __________________________

Note: When using your orbital model to make calculations, move the planets counterclockwise in their orbits, keeping the strings tight. When measuring distances, measure from the center of each planet.

1. On one of the blank orbital pictures below, add Venus and Mars to their orbital paths as close as possible to Earth. Label Venus with the letter V and Mars with the letter ***M.*** On the remaining blank orbital picture below, add Venus and Mars to their orbital paths as far as possible from Earth. Label the planets again.

Figure 1.4—Orbital Model.



2. If 1 meter on your orbital model represents 150 million actual kilometers, what is the shortest distance that can occur between

Earth and Venus?

Earth and Mars?

3. What is the greatest distance that can occur between

Earth and Venus?

Earth and Mars?

Comparative Planetology
Searching Earth, Mars and Venus for Signs of Life!!

Planet Attribute Cards

Earth

Gravity (Earth = 1): 1
Average Distance from Sun (million km): 150
Average Distance from Sun (AU): 1
Year Length: 365.26 days
Day Length: 23 hr., 56 min., 43 sec.
Axis Tilt: 23^{o} 27'
Diameter at Equator (km): 12,756
Volume (Earth = 1): 1
Main Components of Atmosphere: Nitrogen, Oxygen
Atmospheric Pressure (Earth = 1): 1
Known Natural Satellites: 1

Mars

Gravity (Earth = 1): 0.38
Average Distance from Sun (million km): 228
Average Distance from Sun (AU): 1.524
Year Length: 6,787 days
Day Length: 24 hr., 37 min., 23 sec.
Axis Tilt: 23^{o} 59'
Diameter at Equator (km): 6,787
Volume (Earth = 1): 0.15
Main Components of Atmosphere: Carbon Dioxide
Atmospheric Pressure (Earth = 1): 0.006
Known Natural Satellites: 2

Venus

Gravity (Earth = 1): 0.9
Average Distance from Sun (million km): 108
Average Distance from Sun (AU): 0.723
Year Length: 224.7 days
Day Length: 243 days (retrograde).
Axis Tilt: 3^{o}
Diameter at Equator (km): 12,104
Volume (Earth = 1): .86
Main Components of Atmosphere: Carbon Dioxide
Atmospheric Pressure (Earth = 1): 90
Known Natural Satellites: 0

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Comparative Planetology
Searching Earth, Mars and Venus for Signs of Life!!

Blank Planet Attribute Cards

Planet: ______________
Gravity (Earth = 1):
Average Distance from Sun (million km):
Average Distance from Sun (AU):
Year Length:
Day Length: .
Axis Tilt:
Diameter at Equator (km):
Volume (Earth = 1): .
Main Components of Atmosphere:
Atmospheric Pressure (Earth = 1):
Known Natural Satellites:

Planet: ______________
Gravity (Earth = 1):
Average Distance from Sun (million km):
Average Distance from Sun (AU):
Year Length:
Day Length: .
Axis Tilt:
Diameter at Equator (km):
Volume (Earth = 1): .
Main Components of Atmosphere:
Atmospheric Pressure (Earth = 1):
Known Natural Satellites:

Planet: ______________
Gravity (Earth = 1):
Average Distance from Sun (million km):
Average Distance from Sun (AU):
Year Length:
Day Length: .
Axis Tilt:
Diameter at Equator (km):
Volume (Earth = 1): .
Main Components of Atmosphere:
Atmospheric Pressure (Earth = 1):
Known Natural Satellites:

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Comparative Planetology
Searching Earth, Mars and Venus for Signs of Life!!

Attributes of the Planets-Optional Worksheet

Name: ____________________________ Date: ________________________________

Describe each of the following planets as completely as you can. Use information from the video image show, from your orbital model, and from the "Planet Attribute Cards." Note anything that would make each planet either suitable or unsuitable for life as we know it.

Earth:

Mars:

Venus:

Mission 2
There's Power in Numbers! (Phase 1)

Journeys to Microworld and Macroworld Earth

Notes

In mission 1, *students journeyed* to *Mars, Earth, and Venus in* a *video image show. Size and distance in the video photographs were difficult* to *appreciate. No discussion of the search for life should take place with· out mention of the scales involved in* an *observation. The distance* to *another planet or satellite in the solar system is measured in tens of millions of kilometers, while the size of* a *carbon atom is measured in angstroms* (1 *angstrom =10,10 meters). Such large distances and small sizes are difficult* to *imagine because they are so far removed from daily life.*

Teacher's Note: Make sure all ZOOM! Cards are laminated.

Overview

In mission 2.1, students use ZOOM! Cards depicting Earth to explore scale and powers of 10. They develop a better understanding of scale and learn its importance to determining the type of life signs that might be detected. Students use the ZOOM! Cards to journey to "Microworld Earth." In mission 2.2, students use ZOOM! Cards to journey to "Macroworld Earth."

Mission 2.1
Materials

For a Class of 30

- "Journey to Microworld Earth" script

For Each Team

- Transparency marker or grease pen
- ZOOM! Cards for Microworld Earth
- ZOOM! Cards for Macroworld Earth

For Each Student

- “Journey to Microworld” worksheet
- Pencil

Getting Ready

1. If you have not yet done so, cut apart the individual cards on the sheets of ZOOM! Cards. If possible, to preserve them for future use, laminate the sheets of ZOOM! Cards before cutting them. (Clear contact paper works well, but be sure to cut apart the cards and cover each one separately, leaving a border.)Assemble six complete Earth decks (19 cards each). (This is a good time to make the six Mars decks and the six Venus decks that will be used in mission 4.)

2. Test the markers or grease pens to be sure that they can be wiped off of the laminate or contact paper.

3. Copy the worksheet “Journey to Microworld” for each student (or each team).

4. Study the Earth ZOOM! Cards to refresh your perception of distance and size. Read through the script “Journey to Microworld Earth,” anticipating students' questions.

Classroom Action

1. **Activity.** Divide the class into six groups. Give each team a deck of Earth ZOOM! Cards (19 cards total). Hand out a copy of the worksheet “Journey to Microworld” to each student (or each team). Have students shuffle their decks and lay all the cards face up on a table. Ask students to arrange the cards so that they are “in order.” Do not tell them what is meant by “in order” (largest scale to smallest scale). Ask them to sort the Earth ZOOM! Cards by looking only at the pictures. Arranging the Earth ZOOM! Cards in scale order should be easy because of familiarity with Earth. Students should be able to discover that the differences among the cards are the scales used in the picture. Also, each card shows either something that is smaller than a person or something that is bigger than a person. The ZOOM! Cards form a series of changes in scale, a series of enlargements (or reductions, depending on your perspective).

   After they have had an opportunity to discover this, tell them that each card is a power of 10. On this scale, 0 is “life-size.” Numbers with positive exponents are larger than life-size, and those with negative exponents are smaller than life-size. After they have had an opportunity to discover this, tell students that the view in each card represents a different scale: 3 inches, or about 8 cm (the width of each card) equals; distance in meters that is a power of 10 *(e.g.*, 10 meters, lo4 meters, meters). Each card has a different power of 10. On this scale, a power of B 0 is used for a picture of a child (the “10 meters” card), a power that is a positive number is used for something that is larger than the child (*e.g.*, the “lo4 meters” card showing an entire city), and a power that is a negative number is used for something that is smaller than the child (*e.g.*, the “10- meters” card showing muscle and blood tissue). If necessary, review exponential numbers and scientific notation with the class. Invite them to examine their cards again, looking for clues to scale. Ask them to make guesses about the size of the pictured things. At this point, do not reveal the correct order, even if students do not know where to place each card, or exactly what each card shows.

2. **Script.** Read or paraphrase the script “Journey to Microworld Earth” card by card. Tell students that this script will describe, in order, the first 11 of their cards. Ask groups to find each card as you discuss it, and organize their ZOOM! Cards into your order. (Many arrangements are proper.) Give students time to fill out their worksheets during the reading of the script. Encourage discussion of each card, especially about scale and any signs of life that can be seen at that scale. Have students use transparency markers or grease pens to mark the scale on each card.

3. **Clean-Up**. If another class will use the cards for mission 2, have students wipe them clean of marks. If not, keep the scales on the cards for use in mission 4. Gather up all the ZOOM! Card decks.

Materials

For a Class of 30

- Overhead projector
- “ZOOM! Cards” transparency
- “Journey to Macroworld Earth” script

For Each Team

- Transparency marker or grease pen
- ZOOM! Cards for Microworld Earth
- ZOOM! Cards for Macroworld Earth

For Each Student

- “Journey to Macroworld” worksheet
- Pencil

Getting Ready

1. Copy the worksheet “Journey to Macroworld” for each student (or each team).

2. Study the Earth ZOOM! Cards to refresh your perception of distance and size. Read through the script “Journey to Macroworld Earth,” anticipating students' questions.

3. Prepare the “ZOOM! Cards” transparency and set up the overhead projector.

4. Reassemble the class into the previous six groups.

Classroom Action

1. **Activity.** Divide the class into the same groups that were formed for mission 2.1. Give each team a deck of Earth ZOOM! Cards (19 cards total). Hand out a copy of the worksheet “Journey to Microworld” to each student (or each team). Have students lay out their ZOOM! Cards “in order,” as they did in mission 2.1 (students will know the correct order for the first 11 cards).

2. **Transparency.** Show the overhead transparency “ZOOM! Cards.” Explain that these three cards show the same scene, but at a different magnification, as if you were backing away from or zooming in on the scene. If you are moving toward the scene (as a spacecraft approaching a planet, for example), which is the sequence from right to left for these three cards, the objects shown in the scene on each card are shown 10 times larger than on the previous card. Conversely, if you are backing away from the scene, which is the sequence from left to right, the objects on each card are shown 10 times smaller than on the previous card. If necessary, review exponential numbers and scientific notation with the class. On the transparency, draw a rectangle on the “lo0 meters” and the “10' meters” cards that represents the image that is seen on the “lo-' meters” card. For example, on the “lo0 meters” card, draw a rectangle around the girl's hand, which is all that can be seen on the card with the next increase in magnification (the “lo-' meters” card).

3. **Script.** Read or paraphrase the script “Journey to Macroworld Earth” card by card. Tell students that this script will describe, in order, the eight cards not described in mission 2.1. Have groups find each card as you discuss it, and organize their ZOOM! Cards in the proper order. Give students time to fill out their worksheets during the script. Encourage discussion of each card, especially about scale and any signs of life that can be seen at that scale. Have students use transparency markers or grease pens to mark the scale on each card.

4. **Clean-Up.** Have students wipe off any rectangles they have marked on the cards. If another class will use the cards for mission 2, wipe them clean of students' marks. If not, keep the scales on the cards for use in mission 4. Gather up all the ZOOM! decks.

Activity: Detecting “Life Objects”

Hand out one Earth ZOOM! Card to each team. Select the cards randomly, or choose specific cards. Some cards will be “easier” than others, such as plants, animals or artificial structures that student's can identify. Have each team brainstorm on impressive and unique “life objects” that exist on the scale of their card. **A** “life object” (something essential to life as we know it) need not be an individual animal or plant; it may be a body of water, or a carbon atom. They are not limited to the objects actually seen on their card; they should imagine new objects of the same scale. Challenge each team to explain why their scale is the best magnification to use when looking for life on another planet. Discuss which "life object" would best indicate life at each team's scale of observation. Remind students of their search for signs of life in the video images from mission 1; discuss any signs of life seen in the ZOOM! Cards.

Activity: Classroom Display

Ask groups to draw their "life objects" from the "Going Further" activity above onto blank 5-by-8- inch index cards. Hang up one set of Earth ZOOM! Cards and the groups' pictures of life objects along the front wall of the classroom. Use yarn to connect the life objects to the ZOOM! Cards that have the same scale. This is a useful tool for gauging scale throughout the remaining missions.

Activity: How Big Is It?

Cut pictures from magazines and give students several pictures of various objects, familiar and unfamiliar, or show the class images of these objects. Ask students how big each object is? How can they tell? If an object is familiar to students, they will rely on past experience and stored knowledge. Point this out to them and ask for clues to size and scale that could be used if they had never seen such an object.

Show and Tell: Scale Models

Students make or buy scale models all the time. Ask them to bring into the classroom some of these models. They should know the scale of the objects they bring in (*e.g.*, some doll-house furniture has a scale of 1 inch = 1 foot). Have students estimate the scales for their classmates' models. Some models should be larger than life-size (*e.g.*, plastic fly), while others should be smaller than life-size (e.g.? plastic dinosaur). Others should actually be life-size.

Activity: Microscopic Monsters

Ask students to use microscopes and prepared slides. Try a slide of a fruit fly, an amoeba, or a nematode worm. First, have students guess the size of a microscopic monster; then have them calculate its size. Ask students how this varies when they are using a low-power objective microscope. How does the apparent size vary with higher powers of magnification? (Do the microbes seem to be bigger when viewed at a higher magnification?) How is this important in our search for life on Mars or Venus? Would we need to look at Martian soil with a microscope? What magnification would we need?

Living microscopic monsters are even more fun. Pure cultures can be ordered from biological supply houses, but plenty of microbes can be found in pond water, aquarium water, hay infusions, or growing on slices of raw potato.

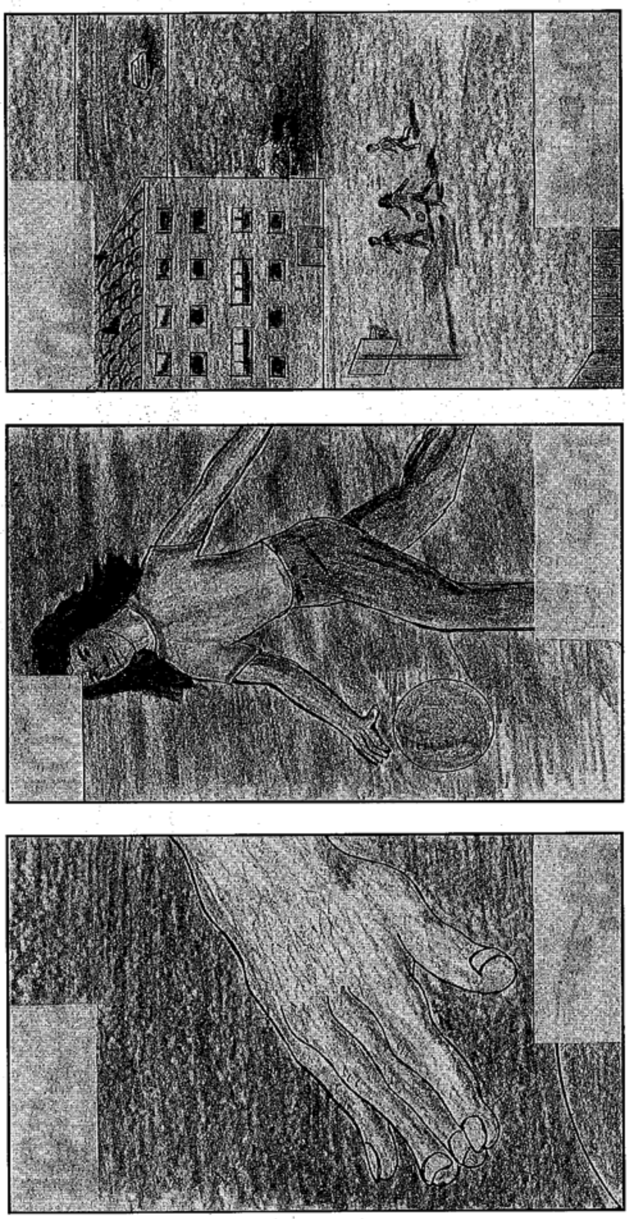
Activity

If your ZOOM! Cards are laminated, have students use transparency markers or grease pens to draw on each Earth ZOOM! Card a rectangle that represents the image that is seen on the card with the next increase in magnification. This will be easy for some cards, difficult for others.

There's Power in Numbers! (Phase I)
Journeys to Microworld and Macroworld Earth

ZOOM! Cards—Transparency

Figure 2.1—Three ZOOM! Cards.



Script for ZOOM! Cards

"Journey to Microworld Earth"

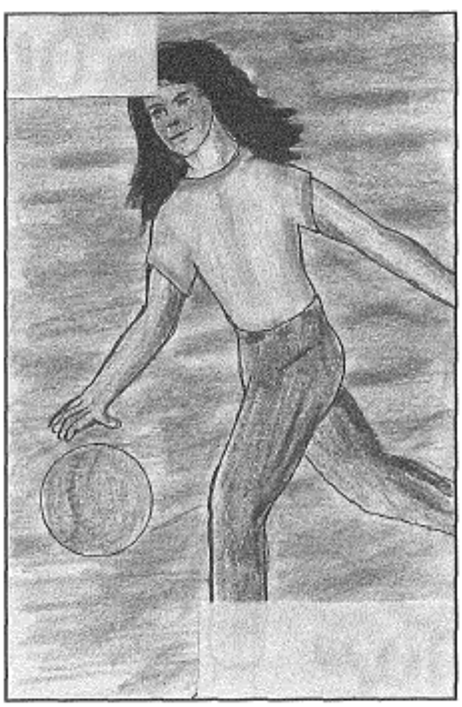
Today we will embark on a fantastic journey to a place that is not very far away. In fact, it is here, in this room, with us now! I am talking about the Microworld, the world of the very, very small. We will learn two things to help us in our search for extraterrestrial life: 1) what things look like at different scales, and 2) what signs of life can be detected at different scales.

We will begin our fantastic journey at a scale that we all understand very well, because it is the scale in which we live out our lives.

Today we will journey by powers of 10. Each card we see will have a magnification that is 10 times greater than the magnification in the previous card; that is, each object in a card will be 10 times larger than it was in the previous card. Try imagining that you are shrinking, like Alice entering Wonderland. Each time you shrink, you become 10 times smaller! How many times do you think you will need to shrink before you can "walk" into the Microworld? Of course, real people can't shrink themselves. But we can do something almost as incredible. By using magnifying lenses and microscopes, we can see the world of the very, very small. Let's take a look!

SCALE: 8 cm =100 meters 10° meters =1 meter

Figure 2.2-Earth Card # ll-A Child



Observed by: Human eye.

Description: We begin our journey, at the scale of 8 cm =100 meters, with a child playing with a ball. It is easy to think of many things that are a meter or two across. We can see these objects with our eyes (without the help of magnification), or take pictures of them with a wide-angle camera lens. But there are countless objects that are far larger and countless objects that are far smaller. Today we will look at those that are smaller.

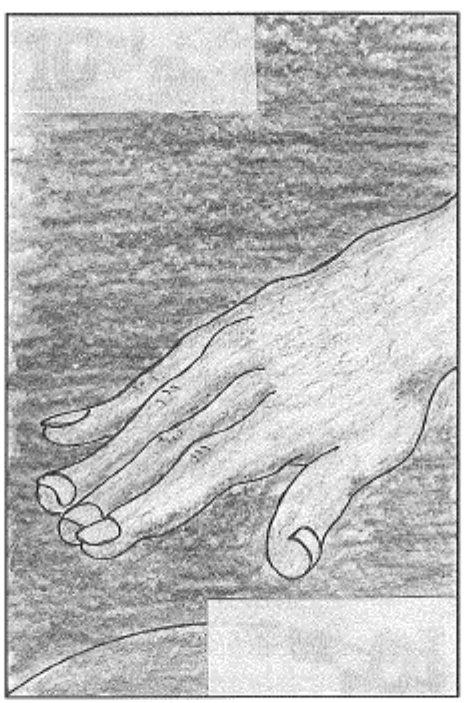
Life or Signs of Life: Yes. A recognizable human being.

Question: Is it possible to see the very largest and smallest things in the universe with a scale of 8 cm = 1 meter? *(No. This scale allows us to easily see things that are approximately the size of human beings.)*

Comment: 10^0 meters is a little over 1 yard long. A meter stick is about 4 inches longer than a yardstick.

SCALE: 8 cm = 10^{-1} meters
10^{-1} meters = 0.1 meter

Figure 2.3-Earth Card #10-A Hand



Observed by: Human eye.

Description: A magnification by 10 times to a scale of 8 cm = 10'1 meters reduces our view to a small portion of the previous image. We now see one-tenth of the girl. We only see her hand. This scale is life-size, which means that the hand in the picture is the size of the girl's real hand. Most of the objects that we use every day, such as books, tools, and toys, are the size of a hand. We can see this scale with our eyes (without the help of magnification).

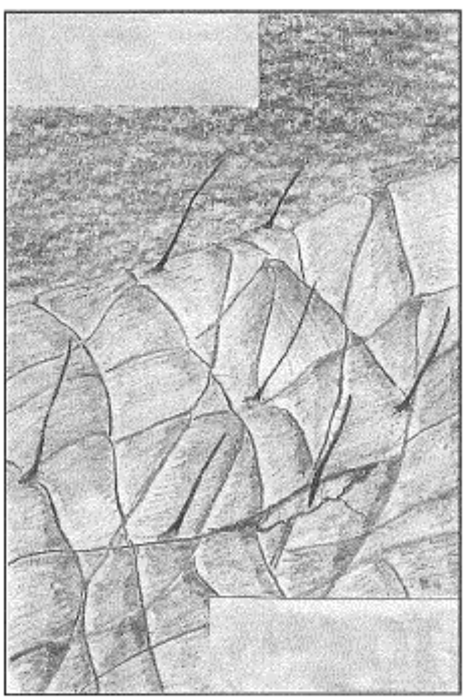
Life or Signs of Life: Any human being would recognize a hand as a sign of life. But consider how hard it might be for an extraterrestrial that has tentacles!

Question: How many hands would it take to cover the length of a football field (l00 yards)? *(If an average hand is* 8 *inches across, it would take 450 hands.)*

Comment: 10-2 meters is about 4 inches.

SCALE: 8 em $=10^{-2}$ meters
10^{-2} meters =.01 meters (l centimeter)

Figure 2.4-Earth Card # 9-Skin



Observed by: Human eye or magnifying glass.

Description: Another magnification by 10 times, to a scale of 8 cm =10-2 meters, takes us into a weird world. Would you recognize this image if you had only been given this card? You are now looking at a 1-centimeterwide section of the skin on the girl's hand. You see a complex structure, with skin folds, little hairs, and an open cut. Could you see this much detail with only your eyes? Try it! Look at your own hand in front of your face.

You will need a magnifying glass to see each tiny hair at the same detail as shown in the picture.

Life or Signs of Life: This is recognizable living tissue, composed of cells. A doctor or biologist would recognize these structures by their appearance.

Question: What does the prefix *centi-* (as in *centimeter)* mean? What other words begin with this prefix? (Centi- *means "hundred." A centipede is an animal with "100" legs [though usually they don't have exactly 100 legs]! A century is a period of 100 years. One cent is a penny;* 1 *out of* 100 *in a dollar.)*

Comment: Your fingers are each about 1 centimeter wide.

Figure 2.5-Earth Card # 8-One Hair

SCALE: 8 cm =10^{-3} meters
10^{-3} meters =.001 meters (1 millimeter)

Observed by: Magnifying glass.

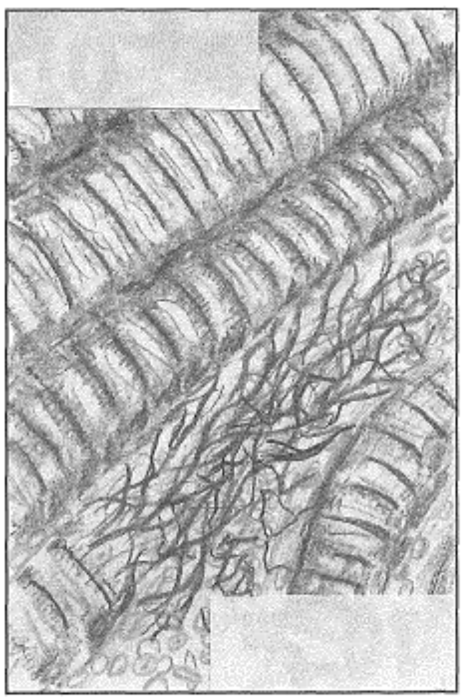
Description: An increase in magnification by 10 times, to a scale of 8 cm =10^{-3} meters, reduces our view to a small portion of the previous image. If you look carefully at this image, you will see another layer of skin beneath the surface layer; it is visible on the edge of the open cut. A single hair is visible growing from a base (called a follicle). Can you see where the hair begins beneath the skin and then pokes through to the surface? To the right of the hair is a tiny muscle. Blood is clotting in various spots in the cut; this is the beginning of the healing process.

Life or Signs of Life: These are recognizable living tissues, composed of cells. A doctor or biologist would recognize these structures by their appearance.

Question: What does the prefix *milli-* mean? What other words begin with this prefix? (Milli- *means "thousand." A millipede has "1,000" legs! A millennium" is 1,000 years.)*

Comment: A millimeter is the smallest division found on most rulers.

Figure 2.6-Earth Card # 7-Muscle and Blood Tissues.



SCALE: 8 em =10^{-4} meters
10^{-4} meters = .0001 meters

Observed by: Optical (light) microscope.

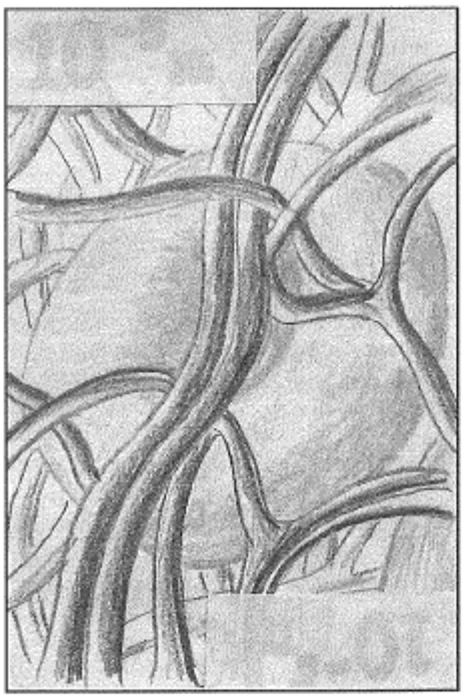
Description: Another increase in magnification by 10 times, to a scale of 8 cm =10^{-4} meters, takes us into the microscopic world. You would need to look at the girl's hand through an optical microscope at low magnification to see this kind of detail. Your entire body is made of units called cells. At this magnification, you can see two types of cells. There are muscle cells, which form striped bands of muscle tissue. They are located next to the hair because they control the hair's movement. This muscle can raise or lower the hair. We now see that the blood is made up of red blood cells, which carry oxygen to the muscle. A group of red blood cells are forming a blood clot in the cut. Notice the tiny fibers that hold these red blood cells together.

Life or Signs of Life: These are recognizable living tissues.

Question: Why does blood clot? *(Blood clots so that a small wound will stop bleeding. This prevents the loss of too much blood from the organism.)*

Comment: 10^{-4} meters is a distance too small for any eye to see without a microscope.

Figure 2.7-Earth Card # **6-A** Red Blood Cell.



SCALE: 8 cm = 10^{-5} meters
10^{-5} meters = .00001 meters

Observed by: Optical (light) microscope.

Description: Another increase in magnification by 10 times, to a scale of 8 cm = 10^{-5} meters reduces our view to a small portion of the previous image. You would need to look at the girl's hand through an optical microscope at a high magnification to see this kind of detail. A single red blood cell fills most of the view. The tiny fibers now appear to be much thicker. They are helping to form a scab by linking many red blood cells in a network of fibers. Doctors can examine red blood cells and other types of cells in a microscope to see if our bodies are functioning properly. All life on Earth is made of these living units, not just people.

Life or Signs of Life: A cell structure is a sign of life. Only life is made of cells.

Question: How many red blood cells lined up would it take to go across your hand? *(A red blood cell is about ,00001 meters across, which can be determined from the scale of the image on this card. If a hand is 10 centimeters across, it would take 1,000,000 red blood cells to equal that distance.)*

Comment: $l0^{-5}$ meters is 1 one-hundredth of a millimeter.

Figure 2.8-Earth Card # 5-Surface of a Red Blood Cell.

SCALE: 8 cm = 10^{-6} meters
10^{-6} = ,000001 meters
(1 micrometer)

Observed by: Optical (light) microscope or electron microscope.

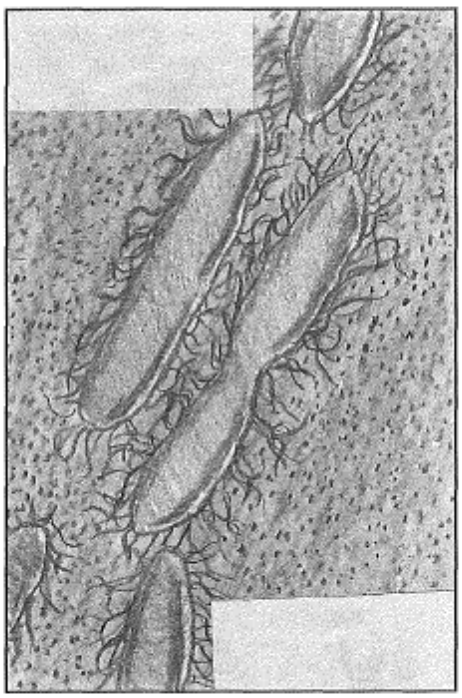
Description: Another increase in magnification by 10 times, to a scale of 8 cm = meters, takes us into a world almost too small to be seen with a microscope that uses light. **A** prepared sample could also be viewed through an electron microscope. This view shows only a small part of the surface of a single red blood cell. On the surface of this red blood cell, you can see some small brown dots. Are they small colonies of bacteria? Bacteria are everywhere in our bodies, all the time. Each bacterium is a single living cell-a microorganism or microbe.

Life or Signs of Life: Whole bacteria. Microbiologists would recognize these bacteria, if seen under a microscope, just as you would recognize a dog or cat on the street.

Question: If bacteria are everywhere, all the time, why aren't we sick all the time? *(Few bacteria are capable of making people sick. Most bacteria are harmless, and many are beneficial.)*

Comment: There are as many micrometers in a meter as meters in 1,000 kilometers.

Figure 2.9-Earth Card # 4-Bacteria.



SCALE: 8 cm = 10^{-7} meters
10^{-7} meters = .0000001 meter

Observed by: Electron microscope.

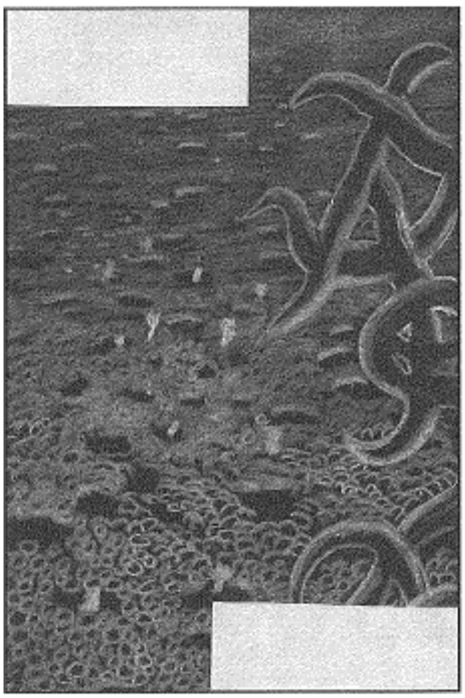
Description: Another increase in magnification by 10 times, to a scale of 8 cm = 10^{-7} meters reduces our view to a small portion of the previous image. The little brown dots are bacteria. Bacteria are single-celled life-forms that exist all over the Earth, not just in human bodies. In this scene, the bacteria are attaching themselves to the human red blood cell with tiny "hairs" (called cilia) around their edges. One bacterium is dividing to form two bacteria. This is how bacteria reproduce. Other kinds of bacteria live in soil or in water. Some even "fly" (by floating) through the air. Most kinds of bacteria are larger than these, and are visible even with an optical microscope!

Life or Signs of Life: Whole bacteria.

Question: Is each bacterium a unique individual or just a copy of all the others? *(Bacteria that have descended from one common ancestor are clones, or genetic copies. They are exactly the same, unless a mutation [which is rare] has occurred.)*

Comment: Placed end to end, over 10 million bacteria would fit into a distance of 1 meter.

Figure 2.10-Earth Card # 3- Surface of a Bacterium



SCALE: 8 cm = 10^{-8} meters
10^{-8} meters = .00000001 meters

Observed by: Electron microscope.

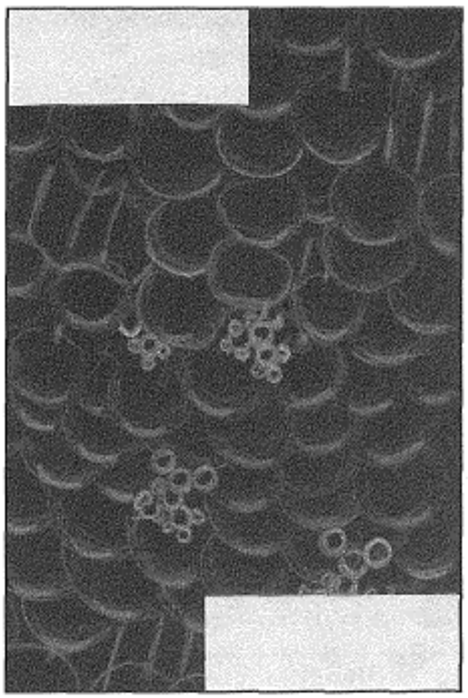
Description: Another increase in magnification by 10 times, to a scale of 8 cm = 10^{-8} meters, takes us into an even smaller world. Behind the bacterium's hairs, the bacterium's cell membrane is still visible. The surface of any cell is a membrane that has "openings" into the cell. All cells are enclosed by a cell membrane. You could not know if there was life on another planet just from looking at an image like this one. If you could see for sure that it was a cell, then it would be a sign of life. If you saw "an image *like* this one," it might be a nonliving structure that only "looked like" a cell membrane. It might be hard to tell for sure.

Life or Signs of Life: A cell membrane is a sign of life.

Question: Why does a cell membrane have "openings" in it? *(So that molecules like water and protein that are necessary for life can enter the cell and so that wastes can leave the cell.)*

Comment: 10^{-8} meters is the size of the smallest living things. No living thing smaller than meters has ever been found.

Figure 2.1l-Earth Card # 2-Molecules.



SCALE: 8 cm = 10^{-9} meters
10^{-9} meters =.000000001 meters
(1 nanometer)

Observed by: Tunneling electron microscope.

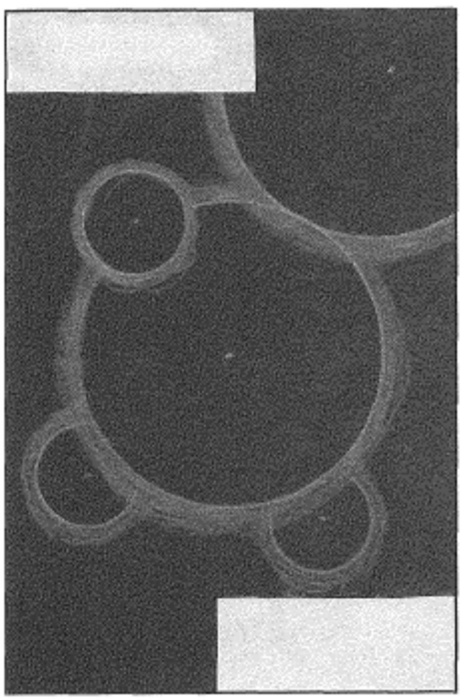
Description: Another increase in magnification by 10 times, to a scale of 8 cm =10^{-9} meters, reduces our view to a small portion of the previous image. Each cell is surrounded by a membrane that keeps some molecules in and some molecules out. Openings in the cell membrane allow molecules, such as the proteins shown, to go in and out of the cell. This lets "food" molecules enter, and "waste" molecules leave the cell. Protein molecules make up some of our food. There are protein molecules in chicken and in corn, for example. Our bodies themselves are made of protein molecules (among other types of molecules).

Life or Signs of Life: Proteins are organic molecules *produced* by life. So, the presence of protein molecules indicates the presence of life.

Question: Why do cells need to move materials in and out of them? *(This is necessary for metabolism, the chemical reactions that allow life to continue.)*

Comment: One billion scenes like this one could be lined up along the edge of a meter stick.

Figure 2.12-Earth Card # 1Atoms.



SCALE: 8 cm = 10^{-10} meters
10^{-10} meters =.0000000001 meters

Observed by: Tunneling electron microscope.

Description: Another increase in magnification by 10 times, to a scale of 8 cm =10^{-10} meters, takes us into the atomic world. Here, an atom of carbon is shown. It is bonded to three hydrogen atoms and to one oxygen atom. The same carbon atoms are found in both living and nonliving things on Earth. The carbon atom is the most important atom to a living organism because it can form bonds with up to four other atoms. Long chains of carbon atoms make complex organic molecules, such as carbohydrates and proteins. We end our journey into the Microworld here, but ask yourself this: Where would we be and what would we see if we went even farther into the Microworld? What would an atom look like at a scale of 8 cm $=10^{-11}$ meters? At a scale of 8 cm $=10^{-12}$ meters? Where do these increases in magnification end?

Life or Signs of Life: Carbon exists in both living and nonliving things. So, the presence of a carbon atom does not necessarily indicate the presence of life.

Question: Are the atoms in living things unique when compared to the atoms in rocks or air? *(No. They are exactly the same.)*

Comment: It would take 400 million billion atoms to circle the Earth.

There's Power in Numbers! (Phase 1) Journeys to Microworld and Macroworld Earth

Journey to Micro world-Teacher's Key

Fill in the following data table as you journey into the Microworld.

Table 2.1-Microworld Data, Teacher's Key.

Earth Card	Scale	Observed By	Life or Signs of Life
# 11	10^{0} meter	Human eye or camera	Recognizable structure: a child
# 10	10^{-1} meter	Human eye or camera	Recognizable structure: a hand
# 9	10^{-2} meter	Magnifying glass	Cell structure and tissues
# 8	10^{-3} meter	Magnifying glass	Cell structure and tissues
# 7	10^{-4} meter	Light microscope	Cell structure
# 6	10^{-5} meter	Light microscope	Cell structure
# 5	10^{-6} meter	Light or electron microscope	Whole bacteria
# 4	10^{-7} meter	Electron microscope	Whole bacteria
# 3	10^{-8} meter	Electron microscope	Cell membrane
# 2	10^{-9} meter	Tunneling electron microscope	Protein molecules
# 1	10^{-10} meter	Tunneling electron microscope	Carbon atoms

Answers to student questions after they have completed their journey into the Microworld:

1. We enter the Microworld at the scale 8 cm = 10^{-4} meters.

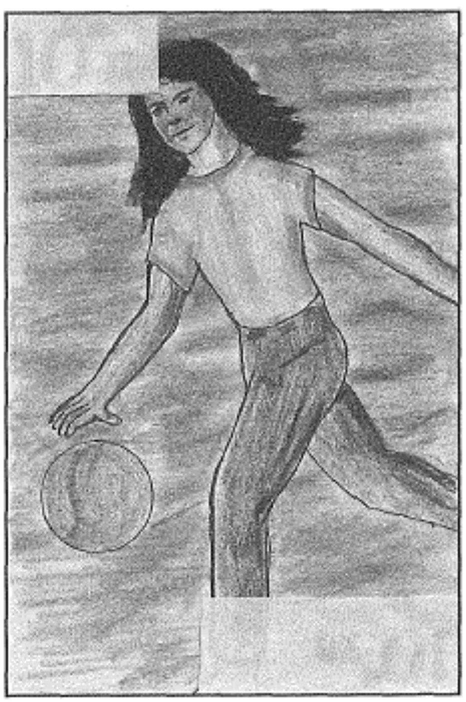
2. No. Bacteria are too small to see at a scale of 8 cm = 10^{0} meters.

Script for ZOOM! Cards

"Journey to Macroworld Earth"

Today we will embark on another fantastic journey to places that are far away. But it starts in this room, where we are nowl I am talking about the Macroworld, the world of the very, very large. As before, we will begin this fantastic journey at a scale that we all understand very well, because it is the scale in which we live out our lives. Scientists call this scale "1 meter = 10° meters," or "1 meter = 1 meter" (which is to say that an object represented at this scale would be life-size). We have seen that reducing our scale, as from 8 cm = 10° meter to 8 cm = 10·meters, increases the magnification and lets us see a larger view of an object. Today we will take another journey by powers of 10. Each card we see today will have a magnification that is 10 times smaller than the magnification in the previous card; that is, each object in a card will be 10 times smaller than it was in the previous card. This means that each card will show 10 times as much as the previous card. Try imagining that you are growing, as Alice did inside the White Rabbit's house. Each time you grow, you become 10 times bigger and so everything else appears to shrink! Some things become so small that they can no longer be seen. How many times do you think you will need to grow before you can "walk" into the Macroworld?

Figure 2.13-Earth Card # 11 A Child



SCALE: 8 cm =10° meters
10° meters =1 meter

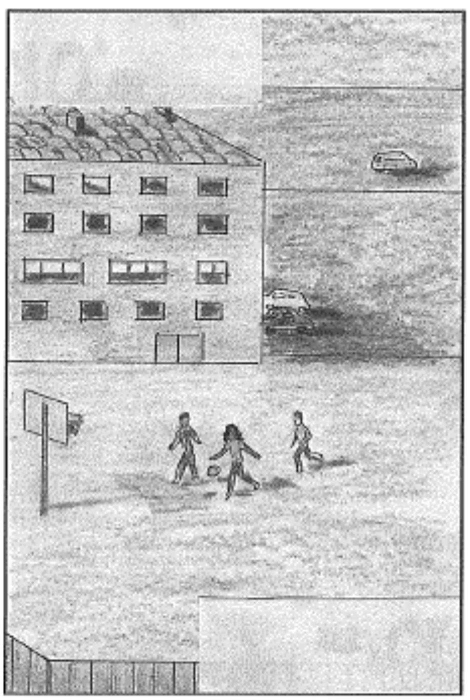
Observed by: Human eye.

Description: We begin this journey where we began our last journey, with the same child playing with the same ball. We can see these objects with our eyes (without the help of magnification), or take pictures of them with a wide-angle camera lens. But there are countless objects that are far larger and countless objects that are far smaller. Today we will look at those that are larger. Life or Signs of Life: Yes. A recognizable human being.

Question: If a spacecraft took a photograph of the surface of Mars, what would the scale of the photograph be? *(It would depend upon the magnification of the camera lens and the distance from the surface to the camera.)*

Comment: 10° meters is a little over 1 yard long. A meter stick is 4 inches longer than a yardstick.

Figure 2.14-Earth Card # 12Children in the Schoolyard



SCALE: 8 cm =101 meters
101 meters =10 meters

Observed by: Human eye.

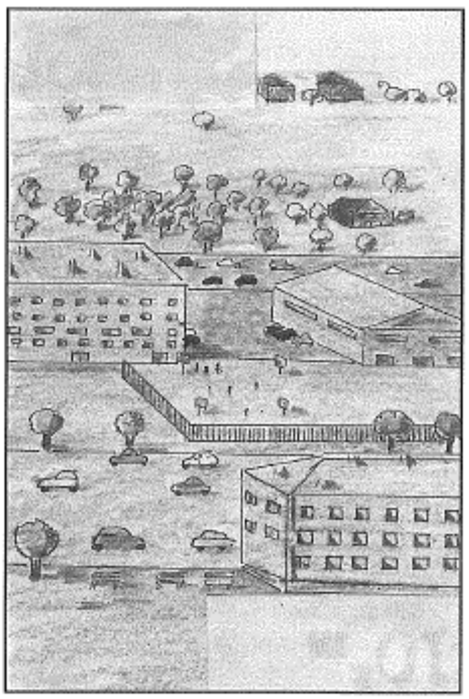
Description: A decrease in magnification by 10 times, to a scale of 8 cm =101 meters, enlarges our view well beyond the previous image. We now see 10 times as much as before. For instance, we see that the child has two friends, and that all three friends are playing in a schoolyard! Other nearby familiar objects, such as cars and buildings, are also now visible. You would see this scene if you were far away from the schoolyard.

Life or Signs of Life: Three recognizable "animal" (moving) forms can be seen. Cars are a sign of life because they appear unnatural, or manufactured. And because they move!

Question: Where would you have to be to see this view of the schoolyard? *(You would have to be some distance away, and looking down, perhaps from a building.)*

Comment: 101 meters is about the height of a two story family house.

Figure 2.15-Earth Card # 13-The Neighborhood.



SCALE: 8 cm =10^2 meters
102 meters =100 meters

Observed by: Human eye

Description: Another decrease in magnification by 10 times, to a scale of 8 cm = 10^2 meters, takes us farther away from the child and her friends. We can now see more of the school and its neighborhood. The people look like ants! This alone should show you that the apparent size of things is not related to their true complexity or importance. Can you still see the three children playing in the schoolyard?

Life or Signs of Life: "Animal" forms can be seen. Trees and grass, because they are green, might be living things. Certain rocks and minerals are green. They are *not* alive.

Question: How could you recognize vegetation from far away? *(On Earth, the green pigment chlorophyll is necessary for most plants to make their food through photosynthesis, so green areas may be plants. Such areas would also change over time, and this change would be observable.)*

Comment: The world's fastest runners can run the length of a football field in less than 10 seconds.

Figure 2.16-Earth Card # I3-The Neighborhood.

SCALE: 8 cm = 10^3 meters
10^3 meters =1,000 meters (1 kilometer)

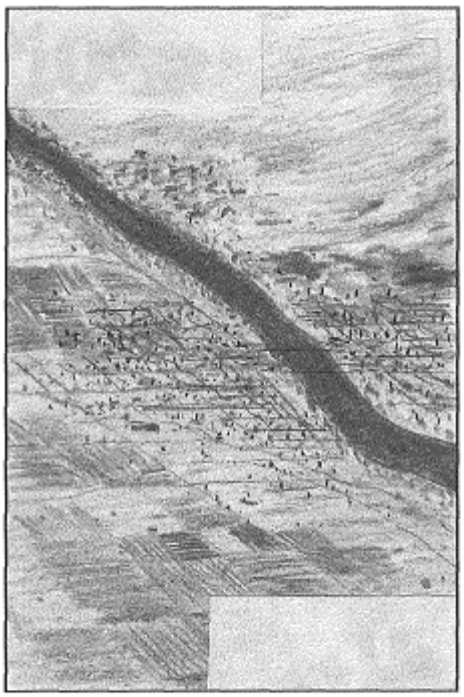
Observed by: Traffic helicopter.

Description: Another decrease in magnification by 10 times, to a scale of8 cm =10^3 meters, enlarges our view well beyond the previous image. The school is now seen as a small part of a city, which consists of many buildings linked by a network of streets. The streets are all straight, but the different kinds of buildings have different shapes, colors, and sizes. Some areas of the city have more vegetation than others. Can you find the school? The three friends? Life or Signs of Life: Identifiable cities are signs of life-intelligent life! A network of straight lines at right angles to one another looks artificial, which means it might have been created by intelligent life. The green areas look like vegetation.

Question: Why do some cities have curved streets? *(City streets may follow rivers, hills, valleys, or property lines.)*

Comment: 103 meters equals 1 kilometer; 1.6 kilometers equals 1 mile.

Figure 2.17-Earth Card # I5-The Entire City.



SCALE: 8 cm =10^4 meters
10^4 meters =10,000 meters

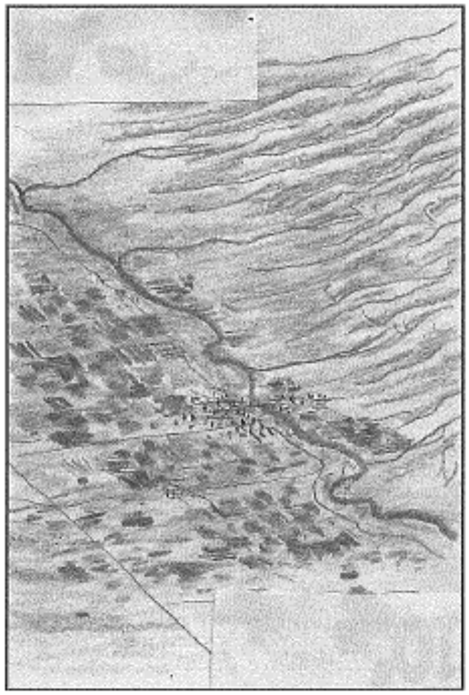
Observed by: Airplane.

Description: Another decrease in magnification by 10 times, to a scale of 8 cm =10^4 meters, takes us even farther away from the city. There is a huge river running through the heart of this city. The networks of roads spread out from the city into the country, and the buildings give way to farmlands. Different crops cause the fields to be different colors. To see this view of the city, you would have to be high in the air, much higher than the traffic helicopter. You may have seen views like this from an airplane window during takeoff or landing. Life or Signs of Life: The straight lines and right angles indicate life. The regular patterns made by crops also indicate life at work. The river is liquid water, which is necessary for life. The green areas look like vegetation.

Question: Why are so many cities built near water? *(Water is necessary for life and commerce.)*

Comment: 10^4 meters is how far a fast marathon runner travels in one hour.

Figure 2.18-Earth Card # 16-The Countryside.



SCALE: 8 cm =10^5 meters
10^5 meters =100,000 meters

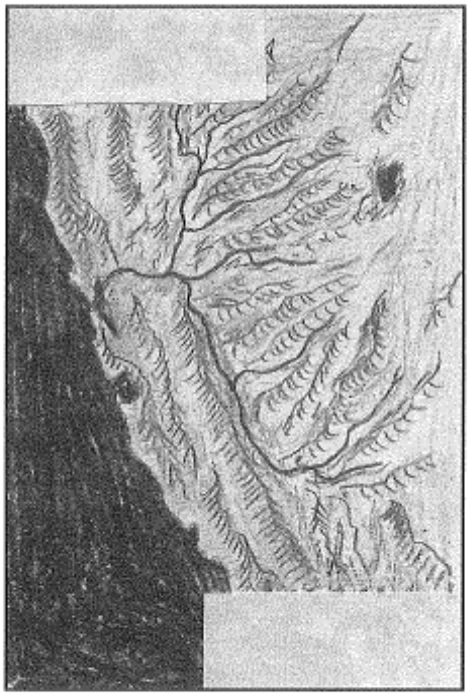
Observed by: Commercial aircraft.

Description: Another decrease in magnification by 10 times, to a scale of 8 cm =10^5 meters, enlarges our view well beyond the previous image. From an airplane, even an entire city seems small compared to the surrounding countryside. We can see many streams running out of the foothills, feeding the river. The colored pattern of fields in irrigated areas contrasts with the dry landscape. Life or Signs of Life: The regular patterns made by crops indicate life. The river is liquid water, which is necessary for life. The green areas are vegetation.

Question: How high would an airplane be flying to have this view? *(About 10,000 meters [33,000 feet].)*

Comment: 10^5 meters is the distance a car traveling 100 kilometers per hour (60 miles per hour) can travel in one hour.

Figure 2.19-Earth Card # 17California.



SCALE: 8 cm = 10^6 meters
10^6 meters =1 million meters

Observed by: Space shuttle or low Earth orbiting satellite.

Description: Another decrease in magnification by 10 times, to a scale of 8 cm =10^6 meters, takes us farther away. Have you ever seen a view like this out of an airplane window? No way! The whole state of California is visible in this view, along with some of the dry, western part of the United States. A view comprising this much land could only be seen from an orbiting satellite or a spacecraft during its flight. Most of the landscape is hilly and brown. Irrigation is required for agriculture. Can you tell which of these rivers is the one that runs through the city where the three friends are playing? Are the three friends "invisible" now?

Life or Signs of Life: The river system is liquid water, which is necessary for life.

Question: Can you locate San Francisco Bay? Can you explain why it is such a good place for a port? *(San Francisco Bay is the upper bay, the one with the rivers feeding into it. [The lower one is Monterey Bay.] Ports are often built near bays because the water there is protected and calm.)*

Comment: 10^6 meters is about how far an airliner flies in one hour.

Figure 2.20-Earth Card # 18Planet Earth from Orbit.

SCALE: 8 cm =10^7 meters
10^7 meters =10 million meters

Observed by: Satellite orbiting Earth.

Description: Planet Earth is a little larger than 10^7 meters across. Satellites orbiting our planet have allowed us to observe our entire world at once! This is another decrease in magnification by 10 times, to a scale of8 cm =10^7 meters, which enlarges our view beyond the previous image. We can see much of the North American continent from here. San Francisco Bay has not only become smaller but it is now apparent that there are clouds above it. The clouds show that Earth has an atmosphere.

Life or Signs of Life: If the clouds have oxygen and water (which cannot be determined from a picture), then conditions would be favorable for the existence of life. However, this by itself would not necessarily indicate the presence of life.

Question: If Earth has so many mountains, valleys, and ocean waves, why does the edge look so perfectly round? *(This is a matter of scale. Mountain ranges may appear huge to us, but compared to the entire Earth, they are only tiny bumps.)*

Comment: 10^7 meters is about 6,000 miles.

SETI INSTITUTE

Mission 2
There's Power in Numbers! (Phase 1)

Journeys to Microworld and Macroworld Earth
Journey to Microworld—Worksheet

Name: ________________________________ Date: ____________________________

Fill in the following data table as you journey into the Microworld.

Table 2.3-Microworld Data.

Earth Card	Scale	Observed By	Life or Signs of Life
# 11	10^{0} meter		
# 10	10^{-1} meter		
# 9	10^{-2} meter		
# 8	10^{-3} meter		
# 7	10^{-4} meter		
# 6	10^{-5} meter		
# 5	10^{-6} meter		
# 4	10^{-7} meter		
# 3	10^{-8} meter		
# 2	10^{-9} meter		
# 1	10^{-10} meter		

After you have completed your journey into the Microworld, please answer the following questions:

1. If we define "Microworld" as the world that we cannot see without a microscope, at what scale do we enter the Microworld?

2. When you saw the image of the child, could you see that there were bacteria living in a cut on the child's hand? Why or why not?

Mission 2
There's Power in Numbers! (Phase 1)

Journeys to Microworld and Macroworld Earth
Journey to Macroworld—Worksheet

Name: ___________________________________ Date: ______________________________

Fill in the following data table as you journey into the Macroworld.

Table 2.3-Microworld Data.

Earth Card	Scale	Observed By	Life or Signs of Life
# 11	10^0 meter		
# 10	10^1 meter		
# 9	10^2 meter		
# 8	10^3 meter		
# 7	10^4 meter		
# 6	10^5 meter		
# 5	10^6 meter		
# 4	10^7 meter		
# 3	10^8 meter		
# 2	10^9 meter		
# 1	10^{10} meter		

After you have completed your journey into the Macroworld, please answer the following questions:

1. If we define "Macroworld" as the world that we cannot see until we back away a certain distance from it, at what scale do we enter the Macroworld?

2. When you first saw the image of the child, did you know that the child was playing in California? Why or why not?

Mission 3
Mars Jars! (Phase 1)
Could an Earth Microbe Survive on Venus or Mars?

Overview

In mission 3.1, students culture *Penicillium notatum* to observe how this microbe lives on Earth. In mission 3.2, students observe the early growth of their *Penicillium notaturn* cultures. They simulate the low pressure and low temperature conditions of Mars in an experiment to determine whether *Penicillium notatum* could survive under Martian conditions. Students learn about conditions on Venus. By introducing soil seeded with *Penicillium notatum* to this simulated environment, students become exobiologists assessing the capacity of Mars to support life. In mission 3.3, students observe the continued growth of their *Penicillium notatum* cultures.

Notes

In mission 2, students journeyed to the Microworld and to the Macroworld with ZOOM! Cards; they saw their Earth Environment at microscopic and macroscopic scales. But what about life on other worlds? Exobiologists study the possibility of life on other planets, where there are extremes in temperature, atmospheric pressure, chemical compositions. Certain microscopic organisms can survive in harsh environments, such as green and purple sulfur bacteria, which live in the sulfurous super heated water of sea floor vents. Exobiologists stimulate the environments on other planets and use the resiliency of Earth organisms to test the capacity of these environments to test the capacity of the environments to support life as we know it.

Mission 3.1
Materials

For a Class of 30

- 200 ml of Sterigel Instant Medium (for an alternative recipe, see Making Your Own Mediurn, in appendix)
- 1cup of dry clay and/or sand (red, if possible)
- 3 vials of freeze-dried *Penicillium notatum* spores (MicroKwik Culture is recommended; see Ordering Information, in appendix)
- Two sealable containers (optional) Ice cubes (at least 15)
- (optional) Dry ice (do not store in a sealed container)

For Each Team

- Masking tape

- 2 sterile 60-by-15-mm Petri dishes (see Sterile Dishes, see appendix)
- 2 sterile soil-sample carrying dishes
- 2 stick-on labels or a grease pen
- Spatula
- 2 alcohol swabs
- (optional) Tongs or scoops for handling dry ice
- CulturingPenicillium notatum on Earth directions

Getting Ready

1. f you are sterilizing your own Petri dishes (instead of buying sterilized Petri dishes, which require no preparation), do so the day before class. Follow the instructions in the appendix (see Sterile Petri Dishes, see appendix).

2. f you are preparing your own medium (instead of using the Sterigel Instant Medium), do so the day before class. Follow the instructions in the appendix (see Making Your Own Medium, in appendix).

3. terilize your sealable containers by microwaving with water until the water boils away or by rinsing in boiling water.

4. repare a batch of seeded soil before class. Microwave the clay-sand mixture for three minutes, or heat it in an oven at 400 F for half an hour. Let the clay-sand mixture cool. Separate it into two equal quantities and store in the sterile (sealable) containers. Label one container pure soil and set it aside to be used as a control. Mix the vials of Penicillium lzotatuna into the other sample; label this mixture seeded soil. Seal both soils until you are ready to use them.

   The seeded soil will be used in mission 3.1 and in mission 3.2. When this mission is completed, cover the unused seeded soil and store it in a refrigerator; it will be used in mission 6, Venus Plates and Mars Jars! (Phases II).

5. Copy the Culturing *Penicillium notatum* on Earth directions for each team.

Classroom Action

1. **Discussion.** Ask students if they know of any Earth life that could survive on Venus or Mars without artificial support. Are there any experiments that can be conducted to find such an Earth life-form? Ask them if they could simulate Venusian and Martian environmental conditions here on Earth. What if they were to introduce some life-form into these simulated environments? Would they know, based on such an experiment, if the life-form could survive on Venus or Mars? Explain to students that this is an important method used by exobiologists to study the possibility of life on other planets. Exobiologists also study life in harsh Earth environments to better understand if Earth life can survive in the types of environments

found on other planets. When spacecraft are sent to Venus or Mars, they are carefully sterilized to prevent possible contamination of these planets by sturdy Earth microbes!

Tell students that they will conduct an experiment to determine whether a very resilient Earth microorganism called *Penicillium notatum* could survive on Venus and Mars. This fungus is the source of penicillin. Urge caution when working with the *Penicillium notatum.* Some may have an allergic reaction to the organism. Ask if anyone is allergic to penicillin. If so, make sure those students work: only with the pure soil (the control soil for the experiment, which is free of *Penicillium notatum).*

Explain to students that it is important to understand and test the conditions needed to grow *Penicillium notatum* on Earth so that, after it has been exposed to the simulated environments of Venus and Mars, the *Penicillium notatum* can be checked to see if it has actually survived according to its life processes as they occur on Earth.

2. **Demonstration**. Divide the class into teams of two students each. Wash with soap and water the work area you will be using. Demonstrate the use of Petri dishes. Show students how to sterilize a spatula by wiping it with an alcohol swab. Demonstrate how to plate out a sample of the soil onto the gelatin: using the sterilized spatula, lightly sprinkle about 114 teaspoon of the soil over the gelatin. Discuss the need for a control and its role in any scientific experiment.

3. **Activity.** Hand out the Culturing *Penicillium notatum* on Earth directions to each team. Each team should now make two Petri dishes. Students should wash their hands and their work areas with soap and water. Give teams their sterile Petri dishes and four pieces of masking tape. Have students tape shut their Petri dishes without opening them; this makes a hinge on one side of each dish and a rebreakable seal on the other.

   While students are taping their Petri prepare the Sterigel at a central area in the classroom: Close any windows to pre-drafts. Open an alcohol swab and place it on the table. Open the two jars in the Sterigel kit. Place their lids on the alcohol swab. Pour the Sterigel liquid into the bottle of Sterigel powder and shake the bottle for 30 seconds. Sterigel must be used quickly after it is made; it cannot be melted for later use.

   Teachers Note: *The following instructionsassume the use of Sterigel Instant Medium. If you have prepared your own medium, refer to the appendix at this point.*

   Each team should now obtain nutrient gelatin medium for its sterile Petri dishes by bringing them to the Sterigel area. Make sure students remove only one piece of tape from each dish. The teacher should pour the Sterigel, enough to halfway cover the bottom of each Petri dish. Students should then quickly close and retape their dishes, swirling them gently to evenly distribute the Sterigel. Work rapidly and swirl the Sterigel bottle frequently to keep the nutrient suspension even. The Sterigel in the Petri dishes will set rapidly, and students can add soil samples to their dishes within a few minutes.

Students should obtain two soil samples (pure soil and seeded soil) using the two sterile carrying dishes. Have students plate out one Petri dish with pure soil and one Petri dish with the seeded soil that contains the *Penicillium notatum.* Store the Petri dishes (do not freeze, room temperature is okay) by team for observations during missions 3.2 and 3.3.

4. **Discussion**. Ask students how the conditions on Venus and Mars could be simulated. How would they change the temperature and pressure to simulate Venus? To simulate Mars? The surface pressure on Venus is 90 ATM (atmospheres) and its temperature is 460 C. The surface pressure on Mars is 0.006 ATM and its temperature is -17 C.

   Explain that the surface of Venus is very hot and under extreme pressure. The surface temperature is 460 C and the surface pressure is 90 ATM (atmospheres), which means that the pressure on Venus is 90 times greater than it is on Earth. Ask students what they think such heat and pressure would do to a human body. Could we survive on Venus even with space suits? Tell students that they will simulate the high temperature of Venus and investigate its effect on *Penicilliurn notatum* in mission 6.

   Explain that the surface of Mars is cold enough to freeze any water and that the pressure on Mars is so low that some of the ice would sublimate (change directly from a solid to a gas without becoming a liquid). The surface temperature is -17 C and the surface pressure is .006 ATM. Tell students that frozen carbon dioxide, or dry ice, shows how frozen *water* would sublimate on Mars.

5. **Optional Activity**. Pass out a chunk of dry ice and an ice cube (frozen water) to each team. Explain that regular ice is frozen water and that dry ice is frozen carbon dioxide. Urge caution: dry ice can burn skin! Dry ice should be handled with tongs or scoops. Have students observe the dry ice and the ice cube. Ask them if they can see any water forming on the dry ice as it melts. Which one turns to water? *(Ice cube.)* Which one turns directly into a gas? *(Dry ice.)* Is this gas a water vapor? *(No.)* What is it? *(Carbon dioxide.)* If table knives are available, have students hold the blades against their dry ice; this will produce a chattering sound due to the sublimation.

Mission 3.2
Materials

For a Class of 30

- Overhead projector
- A Mars Jar transparency
- Growth of Microbial Colonies transparency
- Freezer space for several days or weeks
- 8 Cathada syringes, 50 cc or 60 cc (see Ordering Information, in appendix), or any syringes that fit into the rubber tubes
- Small jar of glycerin or liquid soap
- Seeded soil from mission 3.1

For Each Team

- 2 tube clamps
- 250-ml Erlenmeyer flask
- Double-holed stopper (must fit into the Erlenmeyer flask)
- 2 glass tubes (must fit into the stopper holes)
- 2 7-cm rubber tubes (must fit onto the glass tubes)
- Rubber tubing (must fit around the glass tubes)
- 7-cm glass tube
- Balloon
- Beaker
- 20-cm length of string
- Plastic metric ruler
- 2 hand lenses
- Scissors
- Sterile carrying dish for soil sample
- Making a Mars Jar directions

For Each Student

- Growth of *Penicillium notatum* worksheet
- Pencil

Getting Ready

1. Copy the Making a Mars Jar directions for each team and the Growth of *Penicillium notatum* worksheet for each student.

2. Because there is the possibility of students breaking the glass tubes and injuring themselves, you should put the glass tubes into the double-holed stoppers yourself. Use glycerin or liquid soap as a lubricant. Hold the tube at the point where it enters the stopper and twist the tube as you insert it into the stopper. Do not use excessive force! Twist until the glass tubes extend below the stopper by about two centimeters.

3. Sterilize the Erlenmeyer flasks in a microwave by heating on high for 2-3 minutes.

4. Prepare the transparencies A Mars Jar and Growth of a Microbial Colony. Set up the overhead projector.

Classroom Action

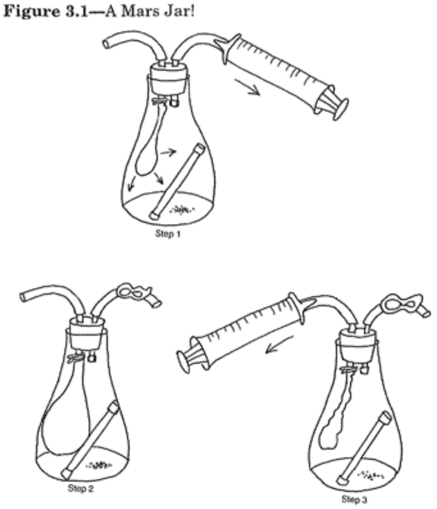
1. **Activity.** Reassemble the teams from mission 3.1. Hand out the Making a Mars Jar directions to each team and the Growth of *Penicillium notatum* worksheet to each student. Have students briefly observe their experimental and control *Penicillium notatum* cultures and

record any signs of *Penicillium notatum* growth without opening the Petri dishes (this would contaminate them). There may not be much growth evident after one day. Each day for the next few days, allow students To briefly inspect their Petri dishes and chart the growth of their *Penicillium notatum.* Have students keep their worksheets; or, you may want to distribute and collect them each day.

2. **Demonstration.** Tell students that both the low pressure and the low temperature on Mars can be simulated in Mars Jars, which will be kept in a freezer for several days or weeks. Show the A Mars Jar transparency as a background to help students envision what you are talking about.

   Demonstrate how to set up the apparatus and how to pump air out of the Erlenmeyer flask as shown in figure 3.1**.**

Figure 3.1—A Mars Jar!



Also, show students how to inflate and deflate the balloons with the syringes. Do not let students inflate the balloons by mouth because there is a chance that someone might inhale *Penicillium notatum* spores. Make sure students understand that differences in air pressure are what cause the balloons to inflate and deflate. Give students time to experiment with the balloon system before they add the seeded soil to their Mars Jars.

Demonstrate the following procedure, which is enumerated on the Making a Mars Jar directions.

Procedure

a) Put 114 tsp. of the seeded soil in the Mars Jar, a sterilized 250 ml Erlenmeyer Flask.

b) Cut four 1 cm. lengths of rubber tubing and carefully cover the four ends of the glass rods that will be exposed to the balloon. Cover the two ends of the glass rods that extend through the stopper and cover the two ends of a short (about 7 cm) glass rod equalization tube.

c) Place the glass rod equalization tube into the Erlenmeyer Flask. (It is used to keep the balloon from sealing with the edge of the flask which would prevent its inflation.)

d) Put a balloon on one of the glass rods that extend through the stopper. (There should be rubber tubing on the tube under the balloon as well, to prevent popping of the balloon by that glass rod.)

e) Make a slip knot around the mouth of the balloon and wrap three inches of string around the mouth to prevent leaking. Put the stopper tightly on the Erlenmeyer Flask, with the balloon hanging inside.

f) Cut two rubber tubes to about 7 cm., and place the rubber tubes over the two exposed ends of the glass rods that extend through the stopper.

To Change Pressure Inside the Mars Jar

a) Tell students to always keep hold of the Erlenmeyer Flask to keep it from falling.

b) First, attach the syringe to the rubber tube that is NOT tied to the balloon. Draw air OUT of the Erlenmeyer Flask with the syringe. The balloon inside the flask will inflate. Keep sucking until the balloon is full, pressing against the glass rod equalization tube. Then use a tube clamp to clamp this rubber tube tightly shut.

c) Attach the Cathada Syringe (or any syringe that fits) to the open rubber tube, with the balloon attached. Ask for a student volunteer to assist you to suck air from the balloon with the syringe until the balloon starts to deflate. To do this you must pinch the rubber tube shut each time you reset the syringe for another pull. The whole operation should take about 25 to 35 pulls of the syringe. Tell students that they should completely deflate their balloon which should take between 25 and 35 pulls on the syringe.

3. **Activity**. Allow students to proceed with their Mars Jars. By the end of one class period, Students should have their seeded soil samples under the simulated atmospheric conditions of Mars. Have students label their jars, record the date, and place them in the freezer until mission 6. Tell students that they will create their Venus Plates in mission 6, Venus Plates and Phase I1 Mars Jars!

   Teacher's Note: *If you have limited freezer space, seed your demonstration Mars Jar with enough soil for the whole class plate out in mission 6. Put this big Mars Jar in the freezer.*

Mission 3.3
Materials

For Each Student

- Harsh Environments worksheet
- Pencil

Getting Ready

1. Copy the Harsh Environments worksheet for each student.

Classroom Action

1. **Activity.** Tell students that, over the next few days, they should make detailed observations and notes of their control and experimental *Penicillircm notatum.* Petri dishes. This is for future reference. By mission 6, Venus Plates and Phase I1 Mars Jars!, these cultures will have died, so students will have to rely on their notes. Stress that scientists always rely on good note-taking skills. Save the Growth of *Penicillium notatum* worksheets for use in mission 6.

2. **Activity**. Hand out the Harsh Environments worksheet to each student. Have students answer these summary questions in class or as a homework assignment.

3. **Disposal.** After all observations of the Petri dishes have been made, the cultures need to be disposed of.

   You may be able to reuse the Petri dishes if they are sturdy enough to be autoclaved or otherwise sterilized.

   Teacher's Note-Caution: *A teacher should dispose of the cultures because they may contain harmful, even pathogenic, microbes. Your school may require certain disposal procedures. Disposal bags can be ordered from any biological supply catalog. Ideally, the cultures should be sterilized (autoclaved or microwaved) before disposal. In a microwave, heat on high for several minutes to boil the water. Avoid touching or inhaling spores from the microbial colonies; you may wish to wear a dust mask.*

Going Further

Activity: Alien Environments on Earth

Invite students to research alien environments on Earth, including superheated and sulfurous saltwaters of sea floor vents and hot springs, the Sahara desert, and the ice sheets and desert valleys of Antarctica. Show a video about an alien environment on Earth.

Ask students if there are any alien environments present where they live. Is there life deep down in the mud of a pond? In the sand of a beach? In a mineral spring? On desert rocks? Conduct an alien hunt to search for life in such places. You may need hand lenses and microscopes!

Ask students to draw some of the alien environments on Earth. Create a mural of an alien environment; have each student contribute a hand-drawn life-form.

Demonstration: Under Pressure

Demonstrate the high pressure on Venus by letting atmospheric pressure crush a can. Find a thin-metal can with a screw-on lid. Fill the can half full with water. Leave off the lid. Paint thinner cans work well, but it is important to remove all traces of paint thinner before use. Place the can on a hot plate and heat it until the water escapes as steam. Nearby, make an ice-water bath using ice or dry ice. Use an oven mitt to put the lid on the can. Immerse the can in the ice-water bath. The can should collapse dramatically. Explain to students that this happened because the pressure outside the can was several times greater than the pressure inside the can.

Activity: Close-up Views of *Penicillium Notatum*

If you have microscopes, slides, and cover slips, try looking at some *Penicillium notatum* under magnification..

Research: Microbes from Earth

When planning the Viking mission to Mars and the Magellan mission to Venus, scientists worried about contaminating these planets. They did not want to accidentally bring along any terrestrial microbial life that might survive in the harsh environments of these two planets. So they went to a great deal of trouble to sterilize the spacecraft before they were launched. Have students research exactly what was done, and why it was done.

Mars Jars! (Phase I)
Could an Earth Microbe Survive on Venus or Mars?

Harsh Environments--Teacher's Key

1. An exobiologist is a scientist who studies the possibility of life on planets that have environments with extremes in temperature, atmospheric pressure, and chemical compositions.

2. An exobiologist would determine if an Earth life-form could survive on Mars or Venus by exposing a microbe such as *Penicillium notatum* to conditions that simulate those on Mars or Venus.

3. It was necessary to culture *Penicillium notatum* under Earth conditions to see what it looks like as it grows, so it can be recognized after it has grown under simulated non-Earth conditions.

4. It was necessary to use a control dish plated with pure soil to see what lifeless soil looks like (for purposes of comparison), and to rule out the possibility of the presence of foreign organisms in the experiment, despite precautions.

5. Student answers will vary. Accept all reasonable attempts. Some students will think that the *Penicillium notatum* will die; some will think that the *Penicillium notatum* will live. The point is this: One may guess, but one doesn't know for certain what the result will be. This is the point of performing any experiment.

Mission 3 Logbook
Mars Jars! (Phase 1)
Could an Earth Microbe Survive on Venus or Mars?
Culturing *Penicillium notatum* on Earth

Directions

We need to see how *Penicillium notatum* grows on Earth so that, after it has been exposed to the simulated environments of Venus and Mars, the *Penicillium notatum* can be checked to see if it has actually survived according to its life processes as they occur on Earth. Today you will prepare two Petri dishes with a food supply for microbes-a nutrient gelatin medium. You will add seeded soil containing *Penicillium notatum* to one Petri dish; the other will serve as a control. You will observe both dishes for a few days and record the normal growth of *Penicillium.* They will be too small to see at first, but they will multiply at room temperature and grow numerous enough to see as colonies in a few days. This process is temperature dependent.

Procedure

1. Wash your hands and your work areas with soap and water.

2. Obtain two sterile Petri dishes and four pieces of masking tape. Tape shut your Petri dishes without opening them; this makes a hinge on one side of each dish and a rebreakable seal on the other. Write your names on both dishes. Write Control on one dish and Experimental on the other.

3. Take your Petri dishes to the central area of the classroom where the nutrient gelatin medium is being prepared. Remove one piece of tape from each dish. Your teacher will pour the nutrient medium into your Petri dishes. You must work quickly to close and retape them. Gently swirl the dishes to distribute the gelatin evenly across the bottom of the Petri dish.

4. Obtain two soil samples using the two sterile carrying dishes. One will be pure soil and the other will be seeded soil, which contains *Penicillium notatum.* Remember which is which!

5. Be careful when adding the seeded soil containing *Penicillium notatum* to your Petri dishes. Do not inhale close to the seeded soil. Some people have an allergic reaction to this organism. If you are allergic to penicillin, let your partner handle the seeded soil while you handle the pure soil.

6. Sterilize a spatula with an alcohl swab. Sterilize the spatula before each use.

7. For the Experimental Petri dish, plate out a sample of the seeded soil onto the nutrient gelatin: using the sterilized spatula, lightly sprinkle about 1/4 teaspoon of the soil over the surface of the cooled, set gelatin.

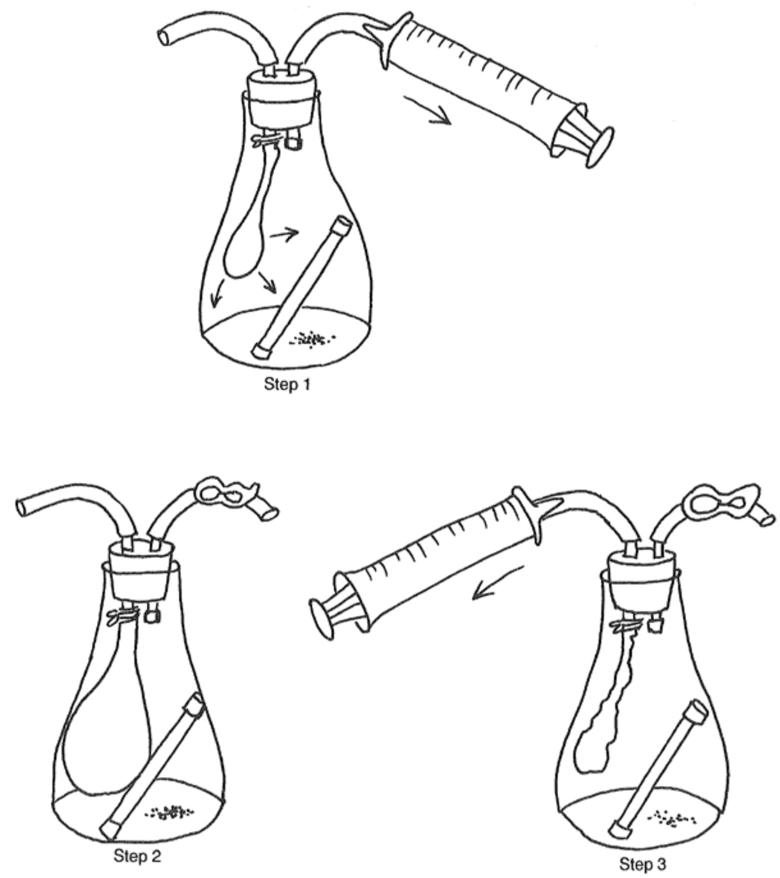
8. For the Control Petri dish, plate out a sample of the pure soil onto the nutrient gelatin: using the sterilized spatula, lightly sprinkle about 1/4 teaspoon of the soil over the surface of the cooled, set gelatin.

9. Draw an arrow on each Petri dish. Use the arrow to orient your dishes the same way each time you look at them; this way you can identify colonies and chart their progress as they grow bigger. Store both Petri dishes. You will be observing them over the next several days. Both dishes should be left at room temperature.

Mars Jars! (Phase 1)
Could an Earth Microbe Survive on Venus or Mars?

A Mars Jar – Images

Figure 3.2—Making a Mars Jar.



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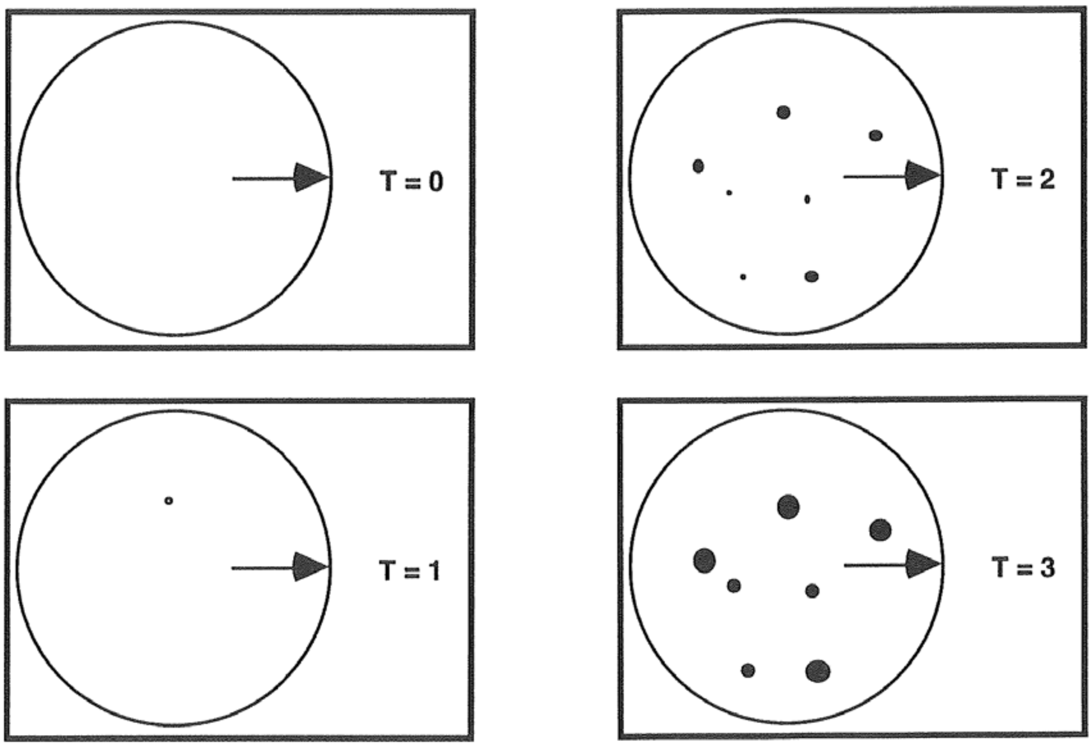
Mars Jars!(Phase 1)
Could an Earth Microbe Survive on Venus or Mars?
Growth of Microbial Colonies – Image

Figure 3.3.



Mars Jars! (Phase 1)
Could an Earth Microbe Survive on Venus or Mars?

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Making a Mars Jar – Directions

To set up a Mars Jar:

1. Obtain a sample of seeded soil using the sterile carrying dish. Put 114 teaspoon of seeded soil into a sterilized 250-ml Erlenmeyer flask.

2. Obtain a double-holed stopper that has two glass tubes in it.

3. Cut four 1-cm lengths of rubber tubing and use them to carefully cover the four ends of the glass tubes that will be exposed to the balloon: the bottom ends of the two glass tubes that extend through the stopper and the two ends of the 7-cm glass tube (the equalization tube).

4. Place the glass equalization tube into the Erlenmeyer flask. (The tube is used to keep the balloon from sealing with the inside of the flask, which would prevent its inflation.)

5. Put your balloon on the bottom end of one of the glass tubes that extends through the stopper.

6. Make a slip knot around the mouth of the balloon. Wrap three inches of string around the mouth of the balloon to prevent air from leaking. Put the stopper tightly on the Erlenmeyer flask, with the balloon hanging inside.

7. Fit the two 7-cm rubber tubes over the exposed ends of the glass tubes that extend up through the stopper.

To decrease the pressure inside a Mars Jar:

Note: Always keep hold of the Erlenmeyer flask to keep it from falling over.

1. First, attach a syringe (with its plunger pushed completely into the syringe) to the rubber tube that does not have the balloon tied to it. Suck air out of the Erlenmeyer flask with the syringe. The balloon inside the flask will inflate. Keep sucking until the balloon is full and pressed against the glass equalization tube.

   To do this you must pinch the rubber tube shut with a tube clamp each time you reset the syringe for another pull. When the balloon is full, use a tube clamp again to clamp this rubber tube tightly shut.

2. Attach the syringe to the rubber tube that has the balloon tied to it. Suck air from the balloon with the syringe until the balloon starts to deflate. Completely deflate your balloon. This

should take between 25 and 35 pulls on the syringe. When the balloon is deflated, use a tube clamp again to clamp this rubber tube tightly shut.

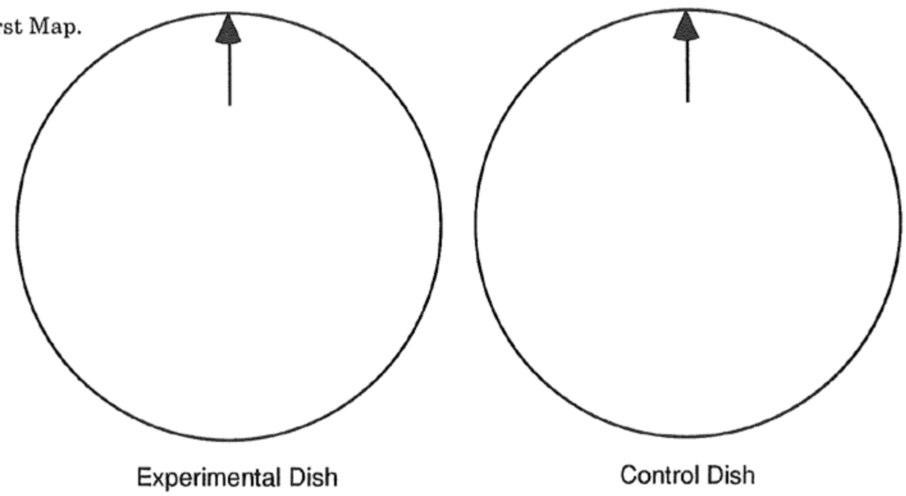
3. Label your Mars Jar with your names and the date and place it in a freezer to simulate the temperature conditions on Mars.

Mission 3 Logbook
Mars Jars! (Phase 1)
Could an Earth Microbe Survive on Venus or Mars?
Growth of Penicillium notatum – Worksheet

Name : ___________________________________ Date: _______________________________

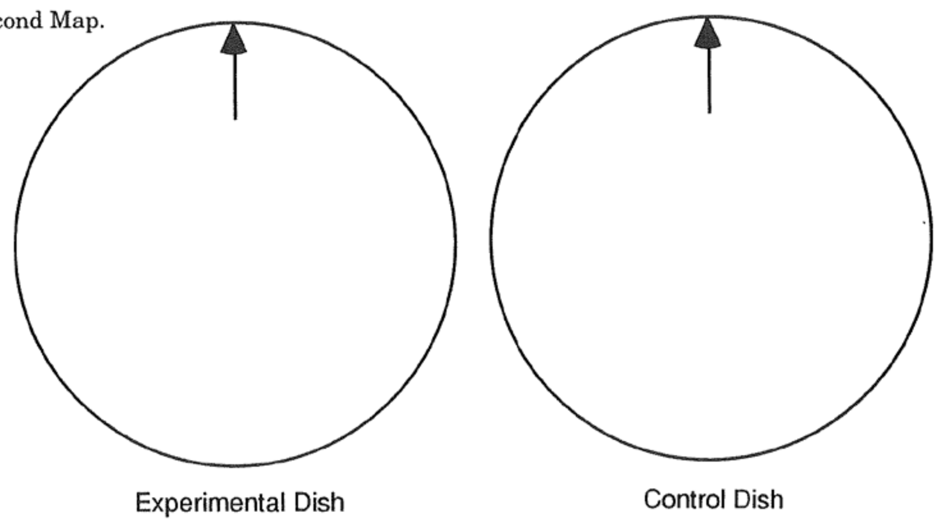
1. First map of *Penicillium notatum* growth. Date of Observations:

Figure 3.4—First Map.



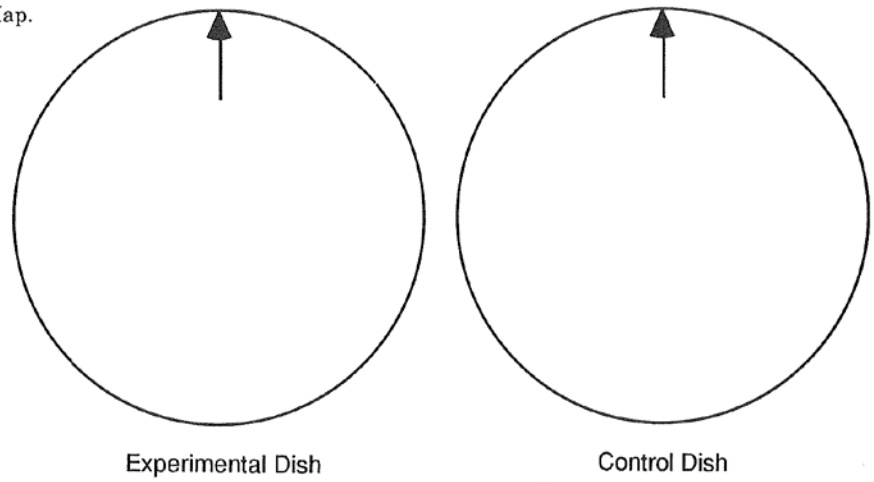
2. Second map of *Penicillium notatum* growth. Date of Observations:

Figure 3.5—Second Map.



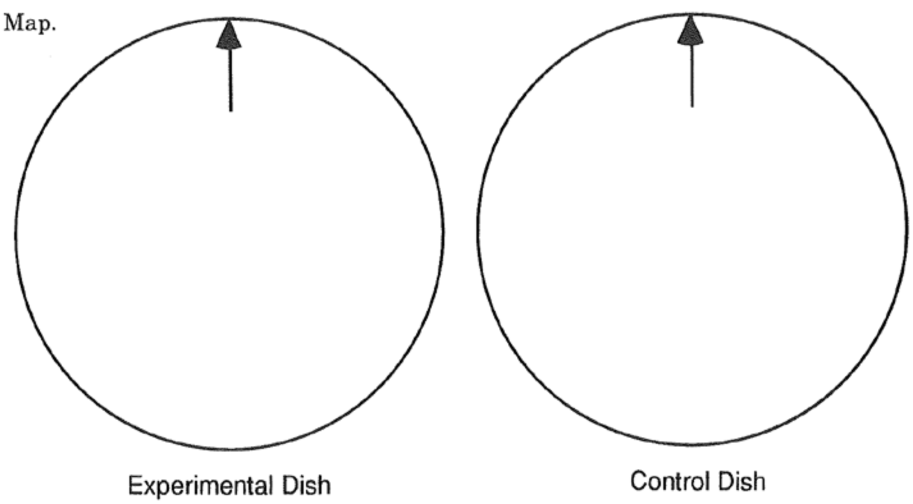
3. Third map of *Penicillium notatum* growth. Date of observations:

Figure 3.6—Third Map.



4. Fourth map of *Penicillium Notatum* growth. Date of observations.

Figure 3.7—Fourth Map.



Mars Jars! (Phase 1)
Could an Earth Microbe Survive on Venus or Mars?

Harsh Environments – Worksheet

Name: ________________________________ Date: ______________________________

1. What is an exobiologist?

2. How would an exobiologist determine if an Earth life-form could survive on Mars or Venus?

3. Why did you need to culture *Penicillium notatum* under Earth conditions?

4. Why did you use a control dish that was plated with pure soil?

5. What do you think will happen to the *Penicillium notatum* that was put into your Mars Jar?

Mission 4
There's Power in Numbers! (Phase II)
Journey to Mars and Venus

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Overview

In mission 4, students apply their understanding of scale to the search for life on other worlds. They see how scale is important in deciding what signs of extraterrestrial life to look for. In mission 4.1, students use ZOOM! Cards to journey to Mars. In mission 4.2, students use ZOOM! Cards to journey to Venus.

Notes

In mission 3, students simulated harsh conditions found on Mars and learned about the even harsher conditions found on Venus; In mission 2, they learned about strange worlds of the very small and the very big- Microworld Earth and Macroworld Earth.

Mission 4.1
Materials

For a Class of 30

- Journey to Mars script

For Each Team

- Transparency marker or grease pen
- ZOOM! Cards for Microworld and Macroworld Earth (19 cards total)
- ZOOM! Cards for Mars (11 cards)

Getting Ready

1. If you have not yet done so, cut apart the individual cards on the sheets of ZOOM! Cards for Mars and Venus. If possible, to preserve them for future use, laminate the sheets of ZOOM! Cards before cutting them. (Clear contact paper works well, but be sure to cut apart the cards apart and cover each one separately, leaving a border.) Cut the laminated illustration sheets into individual cards, and assemble six complete Mars decks and six complete Venus decks.

2. Test the markers or grease pens to be sure that they can be wiped off of the laminate or contact paper.

3. Study the Mars ZOOM! Cards to refresh your perception of distance and size. Read through the script Journey to Mars, anticipating students' questions.

Classroom Action

1. **Activity .** Divide the class into six equal groups Give each team a deck of Earth ZOOM! Cards (19 cards) and a deck of Mars ZOOM! Cards (11 cards). Ask students to line up the Earth cards in order along a table. Ask them to guess where each Mars ZOOM! Card belongs in relation to the Earth deck. For example, the 10^0 meters Mars ZOOM! Card should be placed by the10^0 meters Earth card. Finding the order for the Mars cards will be a challenge, because there are no familiar objects in the images, and because some scales are not depicted (i.e., cards for some powers of 10 are missing because scientists have not imaged Mars at the corresponding scales).

   Remind students that the view in each card represents a different scale: 8 cm (the width of each card) equals a distance in meter? that is a power of 10 (*e.g.*, 10^0meters, 10^4 meters, 10^{-4}meters). Each card has a different power of 10. On this scale, a power of 0 is used for a picture of a child (the 10^0 meters card), a power that is a positive number is used for something that is larger than a child (*e.g.,*. the 10^4 meters Earth card shows an entire city), and a power that is a negative number is used for something that is smaller than a child (*e.g.*, the 10^{-4}meters Earth card shows muscle and blood tissue).

   If necessary, review exponential numbers and scientific notation with the class. Ask them to examine their cards again, looking for clues to scale. Invite them to make guesses about the size of the pictured things. At this point, do not reveal the correct order, even if students do not know where to place each card, or exactly what each card shows.

2. **Stories.** A Journey to Mars script is provided. This is a fictional story written from the perspective of a young explorer who is traveling to Mars. You may wish to read this story to the class. Show students the correct placement of the Mars cards as you read. Or, have students write their own stories for the Mars cards based upon what they have learned, before or after they hear the provided script, either in class or as homework.

3. **Activity.** Have students use transparency markers or grease pens to mark the scale on each card.

4. **Activity.** Have students draw the missing ZOOM! Cards for Mars. Assign each student or each team a specific power of 10.

5. **Clean-Up.** Have students wipe off all their marks. Gather up all the ZOOM! Card decks.

Mission 4.2
Materials

For a Class of 30

- Journey to Venus script

For Each Team

- Transparency marker or grease pen
- ZOOM! Cards for Microworld and Macroworld Earth (19 cards total)
- ZOOM! Cards for Venus (13 cards)

Getting Ready

1. Study the Venus ZOOM! cards to refresh your perception of distance and size. Read through the script Journey to Venus, anticipating students' questions.

Classroom Action

1. **Activity.** Divide the class into six groups. Give each team a deck of Earth ZOOM! Cards (19 cards) and a deck of Venus ZOOM! Cards (13 cards). Have students line up the Earth cards in order along a table. Ask them to guess where each Venus ZOOM! Card belongs in relation to the Earth deck. For the Venus cards, an additional challenge is posed by the layers of clouds that prevent us from seeing the surface for much of the journey, and because some scales are not depicted (i.e., cards for some powers of 10 are missing because scientists have not imaged Venus at the corresponding scales). You may want to tell students that the lo4 meters card shows a view straight down into a volcano! This can help orient them for several other Venus cards.

2. **Stories.** A Journey to Venus script is provided. This is a fictional story written from the perspective of an extraterrestrial being named LARB who is traveling to Venus. You may wish to read this story to the class. Show students the correct placement of the Venus Cards as you read. Or, have students write their own stories for the Venus cards based upon what they have learned, before or after they hear the provided script, in class or as homework.

3. **Activity.** Have students use transparency markers or grease pens to mark the scale on each card.

4. **Activity.** Have students draw the missing ZOOM! Cards for Venus. Assign each student or each team a specific power of 10.

5. **Discussion.** Ask students to explain the differences between the Mars journey and the Venus journey. Which deck of ZOOM! Cards was easier to put in order, Mars or Venus? Point out

that, if a spacecraft were approaching an unknown world, sending back photographs at intervals, we could calculate the scale of each photograph, but we would still have to interpret the pictures without any direct experience of living on that planet.

6. **Clean-Up.** Have students wipe off all their marks. Gather up all the ZOOM! Card decks.

Going Further

Activity: More Powers of 10

Invite students to use the ZOOM! Cards to guess and discover how many powers of 10 steps it would take to get from Earth to Venus or Mars. How many steps would it take to be able to see the nearest star? The center of our galaxy? The nearest galaxy? The far side of the known universe?

Ask students to create a series of ZOOM! Cards for objects in their town or region. Or, have students create a series based on time instead of distance, which could range from 10 billion years ago to 10 billion years from now. In this time series, have students research or speculate times for the Big Bang, the beginning of the solar system, the origin of life on Earth, the age of the dinosaurs, early primates, early humans, hunters and gatherers in North America, the Middle Ages, the Industrial Revolution, the 1980s, last year, last month, eight hours ago, the present moment, the end of the solar system, the end of the universe either as a gnaB giB? (Big Bang in reverse) or a forever expanding universe?

Activity: Cameras and the Electromagnetic Spectrum

Discuss the use of cameras as tools for detecting life on Venus or Mars. Discuss the use of various magnifications (scales!), the use of still cameras or video cameras, and the use of various portions of the electromagnetic (EM) spectrum (such as infrared radiation) to make photographs. What kinds of cameras would be best to use when searching for life on an extraterrestrial world? Scale is not the only consideration when selecting a camera for a spacecraft or lander. Have students look for pictures in magazines taken by special kinds of cameras that use other portions of the EM spectrum than visible light. Have them find actual images taken with infrared cameras. Or, have them bring in such images to share with the class. Discuss what advantages an infrared camera would have when searching for life on an alien world. What portions of the EM spectrum would work best? Would a Martian see as visible light the same portion of the EM spectrum that we do? Does a rattlesnake or a honeybee see the same way that we do?

Activity: Comparative Planetology

Have students recall some of the images from the video show in mission 1. You may wish to show the images again: Discuss which power of 10 each image represents and correlate each image with a ZOOM! Card.

Activity: Postcards from Mars!

Use this activity as an optional substitute for (or an addition to) the Stories activity in mission 4.1. Have the class invent the story of the journey to Mars. Ask each team to divide up its Mars cards so that each person gets one or two. Each team should agree upon a story line in which they are the crew members of a mission to Mars: The cameras have broken down, and the cards are the only images that can be scanned and radioed back to Earth. Each person writes a postcard using his or her card (or cards) to illustrate some aspect of the story. Invite students to read their stories aloud. Discuss them and compare them with the prepared script to be sure that students' stories take into account the temperature and atmospheric pressure on Mars, as well as other features that students probably don't know at the outset of the mission (if they haven't heard the script).

Possible story lines:

The crew are on a crippled spaceship, looking for water on Mars.

The crew are on a life-seeking expedition to Mars.

The crew are looking for traces of a vanished Martian civilization.

The crew are geologists looking for Martian fossils.

The crew are founding the first human colony on Mars.

The crew are looking for a human colony on Mars that has vanished.

The crew is searching for Martian life-forms that resemble rocks.

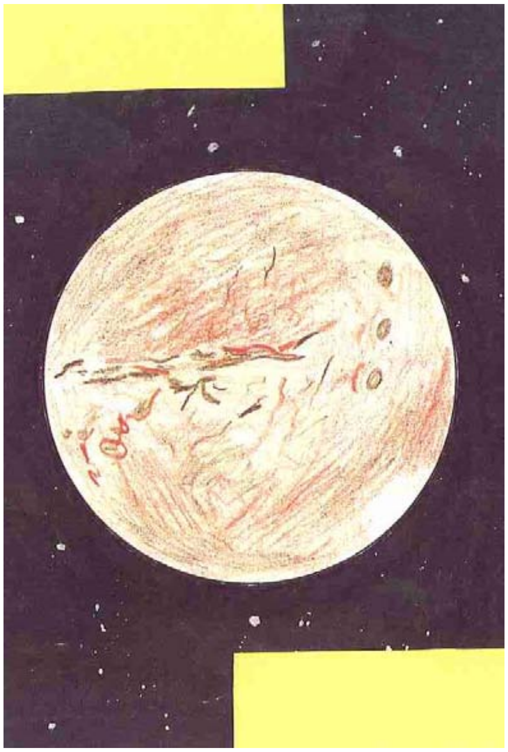
Script for ZOOM! Cards

Journey to Mars

The ZOOM! journey to Mars is not as complete as the journeys into Microworld and Macroworld Earth. Mars cards only show powers of 10 from 10^7 meters to meters. This journey includes images that were seen from the *Viking* landers on Mars. The rest of Microworld Mars has never been seen. The 10^{-10}meters card has been included to stress the existence of the carbon atom on Mars. It has been detected, but not actually seen with any instruments.

Today we will see 11 snapshots from an imaginary photo album of a trip to Mars. For fun, we will consider these to be postcards sent back home to Earth by a young space explorer! The scientific comments made in this script are accurate to the best of current scientific knowledge. The young explorer's comments reflect a joyful, inquiring mind. They are a bit more enthusiastic than sober scientific predictions! But who knows?

Figure 4.1- Mars Card # 11- The Planet Mars.



SCALE: 8 cm =10^7 meters
10^7 meters = 10 million meters

Observed by: Interplanetary spacecraft.

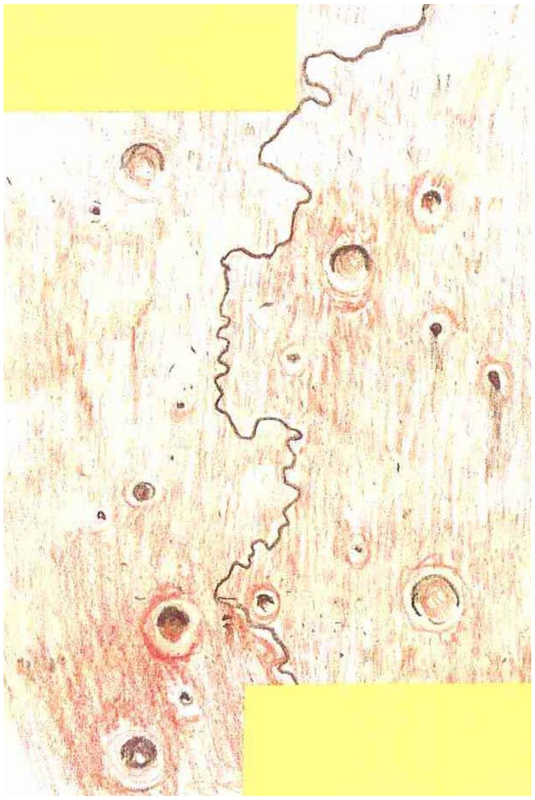
Description: Dear Mom and Dad, after a years travel, I've finally got a view of Mars from my own interplanetary spacecraft! Well, maybe it's not all mine. I guess it really belongs to Captain Kelley and the International Coalition of Space Explorers, but it sure *feels* like it's all mine! Mars is the fourth planet from our Sun. It is only about *112* the size of Earth, but because there are no oceans, there is just as much land on Mars as on Earth. From this distance, 10 million meters away, I can see the entire planet! It really *is* red! I wonder if there will be little green men on the little red planet!

Life or Signs of Life: Not at this distance!

Question: Why is Mars so reddish brown? *(The iron in the rocks combines with oxygen to make iron oxides, which are a rusty red color:)*

Comment: I can hardly wait to get to Mars!

Figure 4.2- Mars Card # 10- Martian Riverbed.



SCALE: 8 cm =10^6 meters
10^6meters = 1 million meters

Observed by: Orbiting spacecraft.

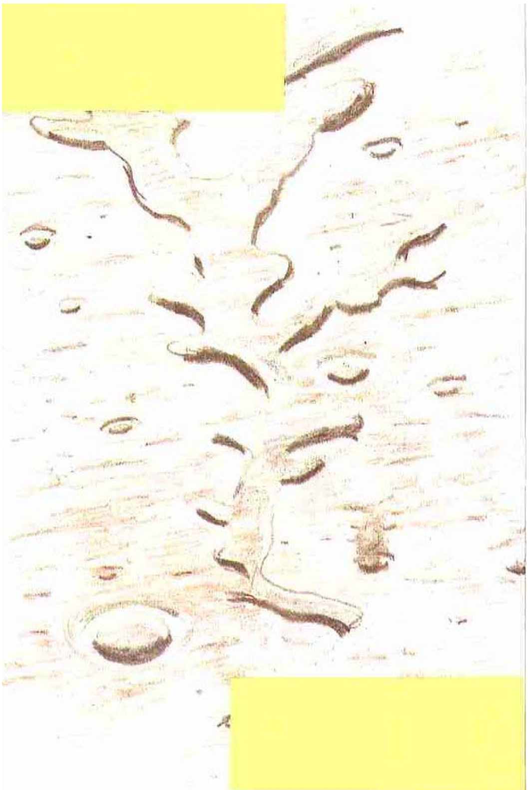
Description: I'm only 1 million meters from Mars now. What is that squiggly line? Could it be a canal? Captain Kelley says that there are no real canals on-Mars, but that robot missions to Mars discovered what look like ancient riverbeds. This riverbed is bigger than the Mississippi! Just imagine the amount of water it would take to fill that river! The robot's cameras also saw many craters, some of which had streaks of dark sand blown out behind them. From here, Mars looks as cratered as Earth's Moon!

Life or Signs of Life: Not at this distance!

Question: Where do these craters come from? *(Some are impact craters from meteorites, and some are small volcanoes.)*

Comment: I wonder if that river is full of fossil fish?

Figure 4.3-Mars Card # 9- Riverbed.



SCALE: 8 cm =10^5 meters
10^5meters = 100,000 meters

Observed by: Orbiting spacecraft.

Description: We are in orbit around Mars at an altitude of 10,000 meters. Soon we will pick a landing site! From here, I can get a better view of that riverbed. It truly is dry! There is no water at all in this Martian Mississippi! Captain Kelley says that the air on Mars is so thin today that liquid water cannot exist. Any water would immediately evaporate. But Mars might have been more like Earth long ago. Maybe there once *were* living creatures in a *real* river at one time. Maybe there is water in solid form beneath the soil surface.

Life or Signs of Life: Not at this distance!

Question: How long ago did the riverbed form? *(About 3.5 billion years ago.)*

Comment: Maybe I'll find plant and fish fossils in the ancient riverbed!

Figure 4.4–Mars Card # 8 – Surface of Mars

SCALE: 8cm = 10^4 meters
10^4 meters = 10,000meters

Observed by: Spacecraft during descent to the surface.

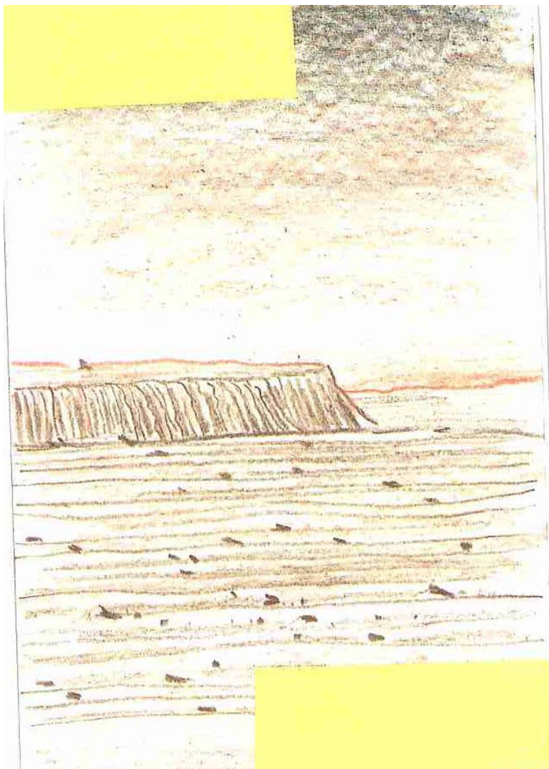
Description: We've picked a spot to land! We're going to check out that old riverbed! As I get closer to Mars, I can see that the surface truly is reddish brown. Captain Kelley says that there is iron in the rocks that combines with oxygen from the thin atmosphere to form iron oxides, which are a rusty red color. Mars is covered with rust! Captain Kelley says that the canyons, valleys, and volcanoes on Mars are *much* larger than any on Earth.

Life or Signs of Life: Not at this distance!

Question: How is Mars like or unlike Earth? *(Compared to the gas giant planets, Mars is like Earth in many ways, but there are differences too. It is colder; drier; and has a very thin atmosphere.)*

Comment: I'm sure getting tired of space pizza and astronaut ice cream!

Figure 4.4– Mars Card # 8 – Surface of Mars



SCALE: 8cm =10^3 meters
10^3 meters = 1,000 meters (1 kilometer)

Observed by: Spacecraft during descent to the surface.

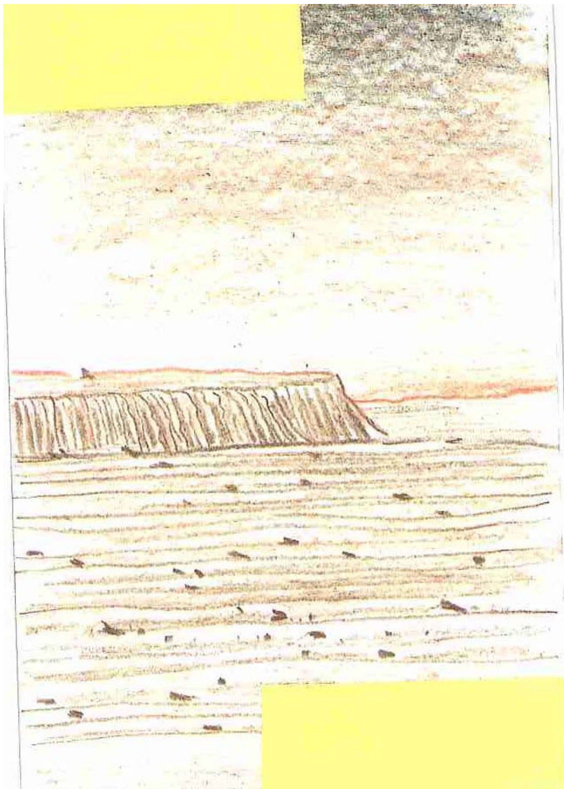
Description: We're almost down! We are only 1,000 meters from the surface. From here, Mars looks like a vast desert of sand and rock. Captain Kelley says that strong winds blow through the thin atmosphere, sandblasting the surface. One canyon, the Valles Marineris, is as long as the United States! I wonder how big that cliff over there actually is. Oh, now I see that the cliff is actually the bank of the river! Captain Kelley says that water probably was more responsible than the sandblasting winds for forming this canyon!

Life or Signs of Life: Not at this distance!

Question: Where does the sand come from? *(As on Earth, the rocks break apart.)*

Comment: I hope there isn't a sandstorm where we land.

Figure 4.6—Mars Card # 6 - Landscape



SCALE: 8 cm = 10^2 meters
10^2meters = 100 meters

Observed by: Spacecraft during descent to the surface.

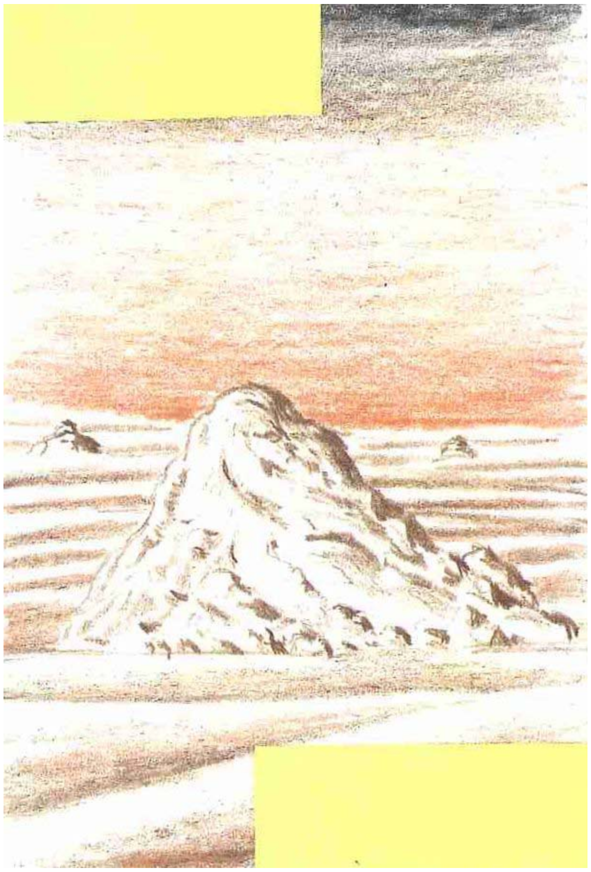
Description: Still closer! We're only 100 meters from the surface! I can see a large field of sand dunes. Captain Kelley says that they are formed by the wind. Lots of red dust is blown into the atmosphere, where it stays for a long time. The sand gives the sky a pale brownish orange color. Mars is truly a red planet, complete with a rusty red sky! They say that the sunsets on Mars are fantastic! I'll bet we kick up a lot of red dust when we land! Maybe some Martian will see us land and come to welcome us!

Life or Signs of Life: Not at this distance!

Question: Why does it take longer for dust to settle on Mars? *(There are constant winds and the gravity is weaker than back on Earth.)*

Comment: I wonder if Mars will be anything like the desert in Arizona?

Figure 4.7—Mars Card # 5- Boulder



SCALE: 8 cm = 10^1 meters
10^1 meters = 10 meters

Observed by: Spacecraft or an observer on Mars.

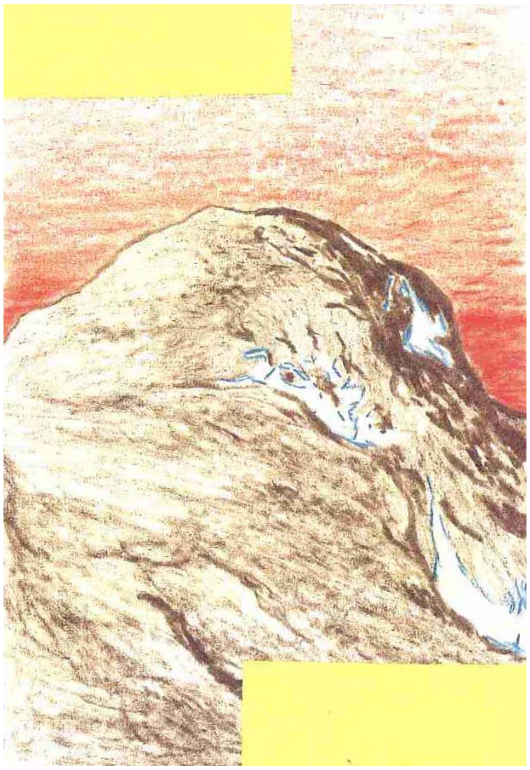
Description: We've landed! We're actually on the surface of Mars! I can see a big boulder, or is it a mountain? I can't wait until I can put on my space suit and go out there and see! It looks like there are many boulders scattered throughout the field of sand dunes. They might be the tops of large rocks that have been buried by sand. Maybe they just *look* like rocks! Maybe they are Martians made out of silicon!

Life or Signs of Life: Can't be sure.

Question: Why is the rock rounded at its top? *(The sandblasting winds smooth off the surfaces of rocks.)*

Comment: What's taking so long, Captain Kelly? Let's *go!*

Figure 4.8—Mars Card # 4- Ice and Dry Ice.



SCALE: 8 cm = 10^0 meters
10^0meters = 1 meter

Observed by: Spacecraft or an observer on Mars.

Description: I'm outside the spaceship, on the surface of Mars! It sure feels odd to walk around in this gravity after being in space for six months. I'm warm enough in my space suit, but this is one *cold* desert. Captain Kelley says that those patches in the shaded portions of the rock are dry ice. Dry ice is frozen carbon dioxide (CO_2)! Do you know how cold it has to be to keep dry ice frozen? About -57º C! There are also huge ice caps at the poles of Mars. The North Pole contains both dry ice and frozen water. So there *is* water on Mars! It's just frozen. (The South Pole is only CO_2.)

Life or Signs of Life: Nothing definite; carbon exists in living and in nonliving things. Water may be necessary for Earth life, but its presence here doesn't that there is life.

Question: Why is there no dry ice at the poles of Earth? *(The Earth is too warm, even at the South Pole. Tell that to a penguin!)*

Comment: I'm actually *walking around* on another planet!

Figure 4.9–Mars Card # 3- Ice and Dry Ice.

SCALE: 8 cm = 10^{-1} meters
10^{-1}meters = .1 meters

Observed by: Spacecraft or an observer on Mars.

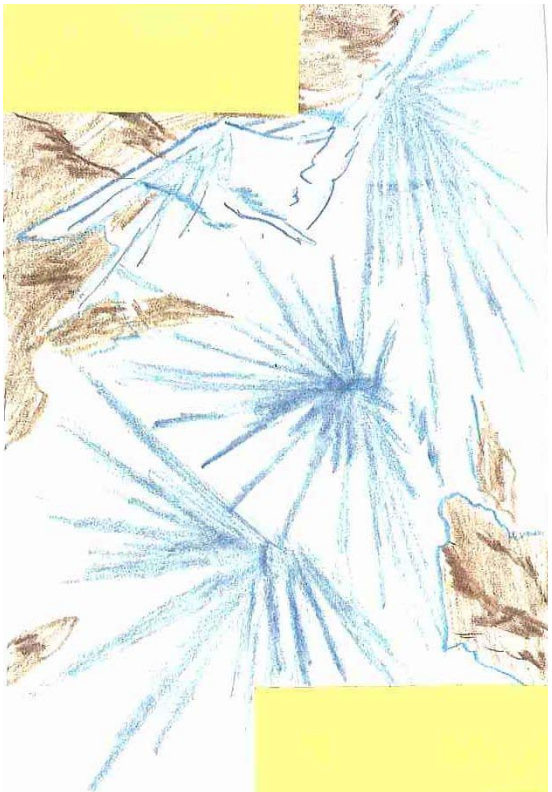
Description: I can't find any fossils, and those rocks sure look more like rocks than Martians! The patch of dry ice looks white and kind of powdery. Captain Kelley says that if all the ice on Mars evaporated, Mars would have a thicker. warmer atmosphere. Water could flow as a liquid and form riverbeds. I wonder if we could melt the ice and terraform Mars? Maybe one day we could even bring fish from Earth! Imagine catching a rainbow trout on Mars!

Life or Signs of Life: Nothing definite; only carbon and frozen water.

Question: Why does Mars have such a thin atmosphere? *(Its volcanism stopped as the planet cooled.*
Many of the elements in the atmosphere combined with the soil. Its small size and weak gravity allowed some of the atmosphere to escape into space.)

Comment: Nothing looks alive; I only see sand and rocks and ice.

Figure 4.10— Mars Card # 2 – Ice and Dry Ice.



SCALE: 8 cm = 10^{-2}meters
10^{-2}meters = .01 meters (1 centimeter)

Observed by: Spacecraft or an observer on Mars.

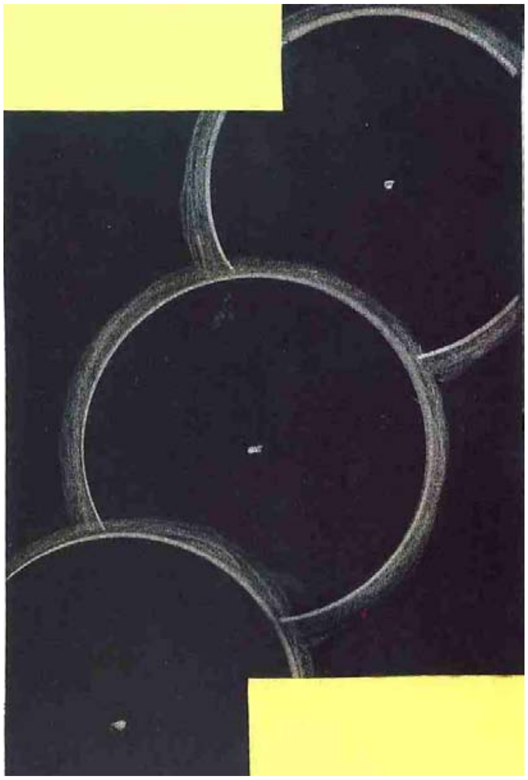
Description: Captain Kelley says that the dry ice here freezes and evaporates like water does on Earth. The water on Mars is always frozen because it melts at a higher temperature than dry ice. On Earth, there are bacteria and even insects that live on the ice and snow, and even in glaciers. And polar bears and penguins like the icy regions of Earth just fine. Maybe there are cold-loving critters living here. Maybe they're just too small for me to see with my eyes.

Life or Signs of Life: Nothing definite.

Question: If Mars once had a thicker atmosphere, could life have evolved there at that time? *Wes. As far as we can tell, all the necessary conditions for life were present when Mars had an atmosphere.)*

Comment: I wish that I had a microscope to look for bacteria and other tiny life-forms.

Figure 4.11—Mars Card # 1- Atoms



SCALE: 8 cm = 10^{-10}meters
$10-^{10}$ meters = .0000000001 meters

Observed by: Imagination!

Description: This is a picture that Captain Kelley showed me. We should have brought a tunneling electron microscope with us so we could look for atoms on Mars! But we know that dry ice is made of molecules of CO_2. This picture shows one carbon atom between two oxygen atoms. It's neat to think that carbon atoms just like this one are inside me right now!

Life or Signs of Life: Nothing definite.

Question: Is this carbon atom any different from the carbon atoms on Earth? *(No. A carbon atom, is a carbon atom.)*

Comment: I guess it's time to go back to Earth now. Hey, wait a minute! I did get a round-trip ticket, didn't I? Captain Kelley! Captain Kelley! Where are you? Oh, there you are! I'm sure glad to see you. Mars is a great place to visit, but I'm starting to miss Earth. It will take another year of travel time, but I'm ready to go home.

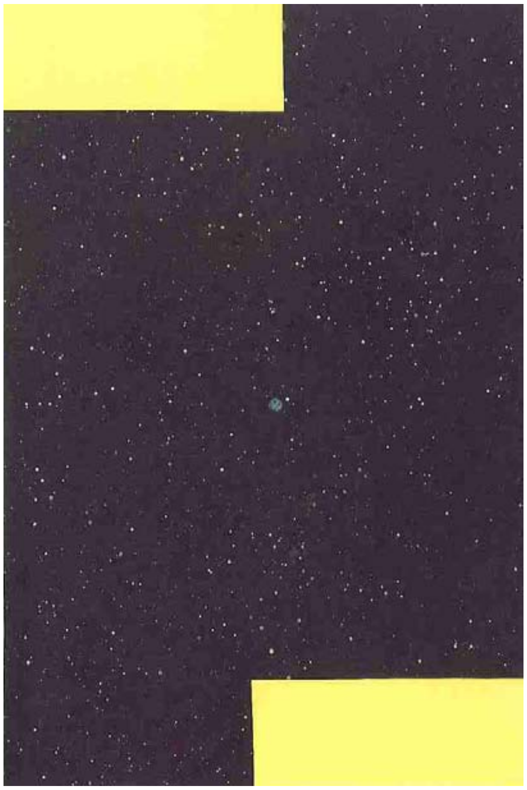
Script for ZOOM! Cards

Journey to Venus

The ZOOM! journey to Venus begins at 10 meters, jumps to 10^8 meters, and then includes views from 10^8 meters to meters. This journey includes images that are created based on data from the *Magellan* mission and the Russian *Venera* landers. However, the rest of Microworld Venus has never been seen by spacecraft instruments. The "10^{-10}meters card has been included to stress the existence of carbon atoms on Venus. They have been detected, but not actually seen with any instruments.

In this scenario, an imaginary extraterrestrial explorer named LARB pilots a spacecraft into our solar system. LARB sees the three Earth-like planets, and decides to take a closer look at Venus. Who knows? Maybe the conditions on Venus will seem like home to this extraterrestrial! Consider the ZOOM! Cards of Venus to be a series of images sent home by Commander LARB. This scenario assumes that LARB has a sensory ability that approximates human vision, as well as technology that is similar to ours! These may not be good assumptions. This scenario also assumes that this extraterrestrial can travel across the galaxy! Such travel is purely science fiction. The scientific comments about Venus are accurate to the best of current scientific knowledge. LARB's comments reflect a non-human, inquiring mind. They may be a bit odd from a sober, scientific Earth perspective! But who knows?

Figure 4.12—Venus Card # 1- Venus, Earth, and Mars.



SCALE: 8 cm = 10^{11} meters
10^{11} meters = 100 billion meters

Observed by: LARB's interplanetary spacecraft.

Description: Report from Commander LARB to Proxima Centauri Base. I have been traveling for over 20,000 glaxes, which is a long time to be alone. I have finally arrived at the target star. As our scientists predicted, there is a planetary system here! There are nine planets orbiting Sol I. From my view screen I can see three planets, all about 100 billion meters away. There is a planet closer to Sol I than these three, but it is too close, and far too hot for liquid water and life as we know it to exist.

Life or Signs of Life: Not at this distance.

Questions: What planets can LARB see? (At this distance, LARB can see Venus, Earth and Mars; in this view, these planets can be seem because each is in a suitable position in its orbit around the Sun.) Can you tell which dot is Earth? Which is Mars? Which is Venus? (This can be determined by size and position).

Comment: The yellow planet, which is the second closest planet to Sol I, looks promising.

Figure 4.14—Venus Card # 3-Close to Venus

SCALE: 8 cm = 10^7meters
10^7 meters = 10 million meters

Figure 4.14- Venus Card # 3 – Close to Venus.

Observed by: LARB's interplanetary spacecraft.

Description: Report from Commander LARB to Proxima Centauri Base. I am approaching Venus, which is only 10 million meters away. The planet fills the entire view screen. There are no rings or moons present, and there are still no details of the surface to be seen. Am I still too far away to see details? No, but the surface of Venus seems to be completely hidden by thick, yellowish clouds. I can see them swirling, but I can't detect anything through them. These clouds may provide shielding for any life on the planet. I'm going in for a closer look.

Life or Signs of Life: Not at this distance, because of those clouds.

Question: How did the *Magellan* spacecraft see through these clouds? *(Magellan used radar to penetrate the clouds; computer program generated images from the radar data.)*

Comment: Will those clouds be a problem?

Figure 4.15–Venus Card # 4- CLouds

SCALE: 8 cm = 10^6 meters
10^6meters = 1 million meters

Observed by: LARB's spacecraft during descent to the surface.

Description: Report from Commander LARB to Proxima Centauri Base. The churning, dense, yellow clouds are well below me. Some of the storm systems look like they are moving five or six times as fast as hurricanes back home. There seems to be a strong movement from the west to the east, against The planetary rotation. There are two permanent vortices at the poles. These clouds are moving fast enough to circle the planet in only four days!

Life or Signs of Life: Not at this distance.

Question: What kind of acids are in the clouds? *(Mainly sulfuric and hydrochloric acids.)*

Comment: Will I be able to go below these clouds?

Figure 4.16—Venus Card # 5 10^5meters =

SCALE: 8 cm =10^5 meters
10^5 meters = 100,000 meters

Observed by: LARB's spacecraft during descent to the surface.

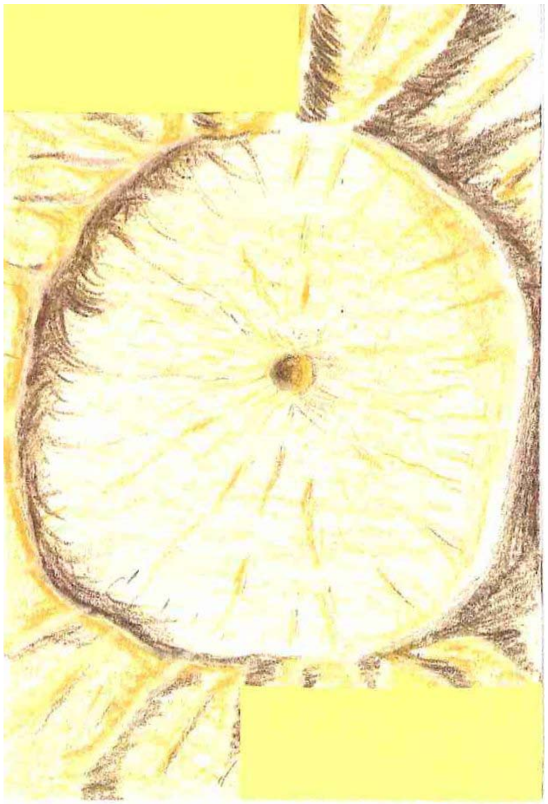
Description: Report from Commander LARB to Proxima Centauri Base. I am about to delve into the midst of the dense Venusian atmosphere. The clouds start at 70 kilometers above the surface. It's starting to heat up, and the pressure is building. I'm not sure what I'm in for, but my intrepid adventurous spirit will lead the way! (I think.) I sure hope that these clouds end a good distance above the surface. It will be hard to land without being able to see.

Life or Signs of Life: Not at this distance.

Question: What are the weather systems in the clouds? *(There are two convection cells, one in each hemisphere.)*

Comment: Will I land in a volcano, or in an ocean? Planetary exploration can be pretty risky.

Figure 4.17—Venus Card # 6 – Below the Clouds.



SCALE: 8 cm = 10^4 meters
10^4 meters = 10,000 meters

Observed by: LARB's spacecraft during descent to the surface.

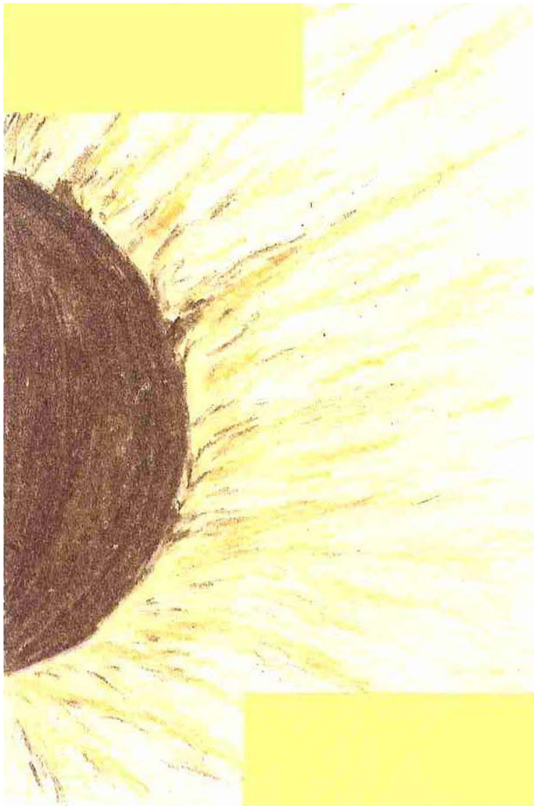
Description: Report from Commander LARB to Proxima Centauri Base. What torture! My instruments are going crazy! The temperature and-pressure are both off the scale! The external chemical sensors read very low pH levels, which means that these clouds must be composed of *acids.* It's a good thing that my spacecraft has protective armor! I actually went through two cloud layers: one from 75 to 55 kilometers above the surface and another from 50 to 40 kilometers above the surface. The landscape below me is fantastic! There are pits and craters and lava flows all over There is a huge volcano right below me. There are no cities, nor are there any signs of roads, spaceports, or agriculture. In fact, there is no vegetation of any kind. The entire surface appears to be lifeless.

Life or Signs of Life: None.

Question: Are the volcanoes on Venus still active? *(Scientists don't know yet. The detection of energy bursts and steep slopes leads to some interesting speculation.)*

Comment: Could there be a thriving civilization below the surface?

Figure 4.18—Venus Card # 7- Crater's Edge.



SCALE: 8 cm =10^3 meters
10^3meters = 1,000 meters (I kilometer)

Observed by: LARB's spacecraft during descent to surface.

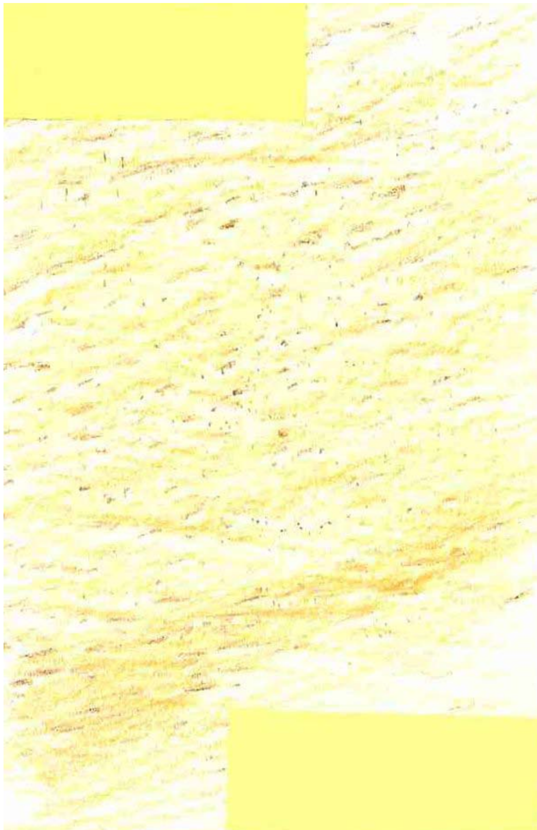
Description: Report from Commander LARB to Proxima Centauri Base. I'm preparing my spacecraft for landing. It looks like its going to be rough. Maybe I can scoot on over past the volcano, onto those flat plains created by the lava flows. The Figure 4.18- Venus Card # 7- volcano looks inactive and the lava is solidified. Crater's Edge. The lava looks like it oozed out of the volcanoes. Because the atmospheric pressure is so high here, the lava probably didn't erupt into the air! There is no wind this close to the surface; this will simplify my landing. I'm sure glad to be out of those clouds, but the temperature and pressure are still rising.

Life or Signs of Life: None.

Question: What are the mounds? *(Pancake domesflat, circular volca,noes about 25 kilometers in diameter and 750 meters high.)*

Comment: I don't want to land on the rim; it looks like a steep drop into the crater.

Figure 4.19—Venus Card # 8- Flat Plains



SCALE: 8 cm = 10^2meters
10^2 meters = 100 meters

Observed by: Landing spacecraft.

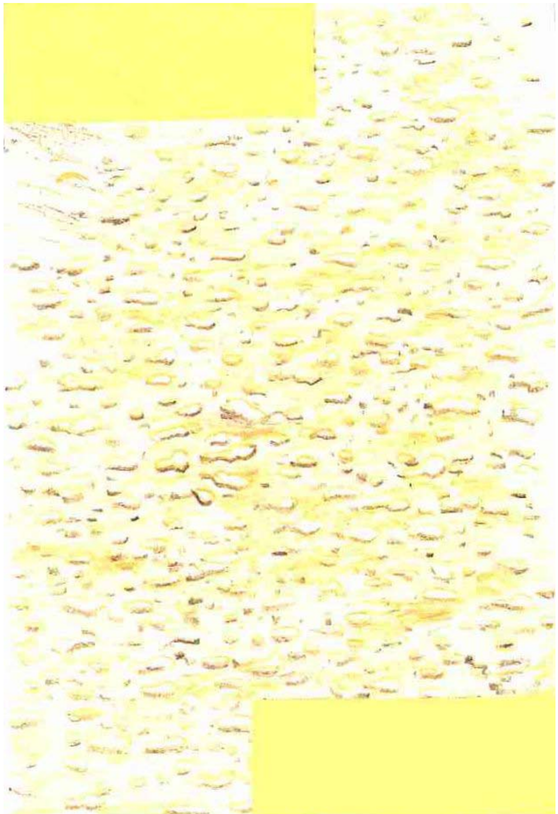
Description: Report from Commander LARB to Proxima Centauri Base. I'm on my final approach. Small rocks litter the plain, but this craft is designed for that. Right? I don't see any animals or plants of any kind. In other places, I saw rift valleys, but now I'm cruising over rolling plains. Some of them appear to be rift-valley trenches filled with lava flows. The surface appears to be a mixture of loose grainy rocks and larger, flatter rocks.

Life or Signs of Life: None.

Question: Is the surface of Venus solid? *(The former Soviet Union landed two spacecraft,* Venera *9 and* Venera 10, *on the surface, which proved to be solid. Only one craft survived the landing; however, it was overcome by the pressure and temperature within an hour.)*

Comment: I'm all set for a perfect landing.

Figure 4.20—Venus Card # 9 – 10 Meters Up!



SCALE: 8 cm = 10^1 meters
10^1 meters = 10 meters

Observed by: Landing spacecraft.

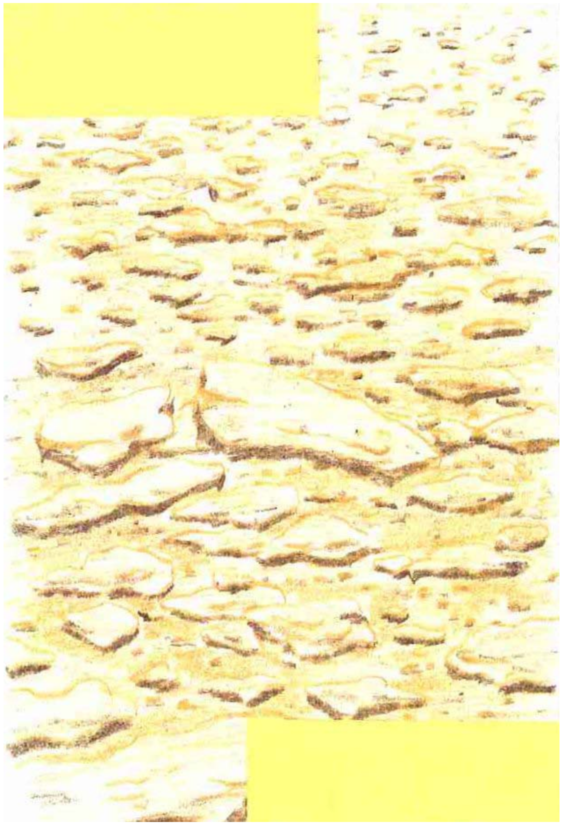
Description: Report from Commander LARB to Proxima Centauri Base. My retro-rockets are firing. I'm going to need all of my tentacles to manipulate the landing controls! I see slab-like rocks about half a meter long littering the surface. Some are granite-like rocks while others appear to be like basalt, which has volcanic origins. I also see clustered, rocky outcroppings. I don't want to land on one of those! My ship could tip over, and I would never be able to launch off this planet; the pressure and temperatures are too high for me to go outside and reposition my spacecraft for a launch.

Life or Signs of Life: No.

Question: Is the surface made of young rocks or old rocks? (A *mixture-granite, an older, metamorphic rock that is a conglomerate of other rocks; and basalt, a younger rock of volcanic origin.)* Comment: I sure hope this spacecraft can land here.

Comment: I sure hope this spacecraft can land here.

Figure 4.21—Venus Card # 10- Landscape.



SCALE: 8 cm = 10^0meters
10^0 meters = 1 meter

Observed by: Spacecraft on the surface of Venus.

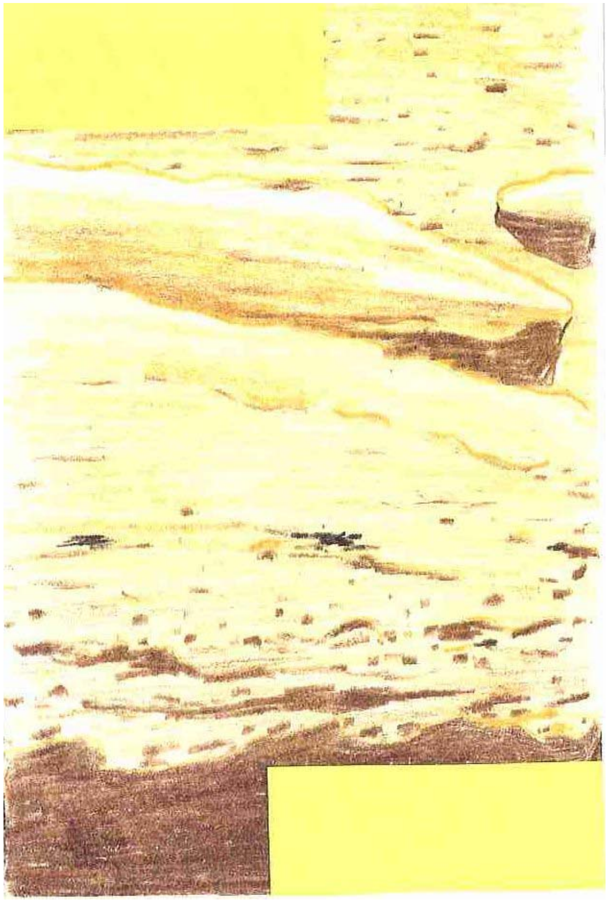
Description: Report from Commander LARB to Proxima Centauri Base. I have landed successfully! Phew!!! This is a well-built spacecraft; it has withstood a temperature that would melt lead and a tremendous atmospheric pressure. The surface of Venus shows volcanic rocks and a desert-like landscape. Some of the rocks have small holes that may have been filled with gas. Other rocks show blunt landscape is yellow. There is no water anywhere; at this temperature, any water would vaporize instantly!

Life or Signs of Life: No.

Question: In Earth terms, how great is the atmospheric pressure on the surface of Venus? *(The atmospheric pressure on Venus is 90 times greater than on Earth .)*

Comment: I made it!

Figure 4.22—Venus Card # 11 Volcanic Rocks.



SCALE: 8 cm = 10^{-1} meters
10^{-1} meters = .1 meters

Observed by: Spacecraft on the surface of Venus.

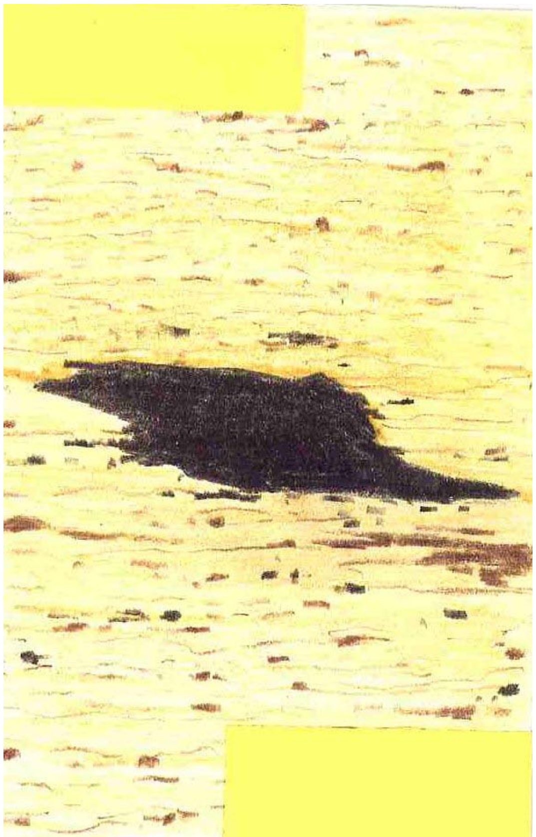
Description: Report from Commander LARB to Proxima Centauri Base. It is so still here. There is nothing moving anywhere. This is a close-up of the volcanic rocks in the last image. There are little black spots all over the rocks. Could they be lifeforms? I will look more closely. Wow! The analyzer says that they are made of darbon atoms! iMaybe they *are* a life-form. If they are, they're sure funny looking.

Life or Signs of Life: Can't be sure. Carbon atoms exist in living and in nonliving things.

Question: Do you think that LARB is a carbon based life-form? *(This extraterrestrial is very excited by the presence of carbon. LARB must know of the existence of carbon-based life-forms. However, we can't know for sure whether or not LARB is carbon-based.)*

Comment: Maybe the black spots think that I'm funny looking!

Figure 4.23—Venus Card # 12- Black Diamonds.



SCALE: 8 cm = 10^{-2} meters
10^{-2}meters = .01meters (1 centimeter)

Observed by: Spacecraft on the surface of Venus.

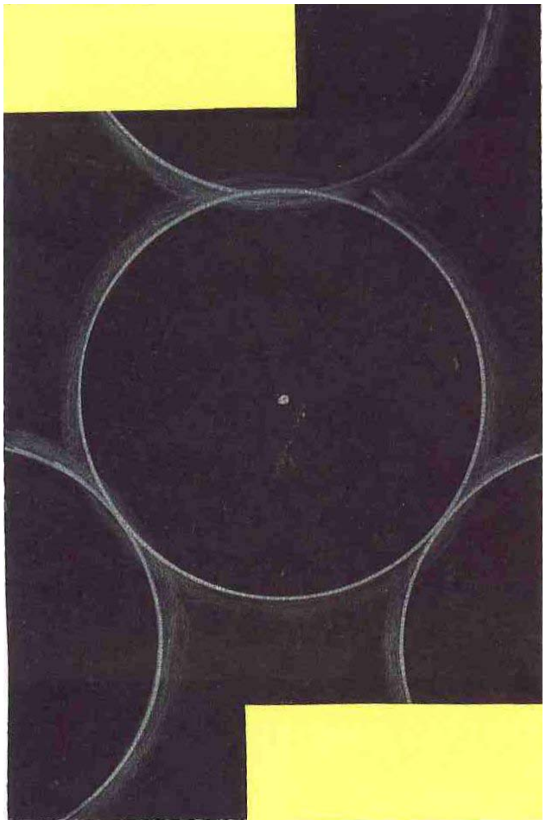
Description: Report from Commander LARB to Proxima Centauri Base. This is a close-up of the back spots seen on the rocks. Analysis shows them to be black diamonds. I will map the planet to see how many diamonds there are, but there probably isn't much sense in mining a planet so far from home, especially for an element as common as carbon. The transportation costs, and the time involved, would be prohibitive.

Life or Signs of Life: No. Black diamonds are carbon, but they are not alive.

Question: Do we really know that there are black diamonds on Venus? *(This idea is based upon conjecture: Because most volcanoes 012 Earth produce black diamonds, it is likely that the volcanoes on Venus produce black diamonds, too.)*

Comment: I'd still like to have my own black-diamond mine!

Figure 4.24—Venus # 13 Carbon Atoms



SCALE: 8 cm = 10^{-10} meters
10^{-10}meters = .0000000001 meters

Observed by: Imagination!

Description: Report from Commander LARB to Proxima Centauri Base. As expected, there are carbon atoms within the black diamond. Although carbon atoms are characteristic in living things, they are also found in nonliving things, such as carbon dioxide gas, dry ice, and black diamonds! Soon I will finish my survey here. Next, I plan to go to the third planet from Sol I. I don't expect to find any life there, though, because the planet is probably far enough away from its star that its water freezes! I'll look anyway. Wish me luck!

Life or Signs of Life: No. Carbon is not proof.

Question: What will LARB find on the third planet? *(Us!)*

Comment: I think I'll name the third planet after me. LARB-I like the sound of that!

Mission 5
Initial Spacecraft and Lander Design Tools of Comparative Planetology and Exobiology

Overview

In mission 5.1, each student designs, diagrams, and describes a spacecraft-lander system to explore one of six specific sites on Mars or Venus. In mission 5.2, students form teams based on common landing sites and design a composite spacecraft-lander system. Each team presents its ideas to the class, summarizing the conditions at their landing site and the components of their spacecraft- lander system and how they are suited to the landing site.

Notes

In mission 4, students journeyed to Mars and Venus. In the real world, comparative planetologists and exobiologists send spacecraft and landers to other planets to discover the characteristics of an alien environment or to search for signs of life. Today's missions are robotic solely because of cost; technically, manned missions are feasible. All successful missions are the products of creative ideas, careful planning, and team work.

Mission 5.1
Materials

For a *Class of* 30

- Transparency of Viking Lander

For Each Student

- Drawing paper
- Drawing and coloring tools (rulers, markers, etc.)
- Landing Site Environment data sheet
- Initial Spacecraft Design worksheet
- Designing a Spacecraft and Lander optional directions
- Pencil

Getting Ready

1. Assemble drawing materials.

2. Make five copies of each Landing Site Environment data sheet. Cut the sheets in half so each student receives only one landing site. (Students who receive the same landing site will work together as a team in mission 5.2.)

3. Copy the Initial Spacecraft Design worksheet and the Designing a Spacecraft and Lander optional directions for each student.

4. Make a transparency of *Viking* Lander.

Classroom Action

1. Preliminary. Hand out the Initial Spacecraft Design worksheets and the Landing Site Environment data sheets. There are six landing sites; each student should get one of these. Distribute all six sites randomly. Be aware that the Atmosphere of Venus site is more challenging than the other sites. (In mission 14, Final Spacecraft and Lander Design, students' landers will set down on these sites. Student teams will be given simulated data to analyze. Students teams in mission 14 will be the same teams formed in mission 5.2, so be sure to record teams and save all completed student pages.)

2. **Discussion.** Explain that a spacecraft never lands on a planet, but it may orbit a planet and do remote sensing. Only a lander actually sets down on the surface of a planet. Discuss with students the importance of spacecraft and landers to the comparative planetologist and the exobiologist. Ask students to name what they think are the major components of a spacecraft. Make sure students conclude that a spacecraft must be able to travel through space undamaged, reach the landing site, deliver the lander, and send data back to Earth. Ask students what can be learned from a spacecraft. How does a spacecraft gather its information? What cannot be learned from a spacecraft? Why not?

   Teacher's Note: *On Mars, the prime meridian is defined relative to a tiny crater in the Sinus Maridiani region of Mars. This entire region was used as the meridian until the Mariner mission (which had the first orbiter), when the position was redefined as the center of this crater.*

   For Venus, before the Russian Venera *missions, there were several definitions for the meridian because each observing group could define its own. The* Pioneer, *the Arecibo Earth-based, and the* Magellan *radar mapping of Venus have led to a consensus-the meridian is now defined as the centralpeak of the Ariadne crater: This peak was chosen because it was present in all three mapping projects and because it is particularly easy to see with radar. The International Astronomical Union (IAU) has a committee in charge of the cartographic coordinates of planets and satellites. It meets every third year.*

   Ask students to name what they think are the major components of a lander. Make sure students conclude that a lander must be able to perform experiments designed to detect life (or the environmental conditions necessary for life) and send data back to Earth. Landers can assess the local planetary conditions: geology, chemistry, or meteorology. Ask students what can be learned from a lander? How does a lander gather its information? What cannot be learned from a lander? Why not?

Put the transparency of the *Viking* Lander on the overhead projector. Have students identify on the *Viking* the major components of a spacecraft they mentioned in their previous discussion. Then have them point out the data collection devices on the *Viking.*

Tell students that there are four major facets of designing a spacecraft-lander system. One, the exterior of the system must be able to withstand the conditions during travel and the conditions at the landing site. Two, the system should include mechanisms for the purposes of propulsion and navigation. Three, the system should include instruments that gather information about the conditions and the existence of life at the landing site and send that information back to Earth. Four, the system should not contaminate the site with life-forms brought from Earth.

Teacher's Note: *The focus of this mission is more the search for life than it is spacecraft and lander design per se. It will be sufficient for students to simplify complex aspects of their spacecraft and landers. For example, they might include black boxes to provide the navigation without explaining how a black box works. For the purposes of this mission, it is not necessary to know how such complex devices work. However, the life detection mechanisms of the spacecraft and landers should be explained in as much detail as possible. The spacecraft-lander systems shouldbe designed uniquely for use at specific landing sites.*

Teacher's Note: *It is vastly more exciting for students to consider manned missions to Mars or Venus, and such missions are feasible. However, they are not very likely in the foreseeable future because they are very expensive compared to robotic missions. Discuss the cold realities of finance with students, but do not kill their dreams.*

3. **Activity.** Have students brainstorm for 10 minutes on what to include in their spacecraft lander system. Each student should consider the solutions to the specific challenges imposed by the landing site (e.g., extra parachutes because of thin atmosphere, or broad based feet to prevent a lander from toppling over in soft soil). After 10 minutes, hand out drawing materials. Have students complete their Initial Spacecraft Design worksheets. (Note that there is no teacher's key for this worksheet because student answers to the questions will vary; all reasonable attempts should be accepted.) Explain that a good drawing is nice, but that labeling and describing the function of the parts is more important. Encourage students to include everything they would need for a successful mission.

   Teacher's Note: *Students will tend to plan for a manned flight unless instructed otherwise. At this point, let them use their imagination to think about how exciting it would be to travel to other planets and to create a plan unhindered by such constraints. In real missions, payload and overall cost are major considerations. Students' final spacecraft-lander designs(mission 14) will include these factors.*

Mission 5.2
Materials

For Each Student

- Design Conference worksheet
- Pencil

Getting Ready

1. Copy the Design Conference worksheet for each student.

Classroom Action

1. **Activity.** Hand out the Design Conference worksheet to each student. (Note that there is no teacher's key for this worksheet because student answers to the questions will vary; all reasonable attempts should be accepted.) Divide the class into teams of students who share the same landing site. Each team should have about five students. Tell students that they will be holding conferences to discuss their spacecraft-lander system designs. Have them use their worksheets to review each spacecraft-lander system and record its unique and outstanding qualities. Tell each team to design a composite spacecraft-lander system based on the best aspects of each individual design. A team might start with one person's design and add to it, or begin anew.

2. **Oral Presentation.** Invite teams to present their work to the class. They are responsible for educating the class about the conditions at their landing site and for presenting and explaining their proposed spacecraft and lander. Hold a Press Conference in which teams tell the public what they intend to do; have the press in the audience take notes and publish a newsletter on the expected launches. Or, have a science fair poster session in which one member from each team stands by the team's drawing while the remaining team members observe the plans of other teams. Have teams draw pictures of their landing sites as well. After all presentations, have teams meet again to rethink some of their ideas and refine their spaceship and lander designs.

3. **Conclusion.** Collect all the designs from each team and save them for mission 14, Final Spacecraft and Lander Design. Display the composite design from each team on a bulletin board.

Going Further

Activity: Do-It-Yourself Spaceship Models

Ask students to bring in various doodads (anything from paper clips to bottle caps and different sized boxes and pieces of cardboard). Have students use these items (and glue, tape, and pins) to construct models of their spacecraft and landers. Have students try to make each component as descriptive as possible while maintaining a low overall weight. This activity can be done by individual students or by the conference teams. Have a show or competition with categories such as best spacecraft, most original lander, most functional spacecraft-lander system, and so on.

Research: American and Russian Spaceships

Ask students to research the design of real spacecraft and share their findings with the class. Did the Americans and the Russians use the same designs? How were they different? Assign each team a specific spacecraft. Have students bring in pictures or drawings of their assigned spacecraft.

Research: The Starship *Enterprise*

The Starship *Enterprise* (in its many manifestations of *Star Trek* fame) was thought out by spacecraft designers. There are also schematics and technical manuals for the *Enterprise.* Ask students to find these schematics and manuals in a library and evaluate the designs. Are they realistic? Functional? Which aspects were put in just for Hollywood? Why doesn't the *Enterprise* ever land on a planet?

Mission 5 Logbook
Initial Spacecraft and Lander Design

Tools of Comparative Planetology and Exobiology

Designing a Spacecraft and Lander -Optional Directions

A spacecraft and lander are of vital importance for the comparative planetologist and the exobiologist who cannot leave Earth! A spacecraft never lands on a planet, but it may orbit a planet and do remote sensing. Only a lander actually sets down on the surface of a planet.

A spacecraft must be able to travel through space undamaged, reach the target planet, deliver the lander, and send data back to Earth. A lander must be able to perform experiments designed to detect life (or the environmental conditions necessary for life) and send data back to Earth.

In this mission, you should be more concerned with the search for life than with spacecraft and lander design. It will be sufficient for you to simplify complex parts of your spacecraft and lander. For example, you might use a black box to provide the navigation without explaining how a black box works. For the purposes of this mission, it is not necessary to know how such complex devices work. However, the life detection mechanisms of your spacecraft and lander should be explained in as much detail as possible.

Your task is to design a spacecraft-lander system for use at your specific landing site (each site is different). There are four major facets of this design.

1. The exterior of your system must be able to withstand the conditions during travel and the conditions at your landing site.

2. Your system should include mechanisms for the purposes of propulsion and navigation.

3. Your system should include instruments that gather information about the conditions and the existence of life at your landing site and send that information back to Earth.

4. Your system should give some consideration to ways of avoiding contamination of the landing site with life-forms accidentally brought from Earth.

   First you will work individually, considering the solutions to the specific challenges imposed by your landing site, such as extra parachutes because of thin atmosphere, or broad-based feet to prevent a lander from toppling over in soft soil. Later you will work in teams to refine your spacecraft-lander design.

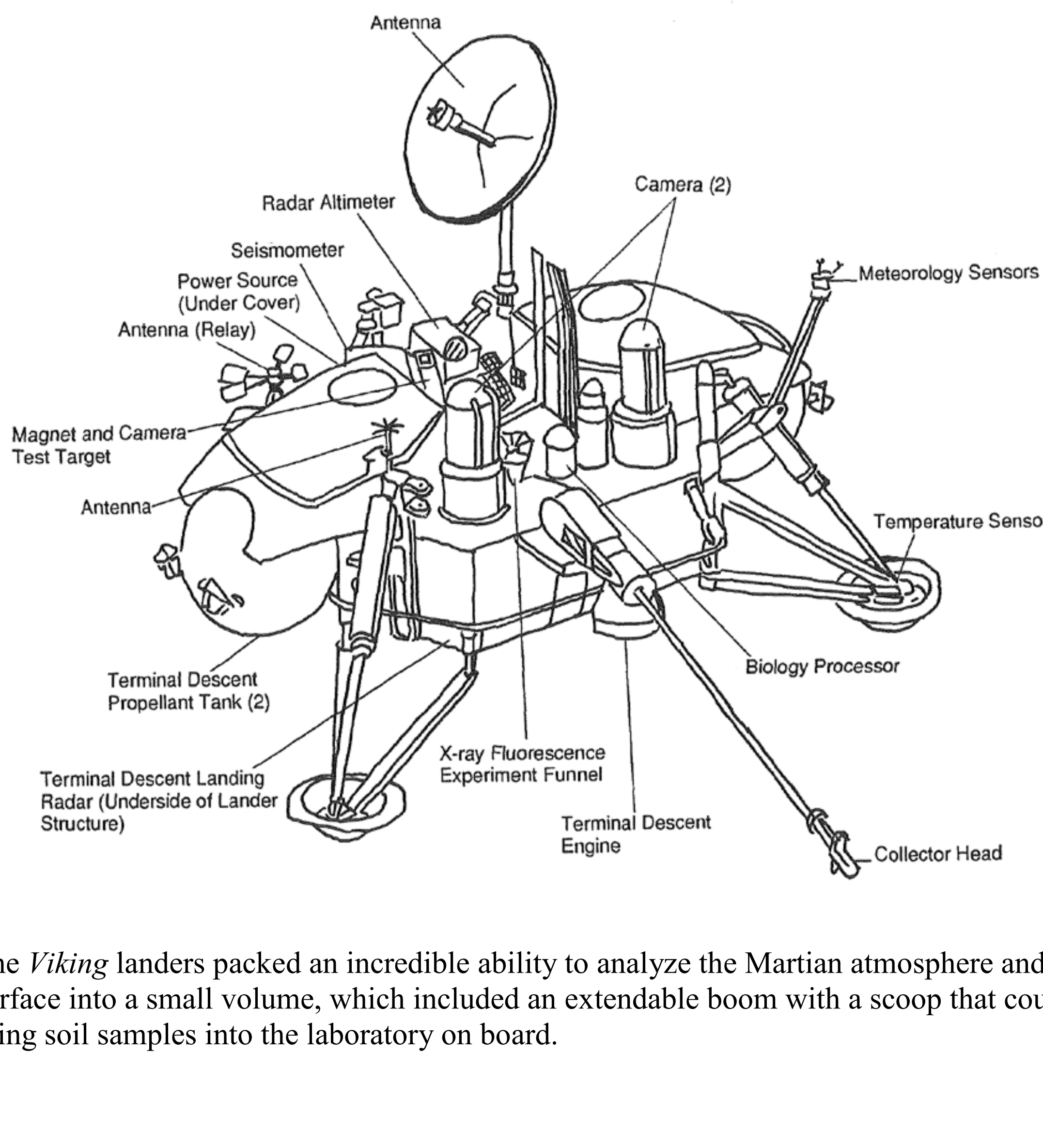
Make a simple drawing of your design. A good drawing is nice, but labeling and describing the function of all the parts is more important. Include everything you would need for a successful mission. In real missions, payload and overall cost are major considerations, but at this point you can create a plan unhindered by such constraints. Your final spaceship design (in mission 14) will include these factors.

Mission 5
Initial Spacecraft and Lander Design

Tools of Comparative Planetology and Exobiology

The Viking Lander—Image

Figure 5.1—*Viking* Lander.



The *Viking* landers packed an incredible ability to analyze the Martian atmosphere and surface into a small volume, which included an extendable boom with a scoop that could bring soil samples into the laboratory on board.

Mission 5 Logbook
Initial Spacecraft and Lander Design
Tools of Comparative Planetology and Exobiology

SETI INSTITUTE

Initial Spacecraft Design - Worksheet

Name: ______________________________ Date: ____________________________

Assigned Landing Site:

1. List the design considerations specific to your assigned landing site. What would your spacecraft need to arrive safely? What would your lander need to function?

2. Brainstorm on major spacecraft and lander components. Draw the design for your spacecraft and lander on another sheet of paper, labeling all components. Describe how the following components work.

   - Propulsion system:
   - Fuel or energy source:
   - Landing gear:
   - Mission control instruments:
   - Communication devices:
   - Data collection devices:
   - Life detection devices:
   - Other devices or capabilities your spacecraft or lander has:

3. Provide a sample of the data your spacecraft would send back.

4. Provide a sample of the data your lander would send back.

5. How will this information help you to decide if life is present at the landing site?

Initial Spacecraft and Lander Design

Tools of Comparative Planetology and Exobiology

SETI INSTITUTE

Landing Site Environment—Data Sheets

Landing Site # I--- Mars, Utopia Planitia Desert

Planet Size: Mars is 52% the size of Earth.
Coordinates: 84 North Latitude, 250º longitude.
Gravity: .38 G (Earth gravities).
Temperature: -58 C.
Atmospheric Pressure: .006 ATM (Earth atmospheres).
Topology: Flat, open area with gentle slopes. Surface strewn with rocks 10-20 centimeters in diameter. A few larger boulders here and there.
Soil Composition: 21% Silicon, 13% Iron, 3% Aluminum, 5% Magnesium, 4% Calcium, 3% Sulfur. The soil is soft. Great wind storms kick up dust that poses a hazard to a lander.
Atmospheric Composition: 95% carbon dioxide; 2% nitrogen; 1.5% argon; 0.1% oxygen; trace amounts of water vapor, carbon monoxide, neon, krypton, and xenon.

Landing Site # *2*- Mars, Olympus Mons Volcano

Planet Size: Mars is 52% the size of Earth.
Coordinates: 18º North Latitude, 133º Longitude.
Gravity: .38 G (Earth gravities).
Temperature: Thin atmosphere due to the great altitude allows for temperatures ranges on Mars from -92º C to 26º C.
Atmospheric Pressure: .006 ATM (Earth atmospheres).
Topology: On the edge, very fine dirt and not many boulders. A sheer cliff skirts the mountain, but this should not present a problem to the landing site because it is well marked on maps of Mars.
Soil Composition: Igneous, crusted, basaltic lava rich in magnesium and iron.
Atmospheric Composition: 95% carbon dioxide; 2% nitrogen; 1.5% argon; 0.1% oxygen; trace amounts of water vapor, carbon monoxide, neon, krypton, and xenon.

Landing Site # 3- Mars, Northern Pole

Planet Size: Mars is 52% the size of Earth.
Coordinates: 90º North Latitude, 0º Longitude.

Gravity: .38 G (Earth gravities).
Temperature: -67º C.
Atmospheric Pressure: .006 ATM (Earth atmospheres).
Topology: Like the surface of dry ice.
Soil Composition: Frozen carbon dioxide, with possible frozen water underneath. Some soil is mixed in the patches of carbon dioxide.
Atmospheric Composition: 95% carbon dioxide; 2% nitrogen; 1.5% argon; 0.1% oxygen; trace amounts of water vapor, carbon monoxide, neon, krypton, and xenon.

Landing Site # 4-Venus, Aphrodite Terra Continental Plate

Planet Size: Venus is 95% the size of Earth.
Coordinates: 0 Latitude, 90º Longitude.
Gravity: .91 G (Earth gravities).
Temperature: 460º C.
Atmospheric Pressure: 90 ATM (Earth atmospheres).
Atmospheric Composition: 96% carbon dioxide; 4% nitrogen; trace amounts of oxygen, water vapor, and argon.
Topology: Unknown.
Soil Composition: Unknown.

Landing Site # 5--- Atmosphere of Venus

Planet Size: Venus is 95% the size of Earth.
Coordinates: An orbit 30,000 feet above the surface.
Gravity: .91 G (Earth gravities).
Temperature: 460º C.
Atmospheric Pressure: 90 ATM (Earth atmospheres).
Atmospheric Composition: 96% carbon dioxide; 4% nitrogen; trace amounts of oxygen, water vapor, and argon.
Topology: Does not apply.
Soil Composition: Does not apply.

Landing Site # 6----Venus, Rhea Mons Volcano

Planet Size: Venus is 95% the size of Earth.
Coordinates: 30º North Latitude, 285º Longitude.
Gravity: .91 G (Earth gravities).
Temperature: 460º C.
Atmospheric Pressure: 90 ATM (Earth atmospheres).
Atmospheric Composition: 96% carbon dioxide; 4% nitrogen; trace amounts of oxygen,
water vapor, and argon.
Topology: Unknown.
Soil Composition: Unknown.

Initial Spacecraft and Lander Design

Tools of Comparative Planetology and Exobiology

SETI INSTITUTE

Design Conference—Worksheet

Name: ________________________________ Date: ___________________________

Assigned Landing Site:

1. Your team is composed of all students who share your assigned landing site. Observe the design of each team member's spacecraft-lander system. What are its unique and outstanding qualities? How is it designed for the specific conditions at your landing site?

Designer's Name   Unique and Outstanding Qualities of the Spacecraft-Lander

2. As a team, design a spacecraft and lander for the conditions at your landing site, using the best aspects of each design. Draw your design for this spacecraft-lander system on another sheet of paper, labeling all components.

3. Describe how the following components work.
   - Propulsion system:
   - Fuel or energy source:
   - Landing gear:
   - Mission control instruments:
   - Communication devices:
   - Data collection devices:
   - Life detection devices:

4. Provide a sample of the data your spacecraft would send back.

5. Provide a sample of the data your lander would send back.

6. How will this information help you to decide if life is present at the landing site?

7. After you have observed the spacecraft-lander designs of other teams, describe the differences in lander design that were necessary for the different landing sites.

Site # 1: Mars, Utopia Planitia Desert

Site # 2: Mars, Olympus Mons Volcano

Site # 3: Mars, North Pole

Site # 4: Venus, AphroditeTerra Continental Plate

Site # 5: Atmosphere of Venus

Site # 6: Venus, Rhea Mons Volcano

Mission 6
Venus Plates and Phase Mars Jars!

Did Earth Life Survive Conditions on Venus or Mars?

Overview

In mission 6.1, students culture *Penicillium notatum* in seeded soil from their Mars Jars, from seeded soil that has been heated to simulate the conditions on Venus, and from seeded soil that was left under cool (refrigerated) Earth conditions. In mission 6.2, students use their records of normal *Penicillium notatum* growth on Earth from mission 3 to analyze their results, and to see if it survived the simulated conditions of Mars and Venus.

Notes

In mission 5, students designed spacecrafi that could take them to Mars or Venus. If they took the Earth microorganism Penicillium notatum to Mars or Venus, would it survive there? Previously, students exposedPenicillium notatum to simulated conditions of Mars. Its survival would provide evidence that at least one form of Earth life could exist on Mars. Penicillium notatum's failure to survive would provide evidence that even a life-form that is highly adapted for survival in harsh conditions on Earth would find the conditions on Mars or Venus unsuitable.

Mission 6.1
Materials

For a Class of 30

- Mars Jars from mission 3
- Seeded soil from mission 3
- Sterile baking pan
- Sterile cookie sheet
- Oven space for an hour
- 400 ml of Sterigel Instant Medium (for an alternative recipe, see Making Your Own Medium, in appendix)
- Sterile sealable container

For Each Team

- Masking tape
- 3 sterile 60-by-15 mm Petri dishes (see Sterile Dishes, in appendix)

- 2 sterile soil-sample carrying dishes
- 3 stick-on labels or a grease pen
- Spatula
- 3 alcohol swabs
- Culturing *Penicillium notatum* on Mars and Venus directions.

Getting Ready

1. Remove the Mars Jars from the freezer. Allow them to warm to room temperature before using them in class.

2. Bake half the seeded soil left over from mission 3 in a baking pan at 400 F for an hour or more. Remove the pan from the oven, cover it with a sterile cookie sheet and allow it to cool to room temperature. This is the soil for making Venus Plates. Put the soil in a sterile sealable container when transporting it to class. If feasible, have students take home portions of seeded soil to bake in their own ovens (but keep a back-up supply).

3. If you are sterilizing your own Petri dishes (instead of buying sterilized Petri dishes, which require no preparation), do so the day before class. Follow the instructions in the appendix (see Sterile Dishes, in appendix).

4. If you are preparing your own medium (instead do so the day before class. Follow the instructions in the appendix (see Making Your Own Medium, in appendix).

5. Copy the Culturing *Penicillium notatum* on Mars and Venus directions for each team.

Classroom Action

1. Discussion.

   Mars-Present the Mars Jars (Erlenmeyer flasks) to the class. Ask students if they think there is still a low pressure (partial vacuum) in the jars. How could they find out? What would they expect to see if they released the clamp leading to the balloon? *(Air should rush in and fill the balloon.)*

   Show students that air rushes back in to fill the partial vacuum, which means that the simulated Martian conditions have been maintained. Ask students how we could know whether or not the *Penicillium notatum* survived these simulated Martian conditions. *(We can try to culture it on Petri dishes.)*

   Venus-Present the seeded soil for the Venus Plates and tell students that you have used the same soil seeded with *Penicillium notatum* that was used for the Mars Jars, and that you have baked it in the oven at 400 F for one hour or more, simulating the high temperature on Venus. Tell students that it would have been impractical to bake this sample for the same time that the Mars Jars were kept cold. However, if the *Penicillium notatum* cannot survive for one hour or more at this temperature, then it certainly cannot survive on Venus! Tell students that it would have been impractical to create the high pressure on Venus. But again, if the *Penicillium notatum* cannot survive the high temperature, then it certainly cannot survive both the temperature and the pressure on Venus. Ask students if they think the *Penicillium notatum* has survived these simulated Venusian conditions.

Earth-Present the rest of the original seeded soil from mission 3 to the class. Remind students that living *Penicillium notatum* was present in this soil in mission 3. Ask them if it could have survived in cool Earth conditions since mission 3's lab. Tell them that they will need to culture the Earth seeded soil again as a control. If *Penicillium notatum* has not survived this long under Earth conditions, it certainly would not survive the conditions on Mars or Venus.

2. **Activity**. Divide the class into their teams from Mission 3. Hand out the Culturing *Penicillium notatum* on Mars and Venus directions to each team. Each team should now make three Petri dishes (or be given pre-made Petri dishes). Students should wash their hands and their work areas with soap and water. Give the team their sterile Petri dishes and six pieces of masking tape. Have students tape shut their Petri dishes without opening them; this makes a hinge on one side of each dish and a re-breakable seal on the other.

   Teacher's Note: *To reduce the number of Petri dishes and media used, consider making class controls- two or three dishes with Earth's seeded soil.*

   While students are taping their Petri dishes, prepare the Sterigel at a central area in the classroom: Close any windows to prevent drafts. Open an alcohol swab and place it on the table. Open the two jars in the Sterigel kit. Place their lids on the alcohol swab. Pour the Sterigel liquid into the bottle of Sterigel powder and shake the bottle for 30 seconds. Sterigel must be used quickly after it is made; it cannot be melted for later use.

   Each team should now obtain nutrient sterile Petri dishes by bringing them to the Sterigel Area. Make sure –students remove only one piece of tape from each. The teacher should pour the Sterigel, enough to halfway cover the bottom of each Petri dish. Students should then quickly close and retape their dishes, swirling them gently to evenly distribute the Sterigel. Work quickly and swirl the Sterigel bottle frequently to keep the nutrient suspension even. The Sterigel in the Petri dishes will set quickly, and students can add soil samples to their dishes within a few minutes.

   Teacher's Note: *The following instructions assume the use of Sterigel Instant Medium. If you have prepared your own medium, refer to the appendix at this point.*

   Students should obtain and plate out the seeded soils from Mars, Venus, and Earth. Review and demonstrate the plating techniques if necessary.

   Ask students to label their Petri dishes with their names and Venus, Earth, or Mars. Store at room temperature until mission 6.2.

Mission 6.2
Materials

For Each Student

- Growth of *Penicillium notatum* After Alien Conditions worksheet
- Did *Penicillium notatum* Survive? worksheet
- Pencil

Getting Ready

1. Copy the worksheets Growth of *Penicillium notatum* After Alien Conditions and Did *Penicillium notatum* Survive? for each student.

Classroom Action

1. **Activity**. Reassemble the class into mission 6.1's teams. Hand out the Growth of *Penicillium notatum* After Alien Conditions worksheet to each student. (Note that this worksheet has no teacher's key because student responses will vary; accept all reasonable attempts.) Return to students their Growth of *Penicillium notatum* worksheets from mission 3**.** Over the next few days, have students check their Petri dishes for growth of *Penicillium notatum.* Observations should be made at the same time intervals as the original observations in mission 3. Have students compare these new results with their previously recorded observations of *Penicillium notatum* growth and form their own conclusions.

2. **Discussion**. It is a good idea to have each team share their results and then pool the class data. Two problems may have arisen: 1) growth might have failed to occur where it should have occurred, and 2) growth might have occurred where it should not have occurred. In the first case, the random sample that was plated out might have failed to contain viable spores, even though spores were present in the seeded soil. In the second case, Petri dishes might have become contaminated with other species of microbes. Encourage students to make sure each new growth they see is *Penicillium notatum.*

The following results are expected:

Earth-Normal *Penicillium notatum* growth

Mars-Normal *Penicillium notatum* growth

Venus-No *Penicillium notatum* growth

Ask students if the results mean that there is life on Mars but not on Venus. *(This does not tell us whether or not there is life on Mars, but only that some forms of Earth Life could survive briefly under the low pressure and low temperature conditions on Mars.)*

Discuss the fact that there are other Martian characteristics that could prevent life from developing, including soil chemistry, reduced oxygen, high ultraviolet radiation due to the thin atmosphere, and desiccation due to low pressure. Each of these might affect life on Mars. Various tests simulating these conditions could be performed in a lab.

Present a wrap-up and reinforcement of the control idea and the fact that Earth conditions have not affected the *Penicillium notatum*. The simulated conditions of Mars and Venus are the variables. Discuss what this means for the possibility of life existing on Mars and on Venus.

3. **Activity.** Hand out the Did *Penicillium notatum* Survive? worksheet to students and have them answer the questions in class or as homework.

4. **Disposal.** After all observations of the Petri dishes have been made, the cultures need to be disposed of. A teacher should dispose of the cultures because they may contain harmful, even pathogenic, microbes. Your school may require certain disposal procedures. Disposal bags can be ordered from any biological supply catalog. Ideally, the cultures should be sterilized (autoclaved or micro-waved) before disposal. If micro-waved, heat on high for several minutes and watch for boiling. Avoid touching or inhaling spores from the microbial colonies; you may wish to wear a dust mask.

   You may be able to reuse the Petri dishes if they are sturdy enough to be autoclaved or otherwise sterilized.

Going Further

Activity: Longer Exposure

If there is time, have the class leave one or more Mars Jars in the freezer for longer periods as a simulation to see how long *Penicillium notatum* could survive the conditions found on Mars. Ask students to make another set of Mars Jars and freeze them, thawing out one or two every month and making cultures.

Activity: Is *Penicillium Notatum* Unique?

Ask students about *Penicillium notaturn's* ability to survive harsh conditions. Is it the only microbe that could survive conditions on Mars? Is it the only microbe that could not survive conditions on Venus? Have students repeat the procedures that they used in this mission using different microbes. Many kinds of microbes may be ordered from Carolina Biological Supply Company (see Ordering Information, in appendix).

Research: Life on Other Planets

Have students research the conditions on Mercury, Saturn, or any other planet. Ask student why the search for life has been narrowed to Mars and Venus. Have we skipped even better candidates for life-bearing planets or moons? Could we devise experiments that would simulate the conditions on Mercury, Saturn, or any other planet or moon?

Research: Life on Antarctica's Ice

Exobiologists are at work in Antarctica, investigating microbes that live in this frozen, rainless desert that is so like Mars. There are microbes that live in the rocks. Have students research the kinds of microbes. Is there higher life as well? How do we detect these microbes? How do the conditions where they live compare with conditions on Mars? There are also microbes living in freshwater lakes in Antarctica that are always covered with as much as 18 feet of ice. How do they survive? Where did they come from? Are there microbes living in permafrost? Could these microbes survive in the frost on Mars?

Venus Plates and Mars Jars! (Phase II)

Did Earth Life Survive Conditions on Venus or Mars?

Culturing *Penicillium notatum* on Mars and Venus—Directions

You have seen how *Penicillium notatum* grows on Earth, and now that it has been exposed to the simulated environments of Mars and Venus, you can see if it has survived in those harsh environments.

Today, you will prepare three Petri dishes with a food supply for microbes-a nutrient gelatin medium. You will use seeded soil (containing *Penicillium notatum*) from Earth (to serve as a control), from Mars, and from Venus. You will culture the Mars and Venus seeded soils, which still contain *Penicillium notatum*, though it is your task to determine whether it is still alive or now dead. You will observe all three dishes for a few days, and record any growth of *Penicillium notatum.*

Procedure

1. Wash your hands and your work areas with soap and water.

2. Obtain three sterile Petri dishes and six pieces of masking tape. Tape shut your Petri dishes without opening them; this makes a hinge on one side of each dish and a rebreakable seal on the other. Write your names on all three dishes. Write Earth on one dish, Mars on the second, and Venus on the third.

3. Take your Petri dishes to the central area of the classroom where the nutrient gelatin medium is being prepared. Remove one piece of tape from each dish. Your teacher will

pour the nutrient medium into your Petri dishes. You must work quickly to close and re tape them. Gently swirl the dishes to evenly distribute the gelatin.

4. Obtain seeded soil from Earth, Mars, and Venus using three sterile carrying dishes.

5. Be careful when adding the seeded soil containing Penicillium notaturn to your Petri dishes. Do not inhale close to the seeded soil. Some people have an allergic reaction to this organism. If you are allergic to penicillin, let your partner handle the seeded soil while you handle the pure soil.

6. Sterilize a spatula with an alcohol swab. Sterilize the spatula before each use.

7. Plate out a sample of the seeded soil from Earth onto the nutrient gelatin of one Petri dish by using the sterilized spatula to lightly sprinkle about 114 teaspoon of the soil over the surface of the cooled, set gelatin.

8. Plate out a sample of the seeded soil from Venus onto the nutrient gelatin of the second Petri dish, using the same procedure.

9. Plate out a sample of the seeded soil from Mars onto the nutrient gelatin of the third Petri dish, using the same procedure.

10. Draw an arrow on each Petri dish. Use the arrow to orient your dishes the same way each time you look at them; this way you can identify colonies and chart their progress as they grow bigger. Store your Petri dishes. You will be observing them over the next several days. Your dishes should be left at room temperature.

Venus Plates and Mars Jars! (Phase II)
Did Earth Life Survive Conditions on Venus or Mars?

Did *Penicillium notatum* Survive?—Teacher's Key

1. Earth conditions allowed the *Penicillium notatum* to survive and grow normally. This is known because the growth appears the same as it did in the Earth cultures in mission 3**.**

2. The simulated conditions of Mars do not seem to have affected the *Penicillium notaturn's* growth patterns! (They survived the cold and the low pressure! Maybe they could even live on Mars!) This is known because the growth appears the same as i t did in the Earth cultures in mission 3**.**

3**.** Earth organisms (at least this microbe!) can survive in the conditions on Mars for a short period of time, but we really don't know if they could survive these conditions for one year or five years or longer.

4. Venusian conditions have severely affected the *Penicillium notatum's* growth patterns; there is no growth.

5. Apparently, *Penicillium notatum* cannot survive in conditions on Venus. They all died in just an hour in the heat of an Earth oven. In all probability, there are no Earth organisms that could survive Venusian conditions.

6. This experiment is significant in our search for life on Mars and Venus because it shows that Mars could support life as we know it. This does not prove that there is any life on Mars. We can also see that Venus is not as hospitable an environment as Mars is-at least for one kind of Earth microbe!

7. Yes, we should be careful. We might introduce an Earth microbe into an environment in which it might grow wild and destroy any native life. Or a microbe could later fool investigators into thinking that it was a species of life that had always lived on Mars.

Mission 6 Logbook
Venus Plates and Phase II Mars Jars!

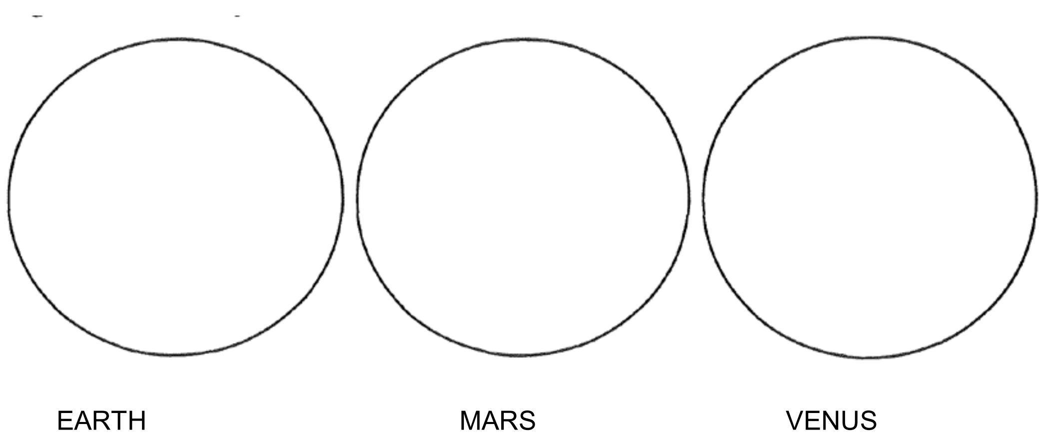
Did Earth Life Survive Conditions on Venus or Mars?

Growth of Penicillium notatatum After Alien Conditions-Worksheet

Name: ______________________________ Date: __________________________

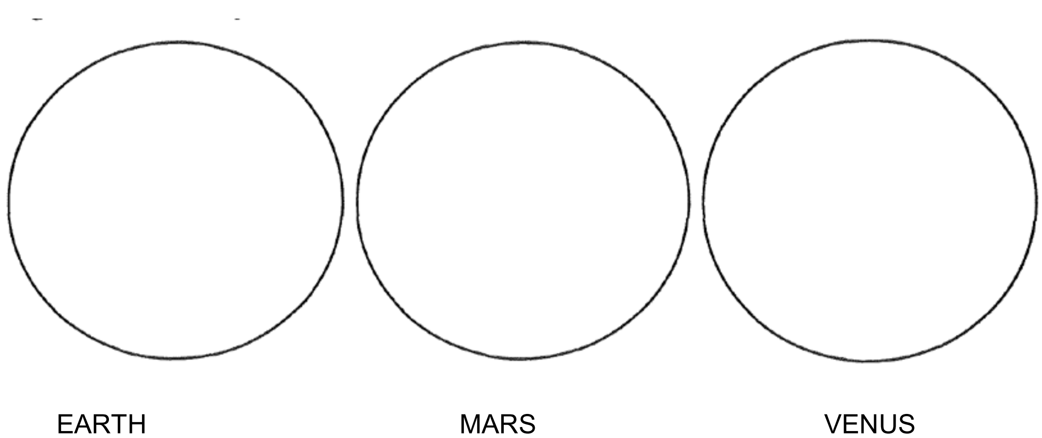
1. First map of *Penicillium notatum* growth. Date of observations:

Figure 6.1-First Map.



2. Second map of *Penicillium notatum* growth. Date of observations:

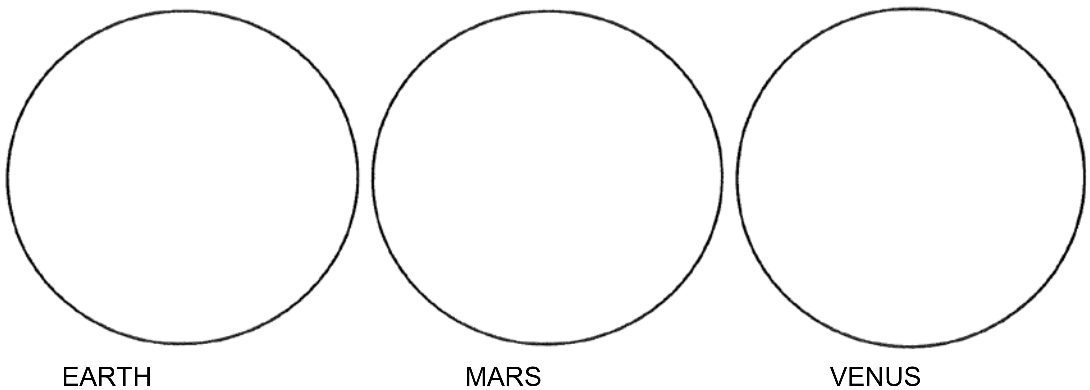
Figure 6.2-Second Map.



3. How does the early growth of *Penicillium notatum* compare to the early growth that you saw in your original experiment? How do you know that any organisms you see are *Penicillium notatum*?

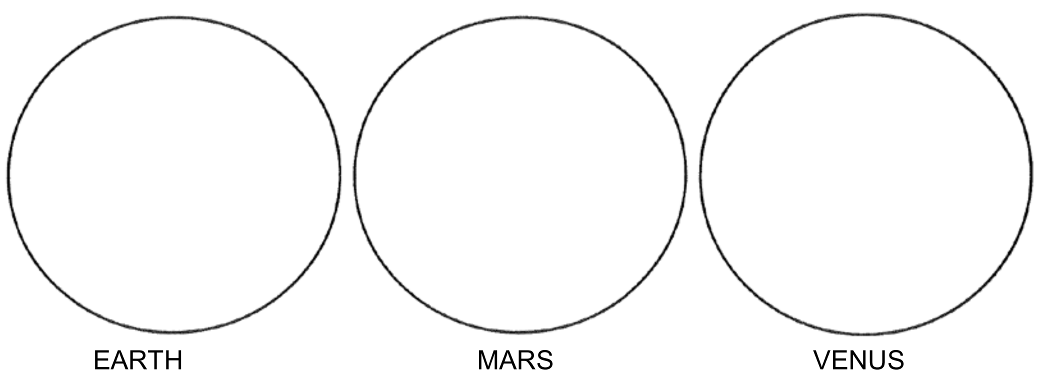
4. Third map of *Penicillium notatum* growth. Date of observations:

Figure 6.3-Third Map.



5. Fourth map of *Penicillium notatum* growth. Date of observations:

Figure 6.4-Fourth Map.



6. How does the later growth of *Penicilliurn notatum* compare to the later growth that you saw in your original experiment?

Mission 6 Logbook
Venus Plates and Mars Jar! (PhaseII)

Did Earth Life Survive Conditions on Venus or Mars?

Did *Penicillium notatum* Survive?-Worksheet

Name: _______________________________ Date: __________________________

1. Have Earth conditions allowed the *Penicillium notatum* to survive and grow normally? How can you tell?

2. Have the simulated conditions of Mars affected the *Penicillium notatum's* growth patterns? How can you tell?

3. Can Earth organisms survive in the conditions on Mars? Are you sure? What if the Mars Jars had been left alone for one month? One year? Five years? Longer?

4. Have the simulated conditions of Venus affected the *Penicillium notatum's* growth patterns? How can you tell?

5. Can Earth organisms survive in the conditions on Venus? Why or why not?

6. What does this experiment teach us about our search for life on Mars and Venus?

7. If Earth microbes might survive on Mars or Venus, should we be careful not to introduce any Earth microbes into their environments? Why?

Mission 7
Water!

How Can We Recognize Water?

Overview

In mission 7.1, students play the role of comparative planetologists who have received clear, colorless liquid samples from their robot spacecraft. Students test these unknown liquids and identify which one is water by its freezing point.

Notes

In mission 6, students saw that life requires suitable environmental conditions. But certain chemicals, such as water, are also essential to life as we know it. Every cell contains water, the solvent in which our other essential chemicals of life are dissolved. It runs through the circulatory system of complex animals, carrying dissolved nutrients and wastes. Would wafer be as important to life on other planets? Exobiologists think so. There is no other liquid we know of that can dissolve so many things and can carry out so many of the chemical reactions that are vital to life's functions.

Mission 7.1
Materials

For a Class of 30

- 3-4 pounds of dry ice
- rubbing alcohol (2 pints total)
- Water (2 pints total)
- Peroxide (2 pints total)
- Paper towels
- Stick-on labels or grease pens
- Clear glass containers (or beakers)
- Overhead projector
- “Ice Bath” transparency
- (optional) additional clear colorless liquids (e.g., white vinegar, ammonia, glycerin)

For Each Team

- Beaker
- 3 test tubes
- Thermometer

- Tongs, scoops, or work gloves (for handling dry ice)
- “Making an Ice Bath!” directions

For Each Student

- “Mystery Liquids” worksheet
- Pencil

Getting Ready

1. Copy the “Making an Ice Bath!” directions for each team and the “Mystery Liquids” worksheet for each student.

2. Prepare the “Ice Bath” transparency. Set up the overhead projector.

3. Put the peroxide, water, and any other clear colorless liquids (all should be nontoxic; avoid strong bases and acids) into clear glass containers, labeled “Mystery Liquid # 1,” “Mystery Liquid # 2,” and so forth. (To especially test students, fill two containers with water.) Be sure to make a key identifying the samples.

4. Set up a central work station where students can get the “Mystery Liquid” samples and other materials, including dry ice and alcohol. Provide an area with water and paper towels where students can wash and clean their equipment.

5. Just before class, break up the dry ice into small pieces. If dry ice is not available, put the alcohol in a freezer to chill it as much as possible. Just before class, add ice cubes to the chilled alcohol. This ice bath will work, but it will take longer than an ice bath made with dry ice.

Classroom Action

1. **Discussion.** Discuss the importance of water to the existence of life as we know it. Point out that blood is mostly water; our bodies are mostly water. A search for life on Mars or Venus might include a search for water. But could we recognize water on another planet? Introduce the idea that not all clear, colorless fluids that look like water are water. It requires more than visual data to decide whether or not a colorless fluid is water.

2. **Optional Demonstration.** Pass around a test tube containing vinegar to demonstrate that some fluids that look like water do not smell (or taste) like water. Note that it is not a good idea to taste, or even smell, unknown liquids. If necessary bring students around to this idea with ammonia!

3. **Discussion.** Ask students how a spacecraft could recognize water on another planet. Water is a clear liquid in most Earth climates, a white solid in cold Earth climates (remember the snow in the winter), and an invisible (sometimes visible) gas in Earth's atmosphere. If a

spacecraft or lander found a clear liquid or white solid or invisible gas on another planet, how would we know it to be water or ice or water vapor, and not alcohol or peroxide or frozen carbon dioxide (dry ice) or carbon dioxide gas? It could not be tasted or smelled. If students did the optional dry ice activity in mission 3, recall how the dry ice turned into a gas without first melting into a liquid. Water on Mars behaves the same way as dry ice does here on Earth, evaporating directly from a solid.

Tell students that they will be considering liquid water. If we were on another planet, a white solid (ice) could be melted before testing and a vapor (gas) could be condensed before testing. Although clear colorless liquids might look identical, they have different molecular structures, and that gives them different physical properties. For instance, they each have characteristic freezing and boiling points. Water freezes at 0^0 C, and boils at 100^0 C.

4. **Activity.** Hand out the "Making an Ice Bath!" directions to each team and the "Mystery Liquids" worksheet to each student. Have each team test samples of three (or more) Mystery Liquids. They should make sure that each one is labeled with the proper number, such as "Mystery Liquid #1," so they can verify their results.

5. **Transparency.** Show the "Ice Bath" transparency to explain the experimental setup.

6. **Activity.** Divide the class into teams. Students should follow their directions. They start out by making an ice bath. They fill their beakers one-third full of alcohol and use tongs, a scoop, or gloves to add small pieces of dry ice until the bath is near -10^0 C. Caution them not to handle dry ice with their bare hands-dry ice can burn exposed skin!

   Students should then put one test tube (or all of their test tubes) into the ice bath and monitor the temperature of the liquid inside to find the one that freezes at 0^0 C. They should rinse and wipe the thermometer each time so as not to contaminate the samples and depress the freezing points. They will see that some liquids stay liquid below 0^0 C. This activity will take time. Emphasize that waiting and observing are what "real science" often requires! Students will also need to monitor the temperature of the bath throughout their investigation to make sure that it remains at about -10^0 C. (optional) If extra thermometers are available, students can leave one thermometer in the ice bath and use the other one in the samples.

7. **Discussion.** After everyone is finished, have students state their hypotheses about their Mystery Liquids. Then reveal which of the "Mystery Liquids" was water. How many students correctly identified them? Reveal to students the identities of the other liquids.

   Pose a question to students: How could a spacecraft and lander be designed to perform the same experiment that you just did? Would this experiment be useful as a remotely controlled part of a life detection device on another world? Make sure students understand the difference between imagination and design: some things that people can do are fairly difficult for a machine, even a robot, to do.

Going Further

Activity: You've Reached My Boiling Point!

Checking the boiling point is another good way to test for water. Tell students that water boils at 100^0 C. If you have the equipment and feel that it can be done safely, have teams heat the Mystery Liquid samples to determine which one boils at 100^0 C. A hot-water bath allows for a more even heating of the samples. You would need to saturate the hot water with salt to elevate its boiling point above 100^0 C so the water samples boil before the water bath (this would obscure the view).

Research: Water on Mars and Venus?

Ask students to research water on Mars and Venus. What are the clouds of Mars composed of? The clouds of Venus? What kind of "ice" are the polar caps of Mars made of? Would they melt? What forms the "frost" that is seen on the surface of Mars? Does Venus have polar caps? Are there geologic features which suggest that Mars or Venus once had liquid water?

Water!
How Can We Recognize Water?

Mystery Liquids-Teacher 's Key

1. All the Mystery Liquid samples are clear (colorless) fluids at room temperature. No, you cannot tell just by looking which samples, if any, are actually water. Some samples may have odors that would lead you to believe that they are not water. Students' tables will vary, depending upon the liquids that were chosen. See Table 7.1 on page 140.

Table 7.1-Teacher's Key**.**

"Mystery Liquid" Sample Number	Original Appearance of the "Mystery Liquid"	Temperature at which the "Mystery Liquid" Freezes
Number will vary Water	Clear, colorless liquid	0 degrees C.
Number will vary Saltwater	Clear, colorless liquid	-20.5 degrees C
Number will vary Peroxide	Clear, colorless liquid	-1.7 degrees C
Number will vary Ammonia	Clear, colorless liquid	-1.1 degrees C
Number will vary White Vinegar	Clear, colorless liquid	-1.6 degrees C
Number will vary Alcohol	Clear, colorless liquid	-89.5 degrees C
Number will vary Glycerin	Clear, colorless liquid	+17.8 degrees C

2. Any liquid with a freezing point below that of water will still be liquid at this point. Yes, any of these would freeze at a lower temperature, at their own freezing points.

3. 0 Degree Celsius

4. Yes. Any liquid that froze at 0 C is assumed to be water.

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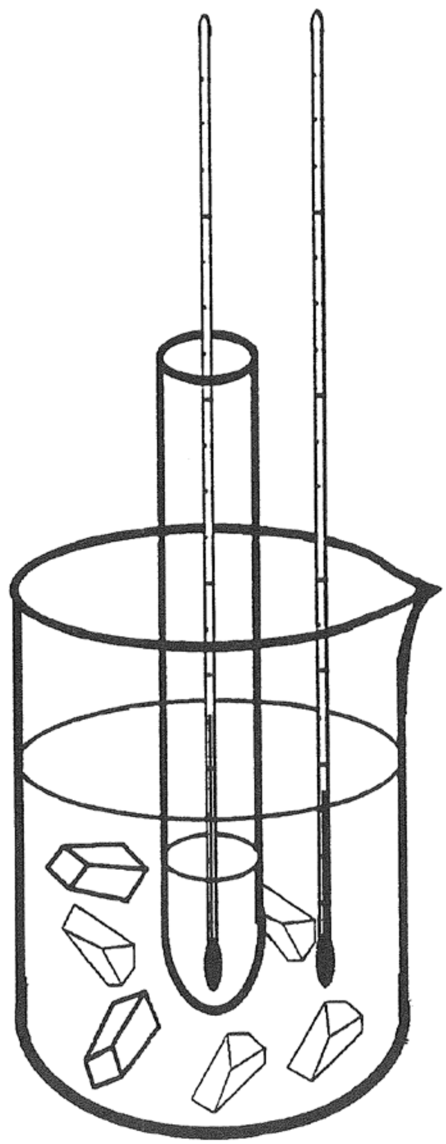
Mission 7 Logbook
Water !

How Can We Recognize Water?

Ice Bath - Image

Figure 7.1—Ice Bath



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Water!
How Can We Recognize Water?

Making an Ice Bath!-Directions

1. You will make an ice bath to attempt to freeze various Mystery Liquid samples.

2. Obtain a beaker (or another clear glass container), a thermometer, and two or more test tubes.

3. Take your beaker to the work station and fill it one-third full of alcohol.

4. Use tongs, a scoop, or gloves to add two or three small pieces of dry ice to the alcohol. Do not handle the dry ice with your bare hands; it will burn you.

5. Measure the temperature of your ice bath. It should be near -10^0 C. If it is not, use tongs, a scoop, or gloves to add more dry ice. Do not stick your fingers into the ice bath!

6. Be sure to rinse the thermometer with water and wipe it each time you use it so that you do not contaminate any samples or the ice bath itself.

7. Take a test tube up to the work station and fill it one-third full with any one of the Mystery Liquid samples. Keep track of each sample's number.

8. Put the clean thermometer into the Mystery Liquid and then put the test tube into the ice bath. Make sure that the Mystery Liquid is below the level of the alcohol. Monitor its temperature as it drops.

9. Record the temperature at which each Mystery Liquid freezes. If a Mystery Liquid is still liquid at -10^o C, which is the coldest this ice bath can be, record "still liquid at -10º C."

10. You will need to monitor the temperature of the bath throughout the investigation to make sure it remains at about -10º C. Clean the thermometer and check the temperature of the ice bath. If the temperature rises, add more dry ice.

11. Test the other available Mystery Liquids, one at a time. Always use clean, rinsed test tubes to get new samples.

12. After each sample either freezes or reaches -10^o C without freezing, set that test tube aside to let it warm up to room temperature. If your teacher permits it, return the re-warmed Mystery Liquids to their proper containers at the work station. Keep track of each sample's number. If so instructed, dispose of the Mystery Liquid samples in another way.

13. When you are finished, make sure that all your equipment is rinsed, wiped dry, and returned to your teacher.

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Water!
How Can We Recognize Water?

Mystery Liquids—Worksheet

Name: ________________________________ Date: _______________________

1. Describe the appearance of each Mystery Liquid sample before you put it into the ice bath. Can you tell by sight if any of your Mystery Liquids are water?

Table 7.2.

"Mystery Liquid" Sample Number	Original Appearance of the "Mystery Liquid"	Temperature at which the "Mystery Liquid" Freezes

2. Which Mystery Liquid samples did not freeze at the lowest temperature the ice cold bath could produce? Do you think they would freeze at lower temperatures?

3. What is the freezing point of water?

4. Is any of your Mystery Liquid samples water? If so, which one? Why do you think so?

Mission 8
What is Life?

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What Can We Observe to Test for Life?

Overview

In mission 8, students confront the difficulty of distinguishing living organisms from nonliving objects. In mission 8.1, students play a game called Five Alive! to explore their ideas about the characteristics of living organisms. Students create a list, of such characteristics. Students begin to appreciate some of the ambiguities associated with identifying living and nonliving matter and processes. This will provide valuable background material for future missions in which students will acquire the information necessary to finalize the designs of their spacecraft-lander systems from mission 5, which will be built to test for life on other planets.

Notes

In mission 7, students identified water, a chemical that is vital for life. But exactly what is "life"? Before it is possible to test for the presence of extraterrestrial life, it is vital to know what constitutes life on Earth. Although this might seem simple at first thought, it is in fact extremely complex. There is no single property that characterizes all living things and only living things. There is no one exact definition of life, or one single test that can determine the presence or absence of life. Instead, there are many *characteristics that most living things share.*

Mission 8.1
Materials

For a Class of 30

- Butcher paper
- Plastic plant and a living plant of similar appearance

For Each Student

- "Characteristics of Life" worksheet
- Pencil

Getting Ready

1. Set up the classroom to accommodate large- and small-group discussion. Post butcher paper or ready another means to collect student responses (or use the chalkboard).

2. Copy the “Characteristics of Life” worksheet for each student.

Classroom Action

1. **Preliminary.** Because students will be searching for life on other worlds, tell them that they will first need to examine what it means to be living by playing the game Five Alive! Explain that you will use the term *object* to refer to a nonliving thing and the term organism to refer to a living thing.

   Explain to the class that Five Alive! Is similar to Twenty Questions, except that participants can only ask five questions. Each team will think of an object (nonliving) or an organism (living); the teacher or the rest of the class will try to determine whether this thing is living or nonliving from the team's answers to five yes-or-no questions. Explain that the questioner cannot ask “Is it alive?” or similar direct questions; instead, the questioner can only ask questions about what it does or doesn't do (behavior), about what it takes in or produces (function), and about its appearance (structure).

   Caution students to word their questions carefully. Carelessly asked questions about the objects can be truthfully answered in ways that are misleading about whether the objects are alive or not. For example, a cloud: “Does it move?” Yes. But a cloud is not, however, self-propelled, which is probably what the questioner now thinks. Prompt students to ask clear questions, and prompt teams to ask questioners to clarify their questions. Also be sure that teams explain why they answered as they did at the end of each set of five questions. (A list of “carefully worded” characteristics appears in step 4.)

   Divide the class into teams of two to six students each. If smaller teams are used, there probably will not be time for all of them to present their object or organism, although everyone still participates in the questioning. Draw lots to see who will present their challenge each round or choose the order yourself.

2. **Demonstration.** Give teams a few minutes to secretly think of their object or organism, and then begin. Demonstrate how to play by picking one team and asking a team member to write the name of the team's object or organism on the chalkboard (the teacher should keep his or her back to the chalkboard) so that the rest of the class can see what you are trying to guess. For each question you ask, the team tells you whether the answer is yes or no. If the rest of the class wants to argue about the team's answer to your question, let them do so, even if this could possibly give away the answer. Their discussion of the attributes of life is the objective of this activity. You should include a few poorly phrased questions and encourage the team to ask you to clarify your meaning. After you've asked five questions and guessed whether or not the thing is alive, have the team reveal their object or organism and explain their answers to your questions.

3. **Activity.** Play the Five Alive! game a few times. If a game is taking too long, restrict the number of teams that can participate in each game. When it seems to be the right moment, reverse the roles. Now the teacher will think of an organism or object and the class will try to determine whether or not the thing is alive or not by asking five yes-or-no questions about its

activities (or lack of activity) and appearance. Choose your examples to present certain concepts, bringing in ideas that have not yet come up.

Make sure students realize that nonliving objects can possess some of the characteristics of life. Some nonliving things that have several characteristics of living things include a crystal, a car, a forest fire, a jigsaw puzzle, a river, dried flowers, a stalactite, and a computer. Characteristics of life include movement, growth, consumption of raw materials (eating), production of waste products, reproduction, complex forms that may have symmetry, and organic molecules. For instance, a flame moves, grows, uses raw materials, produces waste products, "reproduces" new fires, and has a complex form. However, it is not alive.

Make sure students realize that some living organisms may appear to be nonliving objects. Not all life-forms are as obvious as large plants and animals. Some living organisms that are non-obvious examples of life include fungi, lichens, stony marine algae, sponges, molds, bacteria, brine shrimp eggs, chicken eggs, lizard eggs, and plant seeds. Remind students of previous activities involving bacteria.

After the class has guessed whether or not your example is alive, reveal your organism or object and explain your answers to students' questions. Play several games with the roles reversed.

4. **Discussion.** Point out to students that it is obviously important to learn to ask the right questions! Ask the class what they now think "life" is. How could they tell whether or not something was alive? Ask students to name characteristics of something that is alive.

   Let students discuss their ideas. Record on the chalkboard or on butcher paper all the characteristics of life that they feel are important. This list must be readable and usable by everyone in the room when they do their worksheets. Discuss each characteristic as it is presented and see if the entire class can reach a consensus on whether or not individual characteristics are valid. Students should realize that a single exception makes the suggested characteristic invalid. For example, if "the ability to think" is offered as a characteristic, ask students if they can think of any exceptions. For example, a carrot cannot think, but a carrot is alive; so, thinking is not a universal characteristic of life.

Lead students toward developing a list similar to the following:

Living things produce waste products.

Living things reproduce.

Living things grow.

Living things breathe in air or water (exchange gases of some kind).

Living things require liquid water.

Living things eat (consume raw materials).

Living things are complex in form and may have symmetry.

Living things move by their own efforts.

Living things produce heat.

Living things die (cease to function).

Indicate to the class that their list of characteristics may change as their study continues and they learn more.

Note: There are additional characteristics of life that are valid but that may not occur tostudents if they lack a lack a background in biology, chemistry, or physics. These characteristics are also complicated to explain, and may distract students from the focus of this mission. They are not used in the remainder of this guide. Be prepared when introducing any of the following characteristics:

Life is composed of a cell or many cells.

Life has DNA and/or RNA to store information.

Life evolves and adapts to the environment.

Life exchanges energy with the environment.

Life is probably based on carbon (*i.e.*, it is composed of organic molecules, as life on Earth is).

Teacher's Note: *If you want to take two days with mission 8, this is the logical spot to break. Be sure to save the list of characteristics for the next day.*

5. **Demonstration.** Once a final list is agreed upon, show the class a living plant and a plastic plant of similar appearance. Ask them how they could tell which of them is alive. Tell students that they can use their characteristics of life but that they cannot ask any questions. ("Reality" is a new game in itself plants can't talk!) What should they look for? What tests should they use?

   After students have decided how to classify the two plants as living or nonliving, ask how this would be different if all they had to work with was a photograph of the living plant and the plastic plant. Which of the characteristics of life would still be useful? What other tests or experiments would work? Could they tell?

   Ask students how this would be different if the living plant and the plastic plant were located on Mars. Students could still photograph the plants, but encourage them to come up with new techniques. Now which of the agreed upon characteristics of life would still be useful? What other tests or experiments would work?

Ask students if it would be possible to have a spacecraft or lander look for each characteristic, assuming that it sights something interesting (such as a plantlike form) in its vicinity. Ask them to look at the list of characteristics of life and choose the two best characteristics that could be detected by a spacecraft flying over another world. Have students choose the two best characteristics that could be detected, with photographs or specially designed experiments, by a lander landing on another world. Try not to give away specific answers during this discussion. Give enough suggestions to allow students to develop their own experimental plans.

6. **Activity.** Hand out the "Characteristics of Life" worksheet to each student. Have students complete them in their teams.

7. **Discussion.** Have each team, or selected students, state which two of the characteristics of life they felt would be the most useful for detecting life on another world. Conduct a poll to find the top five characteristics that the class chose as a whole. Then indicate the five characteristics of life that this guide has chosen to focus on. (Produces waste products, reproduces, grows, exchanges gases, requires liquid water.) Discuss why these five will work well. Have students circle these five on their worksheets.

   Next, ask teams or students to share their ideas on specific experiments that could detect life on an alien world. Tell them that they will have the opportunity to continue to work on their ideas in later missions.

Going Further

Activity: Super Five Alive!

Now that students know the game Five Alive! and are familiar with the characteristics of life, have them play a variation: instead of just thinking of the name of an object or an organism, one must use a picture of the object or the organism, or even better, the object or the organism itself! This will not be very exciting if the chosen object or organism is obvious, such as a pencil or a fly! However, if the chosen object or organism is a real puzzle, then the game is really fun.

Living organisms that are easy to obtain:

lichen on rocks
plant seeds
mold on bread

Living organisms that can be shown in a photograph:

marine sponge or some other invertebrate
stony (encrusting) marine algae

bacteria or unicellular protozoans

Nonliving objects that are easy to obtain:

crystals (quartz, calcite)
salt, sugar, sand, or lead shot
radio (turned on)

Nonliving objects that can be shown in a photograph:

robotic assembler (car factory)
computer
Commander Data (android from *Star Trek)*

Teacher challenges class: In this version, the teacher researches all chosen objects or organisms and can answer all questions.

Class challenges class: In this version, students form teams. Each student team must know all about their object or organism. Provide them with written information or have them research the chosen object or organism outside of class so that they can answer all questions about it.

Class challenges teacher: In this version, each student must know all about an object or organism that they have brought into class. Have students research their chosen object or organism outside of class so that they can answer all questions about it.

Activity: Extraterrestrial Five Alive!

Macro-extraterrestrial life: In this version of the game Five Alive! each student or team of students creates a large (macro-size) extraterrestrial object or organism. Have students create mental images, draw pictures, make models, or create collages by cutting and pasting together portions of photographs. Teams challenge the teacher or other teams to discover if life is present.

Micro-extraterrestrial life: In this version, each student or team of students creates a small (micro-size) extraterrestrial object or organism. Teams challenge the teacher or other teams to discover if life is present.

Discuss with students the differences between the macro life and micro life games. How does size matter?

Activity: More to Life Than This!

Depending upon allotted time, class background, available equipment, and personal preference, have students demonstrate additional characteristics of life. These include the following:

Life is composed of a cell or many cells.

Life has DNA and/or RNA to store information.

Life evolves, and adapts to the environment.

Life exchanges energy with the environment.

Life is probably based on carbon (i.e., composed of organic molecules, as life on Earth is).

If you have access to microscopes and slides of plants and animals, you could demonstrate that all living organisms are either single cells or composed of cells, while nonliving objects are noncellular.

Ask students to prepare slides of their own cells by scraping the insides of their cheeks with toothpicks. This demonstrates that they, too, are composed of cells.

Use a model of the DNA double helix to briefly discuss the fact that DNA stores information on how to produce an entire organism. Use microscope slides to show DNA. Show slides of horse evolution, noting that DNA is responsible for the mutations that are “naturally selected” by the environment, resulting in adaptation to the environment.

What Is Life?
What Can We Observe to Test for Life?

Characteristics of Life—Teacher's Key

1. Student answers will vary. Accept all reasonable attempts. Here is a fairly complete list of possibilities:

   Living things produce waste products.

   Living things reproduce.

   Living things grow.

   Living things breathe in air or water (exchange gases of some kind).

   Living things require liquid water.

   Living things eat (consume raw materials).

   Living things are complex in form and may have symmetry.

   Living things move by their own effort.

   Living things produce heat.

Living things die (cease to function).

Living things are composed of a cell or many cells.

Living things have DNA and or RNA to store information.

Living things evolve and adapt to the environment.

Living things exchange energy with the environment.

Living things are probably based on carbon (i.e., are composed of organic molecules,as life on Earth is).

2. Student answers will vary. Accept all reasonable attempts.

3. Student answers will vary. Accept all reasonable attempts. If only photos can be taken, growth, death, or reproduction might be seen over time in photos of a true living plant, but none or only some of these might be expected in a photo of a nonliving plant-like object.

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Mission 8 Logbook
What Is Life?

What Can We Observe to Test For Life?

Characteristics of Life-Worksheet

Name: _______________________________________ Date: ______________________

1. List all the characteristics of life that your class considers to be valid:

2. Select the two characteristics of life from this class list that you feel would be best to use to test for the presence of life on another world using a spacecraft or a lander. For each one, describe an experiment that would tell you if a "mystery Martian blob" were alive or not. Be sure to describe the results that you would expect from your experiment if the blob were living (positive results) and if the blob were nonliving (negative results).

Characteristic # 1:

Experiment # 1:

Positive Results:

Negative Results:

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What Is Life?
What Can We Observe to Test For Life?

Characteristics of Life-Worksheet

Name: ____________________________________ Date: _________________________

1. List all the characteristics of life that your class considers to be valid:

2. Select the two characteristics of life from this class list that you feel would be best to use to test for the presence of life on another world using a spacecraft or a lander. For each one, describe an experiment that would tell you if a "mystery Martian blob" were alive or not. Be sure to describe the results that you would expect from your experiment if the blob were living (positive results) and if the blob were nonliving (negative results).

Characteristic # 1:

Experiment # 1:

Positive Results:

Negative Results:

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What Is Life?
What Can We Observe to Test for Life?

Characteristics of Life-Worksheet

Name: ______________________________________ Date: _______________________

Characteristic # 2:

Experiment # 2:

Positive Results:

Negative Results:

3. If you saw photographs of the plastic plant and the living plant on Mars, could you tell if either one was alive? Pick one characteristic of life and design a process or method that would allow your lander to test for that characteristic in these Martian "mystery plants."

Mission 9
Mission to Planet Earth- Life in Soil!

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Can You Recognize Life Up-Close

Overview

In mission 9.1, students examine two soils: an artificial mixture that appears lifeless, and a natural Earth soil, which appears full of life. Both represent samples that might be taken by the extraterrestrial probe.   Students describe what they see and then add water to both soils. In mission 9.2, students discover that the apparently lifeless soil is now filled with brine shrimp that have hatched from dormant eggs in the soil. Students realize that simply looking at something may not be the best way to detect life. Adding water to a soil sample is one way of activating any dormant life.

Notes

In mission 8, students characterized "life" If an extraterrestrial civilization sent a robotic spaceship to Earth to collect soil samples, would that spaceship be able to detect life, or would the extraterrestrial scientists conclude that Earth was devoid of life? This concept also applies to the situation of Earth sending an unmanned spaceship to Mars or Venus.

Mission 9.1
Materials

For a Class of 30

- 3 vials (or 6 grams) of brine shrimp eggs
- 1 cup of clean or sterile fine-grained sand
- 112 tablespoon of rock salt
- 2 cups of organic topsoil (with leaf fragments) from an unsprayed garden
- 2 50-ml beakers for the demonstration
- "Incubation Center"-an area kept warm by lightbulbs
- Chemicals to dechlorinate water (see "Dechlorinated Water," in appendix)
- Dechlorinated water in a large container
- Cups
- Stick-on labels or grease pencils
- (optional) 4 dozen tiny colored glass beads

For Each Team

- 2 50-ml beakers
- 2 hand lens
- 2 Petri dishes with samples 1 and 2
- Low-power microscope or stereo microscope (use hand lenses if microscopes are not available)
- 2 dissection needles or probes
- "Dirty Science" directions

For Each Student:

- "Observing Dry Soil Samples" worksheet
- Pencil

Getting Ready

1. Dechlorinate the water, if necessary. (see "Dechlorinated Water," in appendix)

2. Make two soil sample mixtures as follows:

   Earth Sample # 1.-Gently mix the fine sand, the rock salt, and the tiny colored glass beads (optional) in a clean container.

   Earth Sample # 2-Contains or consists of the organic topsoil (examine the topsoil with a hand lens and a dissection needle or probe to make sure it has easily visible signs of life). Use the soil sample mixtures to prepare a pair of Petri dishes for each student team. Label them "Earth Sample 1" or "Earth Sample 2."

3. Prepare two demonstration beakers. Label the two 50-ml beakers "Earth Sample # 1" and "Earth Sample # 2." To each beaker, add one tablespoon of the appropriate mixture. To Earth Sample # 1, add a pinch of brine shrimp eggs.

4. Copy the "Dirty Science" directions for each team and the "Observing Dry Soil Samples" worksheet for each student.

Classroom Action

1. **Discussion.** Divide the class into teams of two students each. Explain that they will play the role of extraterrestrial scientists who are investigating whether there is life on Planet Earth! The scientists have sent a probe to Earth to collect two soil samples.

   Tell students that their objective is to see if they can tell, by looking carefully with a microscope, whether there is something in the soil that is alive, is dead but was once alive, or was never alive. Tell students that they may see objects that they just can't decide about.

Explain that “Don't Know” is a scientifically acceptable answer. In fact, it is a better answer than an unfounded, wild guess. Students should sketch any objects they find so they can determine their attributes later.

Write these categories on the chalkboard: Alive, Once Alive, Never Alive, Don't Know. Ask the class to name things to look for when trying to decide whether or not something is (or was ever) alive. Write students' one- or two-word answers on the chalkboard. Likely things to look for include movement and familiar shapes.

2. **Activity.** Hand out the “Dirty Science” directions to each team and the “Observing Dry Soil Samples” worksheet to each student. Give each team a pair of Petri dishes containing Earth Sample # 1 and Earth Sample # 2, which represent samples scooped up by an extraterrestrial probe visiting Earth. The two samples will appear very different. Explain that the probe took these samples in two different locations: one was in a desert and the other was in a forest. Also hand out two beakers to each team

   Each student should look at Earth Sample # 1, carefully draw the objects seen, and identify each kind of object as either “Alive,” “Once Alive,” “Never Alive,” or “Don't Know.” Students should be encouraged to look at more than one random part of each soil sample.

   Teams should follow the same procedure with Earth Sample # 2.

3. **Demonstration.** Show the class the demonstration beakers. Pour dechlorinated water into the beakers. Cover the “desert” soil (Earth Sample # 1) with a few centimeters of water to allow the shrimp to swim when they hatch. Just moisten the “forest” soil (Earth Sample # 2); too much water will make it mud and may drown some of the life. Explain that this is a life-form detection experiment. If there are dormant life-forms in the soil, water could activate them. Explain that the drier sample requires more water.

4. **Activity.** Each student should gently pour the viewed sample from the Petri dish into the beaker, being careful to label each beaker. Each student should add dechlorinated water to a sample and label it with his or her name.

   Have teams set these submerged samples under a light bulb (the incubation area); this bulb should remain on all night to keep the samples warm enough to have the brine shrimp eggs hatch within 24 hours. (They do not need light, they need heat.) Too much heat will evaporate the water.

   Teacher's Note: *At 82° F (28°C) it takes 15 hours for the eggs to hatch; if it is warmer, it will take less time; if colder, more time. Test your setup with a thermometer to determine the distance from your heat source. The eggs will hatch in under 48 hours at room temperature, so they can be viewed on the third day after mission 9.1. The brine shrimp will live at least two days after hatching without food. (Food can be dry yeast.) A good plan is to begin this mission on a Friday and finish it on a Monday.*

Mission 9.2
Materials

For a Class of 30

- Common Soil Organisms

For Each Team

- 1 eyedropper

For Each Student

- “Observing Wet Soil Samples” worksheet
- Soil Sample Analysis” worksheet
- Pencil

Teacher's Note: *Mission 9.2 is the same as mission 9.1 except that students examine their wet soil samples. Make sure that the brine shrimp have actually hatched before you begin this activity. The brine shrimp can be seen with the naked eye as glittering red-brown specks that move around. If the shrimp have not hatched, delay this mission for a day or until they hatch.*

Getting Ready

1. Copy the worksheets “Observing Wet Soil Samples” and “Soil Sample Analysis” for each student.

2. Prepare the “Common Soil Organisms” transparency. Set up the overhead projector.

Classroom Action

Figure 9.1-Baby Brine Shrimp

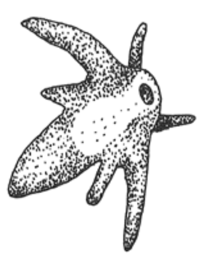
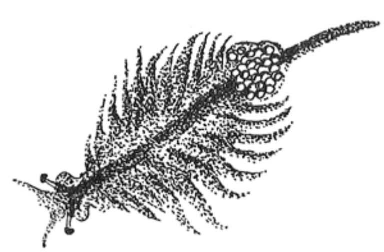


Figure 9.2--Adult Brine Shrimp



1. **Optional Review.** Divide the chalkboard into two sections labeled “Earth Sample # 1” and “Earth Sample # 2.” Ask a few students to start drawing and listing Alive, Once Alive, Never Alive, and Don't Know objects seen in their two Earth Samples. Continue this until each team has listed two or three objects. Use the information on the chalkboard to clear up any obvious misconceptions, or to steer students' thoughts in new directions.

2. **Activity.** Hand out the worksheets “Observing Wet Soil Samples” and “Soil Sample Analysis” to each student. Reassemble the student teams from mission 9.1. Each student should use an eyedropper to take a drop of the water from the top of their Earth Sample # 1 and put it on a Petri dish. Students should label this Petri dish “Earth Sample # 1” and classify any objects seen. Encourage students to look at more than one random part of each soil sample. They may discover, or need to be told, that if they first darken one half of the dish by covering it with paper or their hand, the brine shrimp will swim to the better-lit half. Holding a light to one side of the dish also works. If students take their sample from the well-lit half, they will see more brine shrimp. Students may also discover, or need to be told, that stirring the soil sample a little and then looking at the water again will put a few more objects, including brine shrimp and empty brine shrimp eggs, into view. Teams should follow the same procedure with Earth Sample # 2.

3. **Transparency.** After everyone has looked at the samples, show the “Common Soil Organisms” transparency. This will give you a chance to identify some of the living things that students have seen, and an opportunity to discuss the results of the experiment.

Going Further

Activity: Sea Monkeys!

Brine shrimp are the animals also sold as “sea monkeys.” Have students transfer some brine shrimp into an aerated aquarium, feed them yeast, and watch them grow. They may also be fed to fish!

Activity: Fish out of Water!

Brine shrimp are not the only aquatic animals that have eggs that withstand drying. They are not the only aquatic animals that hatch when exposed to water. There are several species of fish, called annual killifish that live in shallow ponds, mostly along the west coast of Africa. Every year, the ponds dry up, leaving the eggs exposed to the air. When the rains come, the eggs hatch immediately.

An “Instant Fish Kit” using the eggs of the annual killifish *Nothobianchius,* is available from Carolina Biological Supply (see “Ordering Information,” in appendix). The kit contains instructions. You must specify the delivery date for the eggs; the kit comes with a coupon for ordering the eggs. Ask students to add the water to the fish eggs in a Petri dish and watch the hatching, which begins immediately and ends within 90 minutes. Hand lenses or low-power microscopes enhance the experience. Students will see that even complex life can remain dormant until “activated” with water. They will see how life has adapted to a unique environment that is arid for part of the year.

Plan on keeping the fish in a class tropical aquarium. They mature in a few weeks, grow to about two inches, and eat tropical fish food. Perhaps send them home with students, with instructions on their care, or sell them to pet shops that sell fish.

Note: Fish are vertebrates, or animals with backbones. There may be rules that govern the use of vertebrate lab animals at your school.

Discussion: The Lotus

Challenge students with the question: “How long can life remain dormant?” List their ideas and answers on the chalkboard or on butcher paper. Inform students that scientists have taken apparently lifeless lotus seeds from a bone-dry Egyptian tomb and grown one into a regular plant by adding water. These seeds had been entombed for thousands of years. Ask students if this could be the oldest plant on Earth.

Scientists believe that conditions on Mars may have been more favorable to life in the past than they are today. Ask students to suppose that life had flourished on Mars long ago. Could a few dormant seeds remain? What if a probe found such a seed? Could we “activate” it with water?

Activity: Instant Algae

Life (as algae spores) may exist in a water sample, but this is not obvious to the naked eye until there are enough algae cells to turn the water green. Have students seed a mason jar or beaker of dechlorinated water with a few drops of water from an established classroom aquarium (or an algae culture from Carolina Biological Supply-see “Ordering Information,” in appendix). Have students observe the growth of algae by “searching” a drop of the water each day under a microscope. By the time the water turns green, one drop should show many tiny algae cells.

Activity: Soil Search

Life in an organic soil sample may be hard to locate. Have students use Berlese funnels to “sift” through soil samples. This kind of funnel will collect many arthropods from apparently lifeless soil or leaf litter. Have students observe these arthropods under microscopes. (Berlese funnels available from Carolina Biological Supply Company-see “Ordering Information,” in appendix.)

Activity: The Chia Monster

Chia, cress, or any other tiny seeds that appear to be lifeless can be mixed into sterile potting soil and “activated” with water. Have students spread such seeds onto soil samples in patterns, making a “secret message.” When the seeds sprout, the messages can be read.

Mission to Planet Earth-Life in Soil!
Can You Recognize Life Up-Close?

Soil Sample Analysis-Teacher's Key

1. Movement, recognizable shape, growth.

2. Recognizable shape, but it is no longer moving.

3. No movement or recognizable shape; crystalline or geometric form; recognizable as a nonliving thing (*e.g*., a glass bead!).

4. Adding water to the soil caused eggs to hatch into brine shrimp. The water activated dormant life. It was easier to tell that life was present because it made the presence of life obvious: moving, shrimp-shaped animals instead of round nonmoving balls.

5. A single close-up photograph would pose problems. We would have to rely upon obvious shapes. (A series of still photographs taken at the same spot could reveal movement from frame to frame.) Color might help; green might indicate chlorophyll.

6. Yes! In both samples, recognizable animals were moving around.

7. No! There was no obvious life in Earth Sample # 1 when it was dry. (The brine shrimp eggs were not moving so did not look like life.)

8. Life must be abundant on Earth! Two random samples both contained obvious life. Also, life on Earth must like water.

9. Earth Sample # 1 is probably most like soil on Mars since it was much drier, and we know that Mars has no liquid water. Also, the topsoil looked organic, which is very unlikely for Martian soil.

10. It might be difficult to find life on Mars. A random sample would be small and, by chance, might not have life. It would be a good idea to add water to a sample of Martian soil to see if it would activate any dormant life. We know that Mars once had water maybe some life has survived!

Mission 9 Logbook
Mission to Planet *Earth—Life* in Soil!

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Can You Recognize Life Up-Close?

Dirty Science-Directions

Today you will play the role of an extraterrestrial scientist who is investigating whether or not there is life on Planet Earth! You have sent a probe to Earth to collect two soil samples and bring them home for observation and experimentation. You will be given two samples of soil such as might be scooped up by your probe. The probe took these samples in two different locations: one was in a “desert” and the other was in a “forest.”

Your objective is to see if you can tell, by looking carefully with a microscope, whether something in the soil is now alive, is dead but was once alive, or was never alive. Sometimes you will see an object that you just can't decide about. “Don't know” is a scientifically acceptable answer. In fact, “Don't know" is a better answer than a wild guess!

Procedure

1. Obtain a Petri dish with dry Earth Sample # 1.

2. Look carefully at dry Earth Sample # 1, first using your unaided eyes, then using a hand lens, and finally using a microscope (if one is available).

3. Draw the objects that you see. Identify each kind of object as either “Alive, “Once Alive,” “Never Alive,” or “Don't Know.” Look at more than one random part of each soil sample.

4. Follow the same procedure with dry Earth Sample # 2.

5. Put the Earth samples into two separate beakers. Label them Earth Sample 1 and Earth Sample 2.

6. Pour dechlorinated water into the beakers. Cover the “desert” soil with a few centimeters of water. Slightly moisten the “forest” soil. Because this is a life detection experiment, the drier sample requires more water (if there are dormant life-forms in the soil, water could activate them).

7. Label the watered samples with your name so that you can retrieve your own sample the next time the class meets to examine them.

8. Set these watered samples into the incubation area, under a light bulb.

9. Use an eyedropper to take a drop of the water from on top of the wet Earth Sample # 1. Look carefully at the water, first using your unaided eyes, then using a hand lens. Draw and classify any objects as you did before. Stir the soil sample a little and then look again.

9. Follow the same procedure with the wet Earth Sample # 2.

Mission to Planet Earth—Life in Soil! Can You Recognize Life Up-Close?

SETI INSTITUTE

Observing Dry Soil Samples- Worksheet

Name: _______________________________ Date: ________________________________

On this page, describe and draw the objects you see in the dry Earth Sample # 1. Do the same for objects seen in the dry Earth Sample # 2. For each object seen, write "A" if the object is alive, "OA" if it is dead but was once alive, "NA" if it was never alive, or "DK" if you don't know. Show the relative sizes of the things that you see.

Observations of Earth Sample # 1 (dry soil):

Observations of Earth Sample # 2 (dry soil):

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Mission to Planet Earth—Life in Soil!
Can You Recognize Life Up-Close?

Observing Wet Soil Samples - Worksheet

Name: ________________________________ Date: ______________________________

On this page, describe and draw the objects you see in the wet Earth Sample # 1. Do the same for objects seen in the wet Earth Sample # 2. For each object seen, write "A" if the object is alive, "OA" if it is dead but was once alive, "NA" if it was never alive, or "DK" if you don't know. Show the relative sizes of the things that you see.

Observations of Earth Sample # 1 (wet soil):

Observations of Earth Sample # 2 (wet soil):

Mission to Planet Earth—Life in soil! Can You Recognize Life Up–Close?

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Soil Sample Analysis - Worksheet

Name: ____________________________________ Date: __________________________

Answer the following questions, based upon your observations of the two soil samples.

1. How can you tell if something you are looking at is alive?

2. How can you tell if something you are looking at is dead, but was once living?

3. How can you tell if something you are looking at was never alive?

4. What did adding water to the soil do? Did this make it easier for you to tell if life was present in some cases? Why?

5. How would your answers be different if you had only a single closeup photograph of soil to study, as may be the case with a spaceship? Would it help if the photograph was in color rather than black and white?

6. Based upon your observations of the two soil samples, is there life on Earth? Why?

7. If you had only seen Earth Sample # 1, and had only looked at it when it was dry, would you have known that there was life on Earth? Why or why not?

8. As an extraterrestrial scientist, what can you conclude about life on Planet Earth?

9. Which of the two soil samples you saw do you think is most like soil on Mars? (Neither? Both?) Why? Which is most like Venus? (Neither? Both?) Why?

10. From your recent experiences, speculate about Earth scientists' ability to detect life on Mars and Venus.

Mission 10

Chemical Tests for Life—Tests for Carbohydrates and Proteins as Signs of Life

Overview

In mission 10, students test for carbohydrates and proteins in four soil samples. They may also test samples from their own bodies and from other organic and inorganic materials. They ponder the nature of positive-negative tests and the implications of negative test results, which could mean two things: that life was not present or that life may have been present but was not detected. Mission 10.1 focuses on carbohydrates; mission 10.2 focuses on proteins.

Notes

In mission 9, students discovered one way to test for life in the soil of another planet. Can we also detect life by detecting the chemicals that life-forms on other planets are made of? All life-forms need energy in an easily accessible form and information" that tells them how to live. There are only a few atoms that can form complicated molecules to carry out these functions. Carbon is one such atom. Silicon may *be another. All life-forms on Earth use the same types of carbon-based molecules: carbohydrates (sugars and starches), proteins, lipids (fats and oils), and nucleic acids (DNA and RNA).These molecules are made of carbon (C), hydrogen (H)***,** *oxygen (O), nitrogen (N), and a few other atoms, including phosphorus* *Butcher paper (P) *and sulfur 0, all of which are common everywhere in the universe.*

Mission 10.1
Materials

For a Class of 30

- Butcher Paper
- Samples of organic material (e.g., potato, dried leaves, wool, sawdust, human hair, human nails, skin cells, beef jerky, feathers)
- Samples of inorganic material (e.g., plastic, sand, steel wool, plaster, salt)
- Large beaker
- Heat-resistant pad (asbestos recommended)
- Sugar
- Concentrated hydrochloric or sulfuric acid
- Cold cookie sheet or equivalent
- Baking soda
- Iodine

- Box of cornstarch
- 3 cups clean or sterile fine-grained sand
- 4 seltzer tablets (Alka Seltzer works well)
- 8 114-ounce packages of yeast
- 4 tablespoons of dried potato flakes
- 4 soil-sample bowls for the soil
- Stick-on labels or a grease pen

For Each Team

- 4 50-ml beakers
- Mortar and pestle
- Dropper bottle of iodine
- 4 soil-sample carrying dishes for the soil
- "Testing for Carbohydrates" directions
- *(optional)* Bunsen burner and/or matches
- *(optional)* Tongs
- *(optional)* Mirrors or watch glasses
- *(optional)* Toothpicks
- *(optional)* Nail files
- *(optional)* Scissors
- *(optional)* Distilled wate
- *(optional)* Test tubes

For Each Student

- "Testing for Carbohydrates" worksheet
- Safety glasses
- Pencil

Getting Ready

1. Make a large data table on butcher paper for the carbohydrate (iodine) test. Write team numbers 1-15 along the top and materials to be tested down the left side so that teams can Mark '+' for a positive result or "-" for a negative result for each material tested.

2. Make four soil samples as follows. (These amounts make enough for 15 teams.) The first two soil sample mixtures will be made again in mission 12 (make enough for both missions now and/or save any leftovers from this mission). All four sample mixtures will be used again in mission 10.2.

   Earth Sample # 3-Crush the seltzer Tablets into fine pieces using the back of a spoon to press on the packets before they are opened. Open the packets and mix the seltzer with tablespoons of the sand. Put the mixture into a bowl and label it "Earth Sample # 3." (Add 114 of a seltzer tablet and 1 tablespoon of sand for each extra team.)

Earth Sample # 4-Mix the yeast with 16 tablespoons of the sand. Put the mixture into a bowl and label it "Earth Sample # 4."

Earth Sample # 5-Mix the dried potato flakes with 16 tablespoons of the sand. Put the mixture into a bowl and label it "Earth Sample # 5."

Earth Sample # 6-Put 16 tablespoons of pure sand into a bowl and label it "Earth Sample # 6." This will be the control. Microwave this sample to be sure that it is sterile.

3. Copy the "Testing for Carbohydrates" directions for each team and the "Testing for Carbohydrates" worksheet for each student.

Classroom Action

I. **Lecture.** Review safety procedures. Your school probably has a printed set of specific procedures. Ask students to secure long, loose hair and floppy sleeves with rubber bands.

2. **Demonstration.** Put some sugar (a carbohydrate) into a beaker. Slowly add concentrated hydrochloric or sulfuric acid. At some point, there will be a puff of steam (water vapor) and the sugar will bubble up and turn into a lump of carbon. (Pouring baking soda over it will neutralize it for safe disposal.) Hold a cold cookie sheet over the beaker while you pour the acid. This will let the water condense onto the cookie sheet.

   Ask students if the escaping vapor is composed of water molecules. Can we be sure just by looking? How *can* we be sure? *(We could test the condensed liquid as was done in mission 7, "Water!")* Ask students if the black matter is carbon. How can we be sure? *(We could test it.)* Ask students what might happen if they added heat energy instead of chemical energy to a carbohydrate sample. Using a Bunsen burner or matches, char several organic and inorganic samples in front of the class. Have students observe the charring process carefully. If you wish the class to try this on their own, show them how to safely char powdered substances in test tubes. Always handle hot test tubes with tongs, and always wear safety glasses.

3. **Discussion.** Invite the class to brainstorm about what kinds of things will char over a flame, then about what things won't char. Make two lists on butcher paper. Ask students to discover the major single difference between the two lists of items. Lead the class to the conclusion that items on the first list are living (or were once living) organic materials (*e.g.*, wood, toast, rice). Items on the second list are nonliving, inorganic materials (*e.g.,* metals, stones, plastics, glass). Describe to students the charring process: 1) the temperature is raised very high, 2) a lot of steam (water

vapor) escapes, and 3) charred residue is left behind. Ask students what steam is. *Water vapor.)* What the black charred matter is. *(Carbon. Before burning, water and carbon were joined together in a carbohydrate molecule. The fire caused a chemical reaction in which the water molecules escaped, leaving the carbon atoms behind. Before the reaction, the carbohydrate often looks very different.)*

4. **Optional Activity.** Flame test for carbohydrates. Ask students to test some different samples of your choice to see whether or not they are organic materials. They may heat them up in test tubes or hold them directly over a flame. (If you feel this cannot be done safely in the classroom, do a demonstration instead.) Each test should be considered "positive" (+) if carbon forms and steam is given off, and "negative" (-) if this does not happen.

5. **Discussion.** Starch is a complex carbohydrate. Though simple carbohydrates such as glucose can form from nonliving reactions, starch is too complex to form in that way, The presence of starch is good evidence that life is, or was, present, because it must have been produced by a living organism. Ask students how living organisms can make compounds that are not found in nature (produced abiotically).*(They use organic catalysts called enzymes to instigate chemical reactions.)*

6. **Activity.** Divide the class into teams of two students each. Hand out the "Testing for Carbohydrates" directions to each team and the "Testing for Carbohydrates" worksheet to each student. Ask students to determine what a positive test for starch would look like by adding a drop or two of iodine to one teaspoon of cornstarch into a small test-tube. Students rinse all test tubes with water (distilled preferred).

   POSITIVE: A change from yellow-brown to blue-black is a positive (+) result, meaning that starch is present. This indicates that life is, or was, present in the sample. In this case, the corn was alive.

   NEGATIVE: No color change is a negative (-) result. It means that starch is not present, or not detectable for some reason (sample may not be ground up well enough for the iodine to reach the starch or the concentration of iodine may be too low).

   "Soil samples." Students use their four carrying dishes to obtain one teaspoon. or less of each of the four soil samples. Students should put each soil sample into a separate test tube, label the four test tubes, add a few drops of iodine to each test-tube, and look for a color change. Teams should record all their results on the class chart.

7. **Discussion.** Ask students which soil samples contained life (either alive or once was alive). *(Earth Sample* # 5.) Ask students which soil samples did not contain life. *3**,** # 4, and # 6, because these samples gave negative test results.)*

   Now tell students what was in each soil sample. They may be surprised by the yeast, a life-form they did not detect! Note that a negative (-) result does not mean that there is no life; it only means that there is no starch. Life may still be present, because not all living things produce or store starch. But life may also be absent. A negative result is inconclusive.

8. **Activity.** Have students test other samples of your (or their) choice for the presence of starch. A slice of raw potato gives an excellent reaction. Some samples may need to be ground using the mortar and pestle before iodine is used. Be sure to clean test tubes between samples.

Mission 10.2
Materials

For a Class of 30

- 5 grams of Ninhydrin powder (see "Ordering Information," in appendix)
- Cooked chicken breast (or light-colored lunch meat)
- Butcher paper
- Samples of organic material (*e.g.*, potato, dried leaves, wool, sawdust, human hair, human nails, skin cells, beef jerky, feathers)
- Samples of inorganic material (*e.g.*, plastic, sand, steel wool, plaster, salt)

For Each Team

- 4 test tubes
- Hot water baths (60-70" C recommended)
  - Ideal lab equipment
    Beaker (about 150 ml)
    Water (distilled)
    Thermometer
    Bunsen burner
    Ring stand and rack (optional) Any container with heated water poured into it
- Dropper bottle of Ninhydrin solution
- Tweezer***0***
- 4 soil-sample carrying dishes for the soil
- (optional) Mortar and pestles
- (optional) Toothpicks
- (optional) Nail files (optional) Scissors
- "Testing for Proteins" directions

For Each Student

- "Testing for Proteins" worksheet
- "A Biochemical Search for Life" worksheet
- Safety glasses
- Pencil

Getting Ready

1. Make a large data table on butcher paper for the protein (Ninhydrin) test. Write team numbers 1 15 along the top and materials to be tested down the left side so that teams can mark '+' for a positive result or "-" for a negative result for each material tested.

2. Dissolve the Ninhydrin powder into the water to form a saturated solution. Students will need easy access to the Ninhydrin solution. If possible, provide 15 dropper bottles or small labeled beakers of Ninhydrin solution at a central station.

3. Copy the "Testing for Proteins" directions for each team and the worksheets "Testing for Proteins" and "A Biochemical Search for Life" for each student.

Classroom Action

1. **Discussion.** Brainstorm as a class or in teams about proteins. What are they for? Why do we need them? *(Structure and function of the human body.)* Where do we get them? *We eat food containing protein.)* Can you "uncook" an egg? Why not? *(The proteins have been tangled and bent by exposure to heat; there is no way to fix this. Proteins are long, fragile molecules.)*

   Talk with students about amino acids. There are 20 or so common amino acids, including glycine and alanine. All living things that we know of have proteins that are made from combinations of these same amino acid building blocks, which are linked by peptide bonds in long chains, but in different numbers and sequences. (You may want to do the "Going Further 'Exploring Combinations' " activity now.) Proteins are complex molecules. Though amino acids can form from nonliving reactions, proteins are too complex to form and persist in most natural situations. The presence of proteins is also good evidence that life is, or was, present, because they must have been produced by a living organism.

2. **Activity.** Reassemble the class into the previous teams of two students. Hand out the Student Fact sheet: "Biochemistry of Proteins" and the Student Worksheet: "Testing for Proteins." Tell students that they will be testing samples for the presence of proteins. They determine what a positive test for protein would look like by adding a drop or two of Ninhydrin solution to one teaspoon or less of a known protein, chicken muscle. The chicken muscle should be cooked, since raw chicken may contain *Salmonella.* Light-colored lunch meat may be substituted.

   Students add enough of the Ninhydrin solution to cover the chicken, then set the test tube in a hot water bath (about *60"* C; cooler temperatures will produce slower reactions, about 5-10 minutes; hot tap water should. This reaction takes one to two minutes.

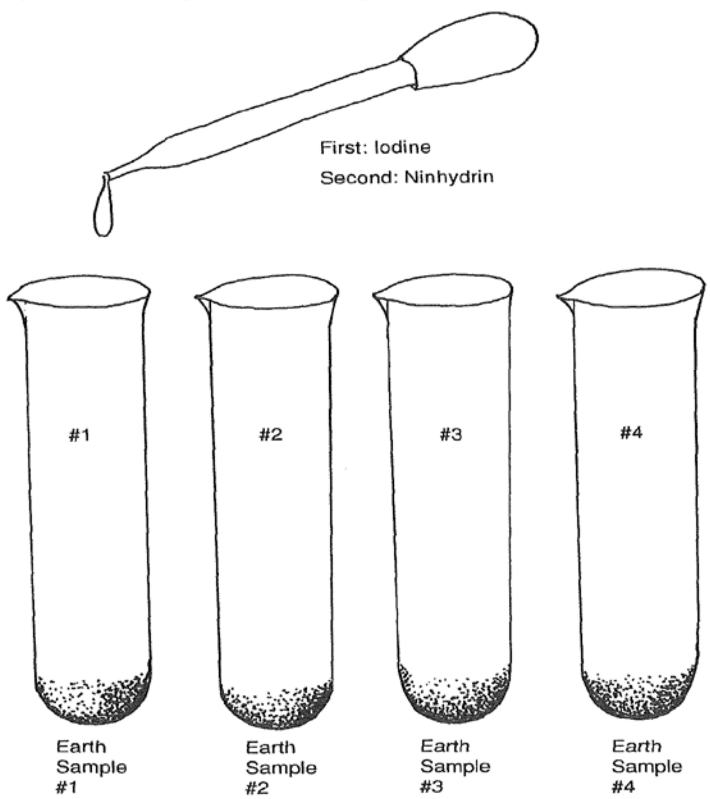
Teacher’s Note: Caution! Have students avoid touching the Ninhydrin solution; it will identify the proteins in their skin by turning it blue! Have students rinse all the mortar and pestles and test with water (distilled preffered).

POSITIVE. A change to blue is a positive (+) result, meaning that protein is present. This indicates that life is, or was, present in the sample. In this case, the chicken was alive.

NEGATIVE. No color change is a negative (-) result. It means that protein is not present, or not detectable for some reason.

“Soil Samples.” Students use their four carrying dishes to obtain one teaspoon or less of each of the four soil samples. Students should put each soil sample into a separate test-tube, label the four test tubes as shown in figure 10.1, cover the soil with Ninhydrin solution, put the four test tubes in the hot water bath, and look for a color change. Students should test all four soil samples. Teams should record all their results on the class chart.

Figure 10.1—Experimental Setup.



Teacher's Note: *Test results* Earth Sample # 3 (seltzer tablets; no life) (-) Earth Sample # 4 (yeast; life) (+) Earth Sample # 5 (potato flakes; life) (+) Earth Sample # 6 (only sand; no life) (+)

3. **Discussion.** Ask students which soil samples contained life according to this test. *(Earth Samples # 4 and # 5; This test does show the living yeast.)* Ask students which soil samples did not contain life. *(Earth Samples # 3 and # 6; the same as mission 10.1.)* But what if these soil samples were from Mars, and no one knew what was in them? Could there be undetected life? Note that a negative (-) result does not mean that there is no life; it only means that there is no protein. Life may still have been present. Perhaps the delicate proteins were destroyed before the test was done. Perhaps alien life would not have proteins. Perhaps the proteins are isolated in some kind of inorganic shell. In those cases, life would still be present; a negative result is inconclusive.

4. **Activity.** Have students test other samples of your choice for the presence of protein, a sign of life. They may collect organic samples from themselves. Students can gently scrape some cells from inside their cheeks, produce some spit (saliva contains proteins), file their nails, and cut up a little bit of hair. It is important to grind up things like hair in a mortar and pestle to free the proteins so that they can react. (Some reactions are slower, and dark hair may not show.)

5. **Discussion.** Give teams a chance to share what they found or learned. There are likely to be items that some teams marked '+'while others marked them '-'. Discuss what this could mean, and the notion of "majority vote." Scientists never use a majority vote. Instead, they require that the results of an experiment be reproducible and corroborated by subsequent investigation. However, the interpretations of results are sometimes debatable. What is the reliability of this test? How might it be possible to get a "false-positive" test? *(Contamination, etc.)* How good would these tests be in determining if there was life on Venus or on Mars?

6. **Activity:** Hand out "A Biochemical Search for Life" worksheet to each student and have students solve these problems either in class or as homework.

Going Further

Activity: Grease Stains

Lipids (fats and oils) are complex organic Molecules that are characteristic of life. An easy way to recognize a lipid is by the grease stain that it makes on paper. Have students test various substances for lipid content. Include high-lipid substances such as vegetable oil, butter, and french fries. Ask students if they can figure out a way to test for lipids in an alien soil or atmospheric sample.

Activity: Exploring Combinations

Ask students to make words using the letters in protein. Give students points for each word (and bonus points for longer words). Decide whether they may use the same letters twice or not. Ask students to do this as a homework assignment or as an in-class team-brainstorming contest.

Tell students that proteins form in the same way: different sequences of amino acids make different proteins (the same way ten and net are different words). Proteins are made from combining about 20 different kinds of commonly found amino acid building blocks into long chains. Typical proteins are hundreds of amino acids long.

Ask students how many different words can be made with 26 letters. Just look at a dictionary! How many different proteins could be made with 20 amino acids?

Research: Vegetarians and Ecology

Students have probably heard that they need meat or dairy products to get enough protein in their diet. Ask them if they believe this. Explain to them that these foods do not have a monopoly on proteins, and that proteins are found in all living cells, both animal and plant. It is possible and feasible for our bodies to make all the protein we need from a variety of vegetable foods (which includes grains). Some vegetarians believe that eating vegetables is better than eating meat because it cuts out so much unnecessary cholesterol from our diet, and because raising so much livestock is such a drain on our environment. Cattle raising can lead to destruction of the rain forest, overgrazing, erosion, loss of critical habitat for endangered species, and even global warming (from methane production)! Of course, some beef can be produced at sustainable levels using ecologically sound practices.

Research: Nutrition and Proteins

Discuss amino acids with students. A protein that contains all the essential amino acids that a body needs is called a complete protein. A protein that does not contain all the essential amino acids is called an *incomplete* protein. Beef, pork, and chicken contain complete proteins. Corn and beans contain incomplete proteins, if a person ate only corn, or only beans, she or he would become ill because some amino acids would be missing. However, if a person ate corn and beans in one meal, she or he could stay healthy because corn has the amino acids that beans are missing and beans have the amino acids that corn is missing.

Chemical Tests for Life
Tests for Carbohydrates and Proteins as Signs of Life

Testing for Carbohydrates--Teacher's Key

Table 10.1-Carbohydrates Test Results, Teacher's Key (Answer to #1 on page 188).

Sample	Is Iodine Test + or - ? Describe Color Change	Is Starch Present	Was Life Present?
Cornstarch	+ From yellow brown to blue-black	Yes	Yes (Corn)
"Earth Sample #3"	- No color change	No	No (Seltzet)
"Earth Sample #4"	- No color change	No*	Yes (Yeast)
"Earth Sample #5"	+ From clear to blue	Yes	Yes (Potato)
"Earth Sample #6"	- No color change	No	No (Sand)

*Students will say "No" because they did not detect any starch. Discuss this!

2. In a "negative" iodine test there is no color change. A negative result means that starch is not present. However, life may be present. *3.* In a "positive" iodine test, the iodine turns color from yellow-brown to blue-black. A positive result means that starch is present. This means that life is (or was) present. 4. An exobiologist would care about starch because it would indicate the presence of life, because only living things produce starch.

Testing for Proteins-Teacher's Key

Table 10.2-Protein Test Results, Teacher's Key (Answer to #1 on page 191).

Sample	Is Ninhydrin Test + or - ? Describe Color Change	Is Protein Present	Was Life Present?
Chicken Muscle	+ From clear to blue	Yes	Yes (Chicken)
"Earth Sample #3"	- No color change	No	No (Seltzet)
"Earth Sample #4"	- From clear to blue	Yes*	Yes (Yeast)
"Earth Sample #5"	+ From clear to blue	Yes	Yes (Potato)
"Earth Sample #6"	- No color change	No	No (Sand)

2. In a "negative" Ninhydrin test there is no color change. A negative result means that protein is not present.

3. In a “positive” Ninhydrin test the color changes from clear to blue. A positive result means that protein is present.

4. Earth Sample # 4 seemed to have no life (based upon the negative test for starch), but the protein test was positive, so there must be some life there (there are yeast cells present).

Chemical Tests for Life
Tests for Carbohydrates and Proteins as Signs of Life

A Biochemical Search for Life-Teacher's Key

1. Based upon these data, there is life in the Mariner Valley! Although the carbohydrate tests were negative, the positive result for protein must be interpreted as indicating life. (Alternative possibilities include a contamination of the sample with protein brought from Earth, or some alien geochemistry that produces proteins without life.) The char test for carbon may be negative if the protein in the soil is too scarce to be revealed by this test.

2. Based upon these data, there is no life in the Rhea Mons area. All the tests were negative. (One could still argue that alien biochemistry would be too different for this to be a conclusive result, or that the random sample missed collecting life.)

3. The iodine turns blue-black, indicating a positive reaction; there is starch in this glob! The Ninhydrin solution does not change color, indicating a negative reaction; there is no protein in this glob! However, one positive is enough to indicate that the glob is (or was) alive. Or at least that parts of it are (were) alive. (It may be forgotten junk food; it may be a pretty pink mold.)

Mission 10 Logbook
Chemical "Tests" for Life

SETI INSTITUTE

Tests for Carbohydrates and Proteins as Signs of Life

Testing for Carbohydrates - Directions

Starch

Starch is a complex carbohydrate. Though simple carbohydrates such as glucose can form from some nonliving chemical reactions, starch is too complex to form and persist in most natural situations. The presence of starch is good evidence that life is, or was, present, because it must have been produced by a living organism.

1. Obtain cornstarch, iodine, four test tubes, and four soil-sample carrying dishes. Follow all indicated safety procedures your teacher reviewed earlier.

2. Add a drop or two of iodine to one teaspoon of cornstarch in each beaker.

3. Look for a reaction. A change from yellow-brown to blue-black is a positive (+) result, meaning that starch is present. This indicates that life is, or was, present in the sample. In this case, the corn was alive. No color change is a negative (-) result. It means that starch is not present, or not detectable for some reason (the sample may not be ground up well enough for the iodine to reach the starch).

4. Rinse all test tubes with water (preferably distilled).

5. Use the four carrying dishes to obtain one teaspoon of each of the four soil samples.

6. Put each soil sample into a separate test tube, label the four test tubes, add a few drops of iodine to each, and look for a color change.

7. You may test other samples of your choice for the presence of starch, a sign of life. A slice of raw potato gives an excellent reaction. Some samples may need to be ground using the mortar and pestle before iodine is used. Be sure to clean the test tubes between samples.

Positive and Negative Tests: Interpreting the Results

Positive: Starch is a complex carbohydrate. Though simple carbohydrates such as glucose can form from nonliving reactions, starch is too complex to form and persist in most natural situations. The presence of starch is good evidence that life is, or was, present, because it must have been produced by a living organism. A positive (+) result indicates that there is (or was) life present.

Negative: A negative (-) result does not mean that there is no life; it only means that there is no starch. Life may still be present, because not all living things produce or store starch. But life may also be absent. A negative result is inconclusive.

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Chemical Tests for Life
Tests for Carbohydrates and Proteins as Signs of Life

Testing for Carbohydrates - Worksheet

Name: ________________________________ Date: _______________________

1. Record the results of your iodine tests for starch as positive (+) or negative (-).

Table 10.3 Testing for Carbohydrates.

Sample	Is Iodine Test + or - ? Describe Color Change	Is Starch Present?	Was Life Present?
Cornstarch			
"Earth Sample #3"			
"Earth Sample #4"			
"Earth Sample #5"			
Earth Sample #6"			

2. What does a "negative" iodine test look like? What does a negative result mean?

3. What does a "positive" iodine test look like? What does a positive result mean?

4. Why would an exobiologist care about starch?

Chemical Test for Life
Tests for Carbohydrates and Proteins as Signs of Life

SETI INSTITUTE

Testing for Proteins - Directions

Protein

Proteins are complex molecules. Though amino acids, the building blocks of proteins, can form from nonliving reactions, proteins are too complex to form and persist in most natural situations. The presence of proteins is good evidence that life is, or was, present, because they must have been produced by a living organism.

1. Obtain cooked chicken muscle or light-colored lunch meat, Ninhydrin solution, test tubes, and four soil-sample carrying dishes. Follow all indicated safety procedures your teacher reviewed with you earlier.

2. Prepare a hot-water bath.

   Bath 1-Set up a beaker half full of water on a ring stand. Light a Bunsen burner and heat the water to 60-70” C.

   Bath 2 *(optional)*--Heat water to 60-70” C with a hot plate or any other means. Pour into any container.

3. Add a drop or two of Ninhydrin solution to one teaspoon of a known protein, chicken muscle, in each test tube (the chicken should be mashed). Try to determine what a positive test for protein would look like.

4. Set the test tube into a hot-water bath (about 60” C; cooler temperatures will produce slower reactions) for about 5-10 minutes.

5. Wait for a reaction. A change to blue is a positive (+) result, meaning that protein is present. This indicates that life is, or was, present in the sample. In this case, the chicken was alive. No color change is a negative (-) result. It means that protein is not present or detectable for some reason. Rinse all the test tubes with water (distilled preferred).

6. Use four carrying dishes to obtain one teaspoon of each of the four soil samples.

7. Put each soil sample into a separate test tube, label them, cover each soil sample with Ninhydrin solution, put the four test tubes into the hot-water bath, and look for a color change. Test all four soil samples.

8. You may test other samples of your choice for the presence of protein, a sign of life. You may collect organic samples from yourself? Gently scrape some cells from the inside of your cheeks, produce some spit (saliva contains proteins), file your nails, or cut up a little bit of your hair. You may test other samples of your choice too. It is important to grind up things like hair in a mortar and pestle to free the proteins so that they can react.

Chemical Test for Life
Tests for Carbohydrates and Proteins as Signs of Life

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Testing for Proteins - Worksheet

Name: _________________________________ Date: ___________________________

1. Record the results of your Ninhydrin tests for protein as positive (+) or negative (-1.
   Table 10.4 Protein Test Results

Sample	Is Ninhydrin Test + or - ? Describe Color Change	Is Protein Present	Was Life Present?
Chicken Muscle			
“Earth Sample #3”			
“Earth Sample #4”			
“Earth Sample #5”			
“Earth Sample #6”			

2. What does a “negative” Ninhydrin test look like? What does a negative result mean?

3. What does a “positive” Ninhydrin test look like? What does a positive result mean?

4. Based upon the results of the protein test, did you reach the same conclusions about the presence of life in your soil samples that you did based upon your starch test? Explain any differences that you found.

Chemical Tests for Life
Tests for Carbohydrates and Proteins as Signs of Life

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A *Biochemical Search for Life—Worksheet*

Name: ________________________________ Date: ____________________________

1. Imagine that your lander scoops up a sample of Martian soil from the Mariner Valley. The photographs show no obvious signs of life. You tell your lander to perform three chemical life detection tests. It sends you the following report:

Char Test:	Negative
Iodine Test:	Negative
Ninhydrin Test:	Positive

What is your analysis of this data? Is there life in the Mariner Valley?

2. Imagine that your lander scoops up a sample of Venusian soil from the Rhea Mons area. The photographs show no obvious signs of life. You tell your lander to perform three chemical life detection tests. It sends you the following report:

Char Test:	? (equipment malfunction)
Iodine Test:	Negative
Ninhydrin Test:	Negative

What is your analysis of this data? Is there life in the Rhea Mons area?

3. Imagine that you find a mysterious pink glob under your bed. It shows no obvious signs of life. You bring it to class and perform two chemical life detection tests. The iodine turns blue-black, and the Ninhydrin solution does not change color. What is your analysis of this data? Is (or was) there life under your bed?

SETI INSTITUTE

Mission 11
Mission to Planet Earth Life Trap!

Can You Detect Life in the Atmosphere?

Overview

In mission 11.1, students construct two Life Traps-nutrient gelatin dishes-and attempt to detect life in Earth's atmosphere. They prepare experimental dish and a control dish of the nutrient gelatin medium. In mission 11.2, students observe both dishes for a few days to watch any collected microbes multiply enough to be seen as colonies. This experiment shows students that life may be detected by growth and by changes in form. In mission 11.3, students observe further microbial growth in their own Life Traps and analyze the results of each other's Life Traps.

Notes

In Mission 40, students tested for life in the solid of an alien planet. But what about life in the atmosphere? If extraterrestrial scientist sent a robotic spaceship to earth to search for life in the air, would they be able to detect life or would they conclude that Earth's atmosphere has no life.

Mission 11.1
Materials

For a Glass of 30

- 200 ml of Sterigel Instant Medium (for an alternative recipe, see "Making Your Own Medium," in appendix)
- Masking tape
- Overhead projector
- "Experiment and Control" transparencies (2 pages)

For Each Team

- 2 sterile 60-mm by 15-mm Petri dishes (see "Sterile Dishes," in appendix)
- *2* stick-on labels or a grease pen "Making a Life Trap!" directions

For Each Student

- "Life in Strange Locations" worksheet
- Pencil

Getting Ready

1. If you are sterilizing your own Petri dishes (instead of buying sterilized Petri dishes, which require no preparation), do so the day before class. Follow the instructions in the appendix (see "Sterile Dishes," in appendix).

2. If you are preparing your own medium (instead of using the Sterigel Instant Medium), do so the day before class. Follow the instructions in the appendix (see "Making Your Own Medium," in appendix).

3. Copy the "Making a Life Trap!" directions for each team and the "Life in Strange Locations" worksheet for each student.

4. Prepare the "Experiment and Control" transparencies (2 pages). Set up the overhead projector.

Classroom Action

1. **Discussion**. Divide the class into teams of two students each. Tell students that they will be playing the role of extraterrestrial scientists who are investigating whether or not there is life in the atmosphere of planet Earth. The extraterrestrial scientists have sent another probe to Earth. This one will not take soil samples; instead, it will be a Life Trap designed to capture any microscopic, airborne life-forms and take them home for observation, or send home the data about them. In this experiment, students will simulate sending a life detection device to some strange location to see if it actually finds life there.

   Each team will prepare two identical Life Traps, dishes with a nutrient gelatin food supply for microbes. The experimental dish will be opened at a strange location for 20 minutes. The control dish will never be opened. Students will observe both dishes each day for a few days to see if any life appears.

   If any microbes settle into the experimental dish while it is open, and if they can use the nutrients in the dish, they will grow. They may be too small to see at first, but if they have enough time to multiply, they will grow numerous enough so that students can see their colonies. Nonliving things that settle into the experimental dish will not grow at all. Therefore, this is a way of finding life-forms that are originally too small to see.

2. **Activity.** Hand out the "Making a Life Trap!" directions to each team. Each team should now make a pair of Life Traps. Students should wash their hands and their

work areas with soap and water. Give teams their sterile Petri dishes and four pieces of masking tape. Ask students to tape shut their Petri dishes without opening them; this makes a “hinge” on one side of each dish and a rebreakable seal on the other.

While students are taping their Petri dishes prepare the Sterigel at a central area in the classroom: Close any windows to pre drafts. Open an alcohol swab and place it on the table. Open the two jars in the Sterigel kit. Place their lids on the alcohol swab. Pour the Sterigel liquid into the bottle of Sterigel powder and shake the bottle for 30 seconds. Sterigel must be used quickly after it is made; it cannot be melted for later use.

Each team should now obtain nutrient gelatin medium for its sterile Petri dishes by bringing them to the Sterigel area. Make sure students remove only one piece of tape from each dish. The teacher should pour the Sterigel, enough to halfway cover the bottom of each Petri dish. Students should then quickly close and retape their dishes, swirling them gently to evenly distribute the Sterigel. Work quickly and swirl the Sterigel bottle frequently to keep the nutrient suspension even. The Sterigel in the Petri dishes will set quickly, and students can write “Control” on one dish and “Experimental” on the other.

3. **Activity.** Hand out the “Life in Strange Locations” worksheet to each student. (This worksheet must be kept for several days.) Each team should agree on a strange location to which one member, or more preferably the whole team, will take the dishes, and where they will leave one open for 20 minutes, after school. These strange locations may include Billy's attic, Abduhl’s doghouse, Juanita's backyard, or wherever. They represent random samples of Earth's atmosphere taken by the extraterrestrial scientists! (Note that there is no teacher's key for this worksheet because student answers will vary. Students should attempt on their maps to be accurate in terms of number of colonies growing, location of colonies, and the general appearance of colonies.)

4. **Discussion.** End this class, or begin the next one, with a discussion of the control dish. Ask students why they are bothering with a dish that they aren't going to open. (A *control is necessary to see if any life accidentally entered the gelatin when the dishes were made.)*

5. **Transparency.** Show the “Experiment and Control” transparencies (2 pages). Explain that each dot represents the presence of life because each dot is actually a colony of bacteria or fungi that has formed from a single bacterium or fungus that happened to land on the dish while it was open. Note that one bacterium is invisible to the naked eye, but one bacterial colony is easily seen.

Ask students how they would interpret the results for the following four possible cases:

- Life appears in the experimental dish but not in the control dish.

- Life appears in neither the experimental dish nor the control dish.
- Life appears in both the experimental dish and the control dish.
- Life appears in the control dish but not in the experimental dish.

6. **Activity.** Students should take their two dishes to the strange location and set them down side by side. The experimental dish should be opened and left open for 20 minutes. Then it should be closed and retaped. Both dishes should be left at room temperature overnight and brought to school the next day. Both should be examined by the team and then set aside to incubate for a few days.

Mission 11.2
Materials

For Each Team

- Plastic metric ruler
- 2 hand lenses
- Grease pen
- “Mapping Microscopic Life” directions

For Each Student

- “Life in Strange Locations” worksheet
- Pencil

Getting Ready

1. Copy the “Mapping Microscopic Life” directions for each team

Classroom Action

1. **Activity.** Reassemble the class into mission 11.1's teams.

   Hand out the “Mapping Microscopic Life” directions to each team. Students should use their “Life in Strange Locations” worksheet to continue making and recording observations. When students return to class with their dishes, they should examine them carefully and make a map of each dish without removing the covers. This is a precaution: certain molds could produce irritating or infectious spores, although most common molds are harmless. Students should mark a line or arrow on the top of the Petri dish with a grease pencil. This will allow students to orient their dishes for observations after they have had a few days to incubate. Have students calculate the minimum time that the Life Trap would have to remain open to catch one microbe at their test location.

After teams have mapped and interpreted their own Petri dishes, have them visit other teams' Petri dishes. A good procedure is for half of a team to remain at their station to explain their findings to visitors while the other half circulates; then switch halves and duties.

2. Storage**.** Have teams put away their pairs of dishes (somewhere at room temperature) for safekeeping.

Mission 11.3
Materials

For Each Student

- "Analyzing Life Traps" worksheet
- Pencil

Getting Ready

- Prepare worksheet.

Classroom Action

1. **Activity.** Have students examine their dishes each day for several days and make new maps of the objects they see growing on the surface of the gelatin.

2. **Activity.** After students have finished all their observations, hand out "Analyzing Life Traps." Have them work on this in class alone, in their teams, or as homework.

3. **Wrap-Up Discussion.** Have a student volunteer list on the chalkboard the locations at which the teams opened their Life Traps. The volunteer should also list whether each team found microorganisms in its experimental dish or in its control dish.

   For cases in which life appeared in the control dish, ask the following questions:

   - When did it get there? *(Probably when gelatin was prepared by the teacher, or when it was poured by the team.)* Can we conclude that the experimental dish really caught life at the test location? *(No, because the life in the experimental dish may not be from the test site; it could be life that was picked up in the classroom before the experiment started in the same way that the control dish picked up life.)*

   - Is there any way that we can use the experimental results, if the control shows life? *(Vies; if there are kinds of microbes in the experimental dish that didn't appear in the control dish, we can guess that they got in at the test location, but* *we can't be as sure as we could if there was* nothing *in the control dish-remember that the perimentaldish was open for 20 minutes.)* For cases in which life did not appear in any control dishes, proceed as follows: Assuming that each visible colony started from one and only one microorganism, list the total number of colonizing microorganisms caught in the experimental dish at each location and the number of minutes that a Life Trap would need to remain open there in order to catch at least one microorganism. Which location was richest in life?

- List the most common kind of organisms (e.g., bacteria or fungus) caught at each location and in the control dishes. Were there any differences between locations?

Finally, ask the following thought-provoking questions: 'Would you have recognized the objects in the Petri dishes as life if you didn't know that they had been growing?" "Is there any nonliving entity that could grow and fool you into thinking that it is alive?" Crystals grow! "Suppose that the Life Traps had been opened on a planet or satellite where there are organisms and the Life Traps cannot use the nutrients in Earth-based gelatin, or they find that Earth-based gelatin is poison to them. What would you have to do then to recognize life?" "Have we seen anything during the course of this experiment that kills life? Could a test for life be based on the use of this procedure?"

4. **Disposal.** After all observations of the Petri dishes have been made, dispose of the cultures.

   Teacher *Note: A teacher should disposeof the cultures because they may contain harmful, even pathogenic, microbes. Your school may require certain disposal procedures. Disposal bags can be ordered from biological supply houses listed in. the appendix. Ideally, the cultures should be sterilized(autoclaved or microwaved on high for a few minutes) before disposal. Avoid touching or inhaling spores from the microbial colonies; you may wish to wear a dust mask.*

Going Further

Activity: Picky Eaters

Make extra Life Traps and order special media that lack certain nutrients from biological supply houses. Have students preform the experiment and compare the number of microbes that grow on each plate. Ask students if it is important to provide certain nutrients in a Life Trap. What would happen if even one crucial ingredient was left out?

Activity: Hands-on Microbiology

Make extra Life Traps. Have students make handprints, or fingerprints, on the gelatin. Have some students wash their hands first. Ask students which of these will probably grow more microbes. Why? Students may not realize it, but everybody has harmless microbes living on their skin all of the time. In most cases, the washed hands will produce more microbes on the culture dish because the washing will have brought microbes nearer to the surface of the skin! Show students some pictures of this normal bacterial life. There are many microbes that are specialized to live on the human body. Variation: Have students write short “secret messages” by brushing the surface of the gelatin with their fingers. See if these messages can be read a few days later.

Activity: Is It Too Hot in Here?

Make extra Life Traps. Have students expose all of them in the same way, at the same time, at the same place. Incubate one-third of them at room temperature, one-third of them in a warmer place, and one-third of them in a cool place such as a refrigerator. Have students predict how this will affect the growth of microbes and then compare their predictions to the results.

Research: A “Micro” Safari

Give each student the name of one specific microbe (e.g., Paramecium, yeast, a green alga) to research and draw. Have each student report to the class what the microbe likes to eat, where it lives, and what enemies it has. Have the class decide if each microbe would be caught by a Life Trap. For those microbes that would not be caught, ask students how they could make a better Life Trap.

Activity: “Moldy Michelangelo”

Make extra Life Traps. Have students use toothpicks to transfer tiny bits of colorful colonies from a thriving Petri dish onto a new one. Have them arrange different colors into patterns to “grow” pieces of art!

Mission to Planet Earth- Life Trap!
Can You Detect Life in the Atmosphere?

Analyzing Life Traps--Teacher's Key

1, 2, 3, 4. Student answers will vary. Accept all reasonable attempts.

5. If you leave the experimental dish open for too short a time, you may not “trap” any life, even if life is present.

6. No. This is only an average calculation. It is till possible that no organisms would land in the dish.

7. If no, then the control was adequately sterilized and tightly sealed. If yes, then the control was either not adequately sterilized or not tightly sealed. Microbes may have gotten in when the gelatin was prepared by the teacher, when it was poured into the

team's Petri dish, or whenever the dish might not have been air-tight. This may have happened right in your classroom, or at the strange location. If a control dish on Mars or Venus showed contamination by life-forms, then we could not determine whether or not there was life there because the life in the experimental dish may not have been from Mars or Venus. It could be the same Earth life that was picked up in the control dish before the experiment started.

If the control from Mars does show "life," there is a way that we could use the experimental results: if there are kinds of microbes in the experimental dish that didn't appear in the control dish, we can guess that they got in on Mars, but we can't be as sure as we could if there was nothing in the control dish.

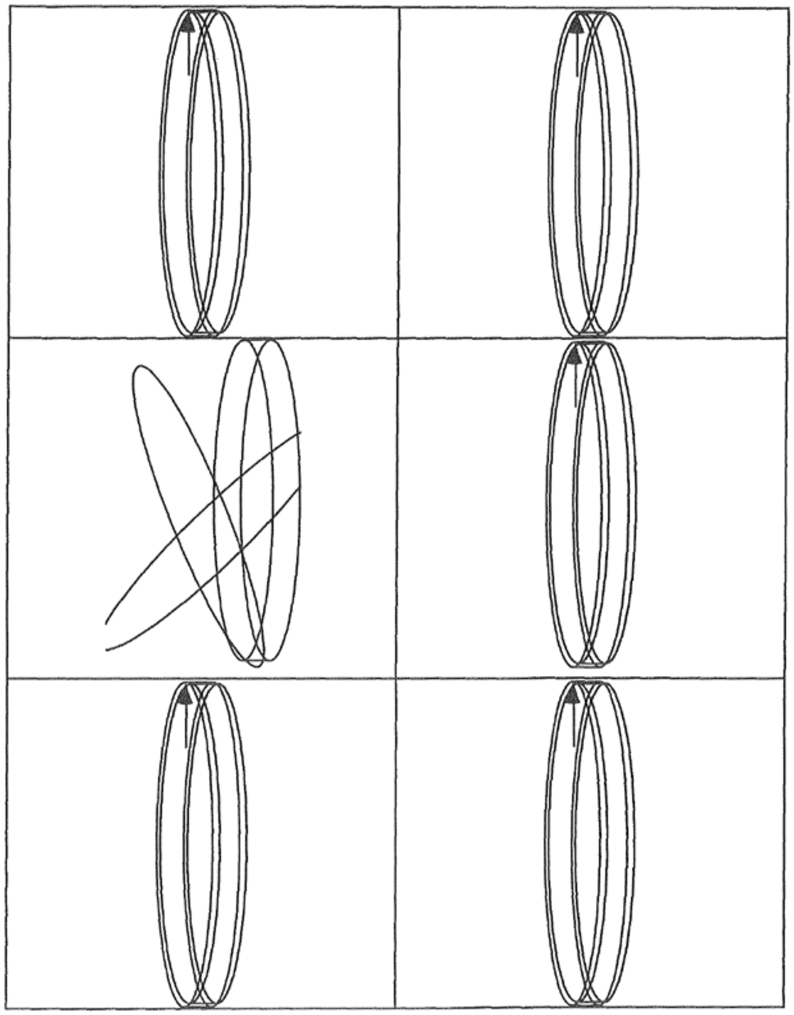
8. Some organisms may not be able to live on the nutrients that are provided in the nutrient medium in the Petri dish

9. You could provide many Life Traps, each with different nutrients, or attempt to put all possible nutrients into one nutrient medium. But you could never be sure!

Mission to Planet Earth- Life Trap!
Can You Detect Life in the Atmosphere?

Experiment and Control Transparency

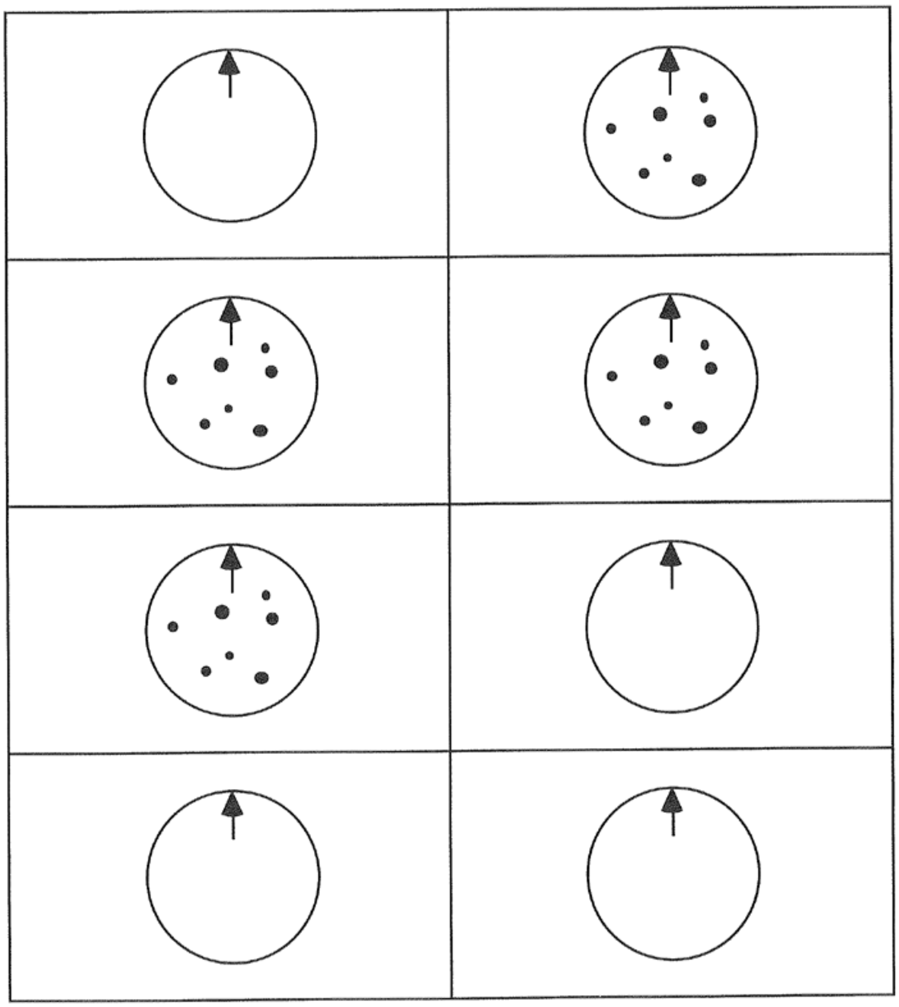
Figure 11.1-Experiment and Control.



Mission to Planet Earth-Life Trap!
Can You Detect Life in the Atmosphere?

Experiment and Control II---Transparency

Figure 11.2-Experiment and Control Maps.



Mission 11 Logbook
Mission to Planet Earth – Life Trap!

Can You Detect Life in the Atmosphere?
Making a Life Trap! - Directions

Today you will become an extraterrestrial scientist who is investigating whether or not there is life in the atmosphere of Planet Earth! You have sent a probe to Earth. This probe will not take soil samples; instead it will be a Life Trap designed to capture any microscopic, airborne life-forms. In this experiment, you will simulate sending a life detection device to some strange location to see if it actually finds life there.

Each team will prepare two identical Life Traps, which are Petri dishes with a nutrient gelatin food supply for microbes. The experimental dish will be opened at a strange location for 20 minutes. The control dish will never be opened. You will observe both dishes for a few days to see if any life appears.

If any microbes settled into the experimental dish while it was open, and if they can use the nutrients in the dish, then they will grow. They may be too small to see at first, but if they have enough time to multiply, they will grow numerous enough so that you can see their colonies. Nonliving things that settle into the experimental dish will not grow at all. Therefore, this is a way of finding life-forms that are too small to see with the naked eye.

Procedure

1. Wash your hands and your work areas with soap and water.

2. Obtain two sterile Petri dishes and four pieces of masking tape. Tape shut your Petri dishes without opening them; this makes a "hinge" on one side of each dish and a rebreakable seal on the other. Write your names on both dishes. Write "Control" on one dish and "Experimental" on the other.

3. Take your Petri dishes to the central area of the classroom where the nutrient gelatin medium is being prepared. Remove one piece of tape from each dish. Your teacher will pour the nutrient medium into your Petri dishes. You must work quickly to close and retape them. Gently swirl the dishes to evenly distribute the gelatin.

4. Agree on a strange location to which one member, or the whole team, will take the Petri dishes after school. These strange locations may include an attic, doghouse, back yard, or wherever. They represent random samples of Earth taken by extraterrestrials!

5. The two Petri dishes should be taken to the strange location and set side by side. The experimental dish should be opened and left open for 20 minutes. Then it should be closed and retaped. The control dish must remain shut. Both dishes should be left at room temperature overnight and brought to school the next day.

6. Both Petri dishes will be examined by your team before they are set aside to incubate for a few days. But they'll be back!

Mission to Planet Earth – Life Trap!
Can You Detect Life in the atmosphere?

Mapping Microscopic Life – Directions

SETI INSTITUTE

1. Examine your team's Petri dishes carefully without opening them. This is a precaution because certain molds could produce irritating or infectious spores, although most common molds are harmless.

2. Make a “map” of the surface of each dish on your worksheet. Mark a line or arrow on the dish with a grease pencil. This will allow you to orient the dishes for future observations after any life-forms have had a few days to incubate.

3. Use a hand lens to examine any growth.

   Here are some of the things you might notice as you examine the dish. Take a guess at what they are, but remember that one must usually use a microscope to be sure of the identification of such small organisms.

   Shiny low circular growths, glistening and. smooth-usually *bacteria.*

   Irregular patches or threadlike things often *funguses* or molds.

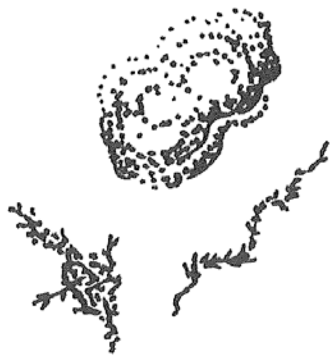
   Dark center is oldest part of colony, may be producing spores. Colony with two older centers was founded by two individuals.

4. Use a plastic ruler to measure any microbial colonies that are growing on your dish. Draw each colony as accurately as you can on your worksheet. Put each colony in the right place on the map and Fungus including mold. draw it the correct size.

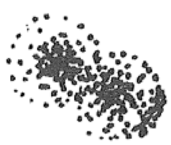
5. After your team has mapped your own Petri dishes, visit other teams. A good way is for half of your team to remain at their station to explain their findings to visitors while the other half circulates; then switch halves and duties.

Figure 11.3—Microscopic Life.

Bacteria.



Fungus including mold.



Colony produced by two spores.

6. Put your pair of Petri dishes away somewhere at room temperature for safekeeping. You will be observing them for a few minutes each day over the next few days.

7. Calculate the minimum time that the Life Trap would have to remain open to catch one microbe at your test location.

8. At the end of the entire experiment, follow your teacher's instructions to dispose of the Petri dishes.

Mission to Planet Earth – Life Trap?

Can you detect Life in the atmosphere?

Life in Strange Locations – Worksheet

Name: ______________________________________ Date: ______________________________

1. After school, pick up both dishes and take them and this data sheet to the test location. Remove the lid from the experimental dish and write the time in the blank below. Let the dish sit open, exposed to the air, for 20 minutes. (Don't put anything into the dish.) Then close and retape the dish and record the time and other data below.

Date of test:

Test location:

Time opened:

Time closed:

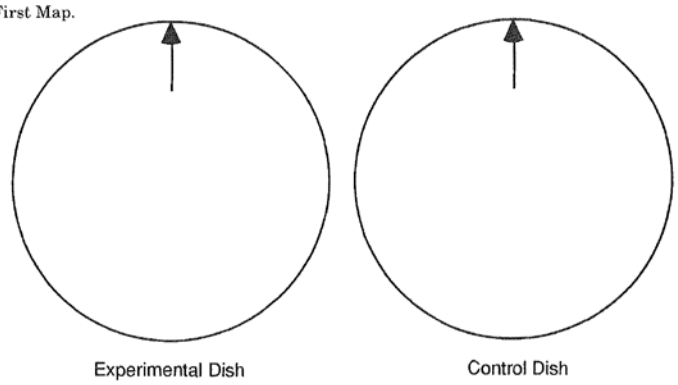
Person(s) observing:

Description of test area (particularly wind conditions, dustiness, and approximate temperature):

How "clean" does the area appear?

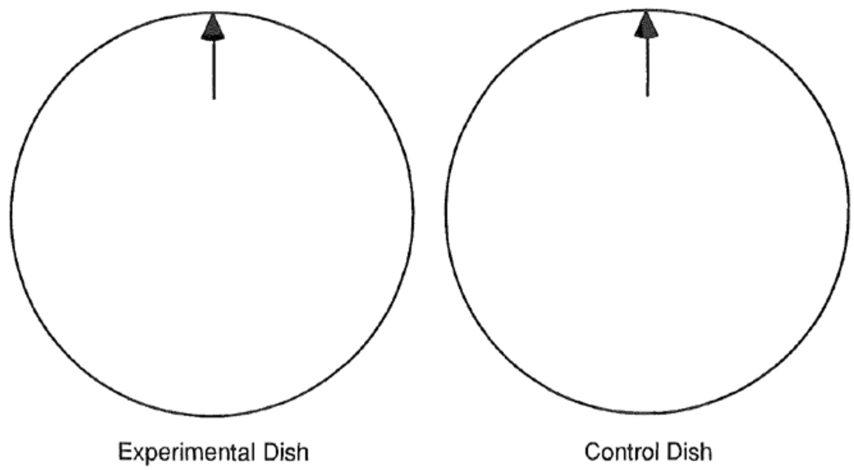
2. Initial Maps of Life Traps. Date of observations:

Figure 11.4—First Map.



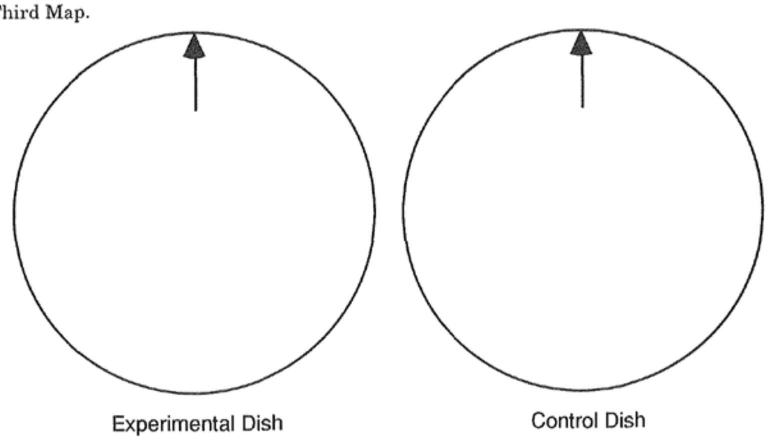
3. Second map of Life Traps. Date of observations:

Figure 11.5—Second Map.



4. Third map of Life Traps. Date of observations:

Figure 11.6—Third Map.



Mission to Planet Earth – Life Trap!
Can You Detect Life in the Atmosphere?

Analyzing Life Traps – Worksheet

Name: ______________________________ Date: ______________________________________

1. As a team, compare your newer maps with the earlier ones. List all of the changes you observed.

2. List the number of original colonizers that invaded your experimental dish and use the identification diagram on your instruction sheet to see what kinds they were.

   Number of colonizers in experimental dish:

   Kinds of colonizers in experimental dish:

3. On average, how many colonizers invaded the experimental dish per every minute that it was open? To find out, divide the number above by the number of minutes that the dish was open.

   Number of minutes the experimental dish was open:

   Average number of colonizers per minute

5. You can now estimate how long you would need to leave the dish open, at your test site, to be reasonably sure of catching at least one of the types of organisms shown. To do so, divide the number of minutes that the trap was open by the number of organisms. (This is the reciprocal of the numbers found in number 3, which is the same as 1 divided by the numbers shown.)

   Number of minutes needed to catch at least one organism:

6. If you had left the experimental dish open for less time than the number of minutes shown in the last blank, what do you think would have happened?

7. If you had left the experimental dish open for more time than the number of minutes shown in the last blank, would you have detected life? Why or why not?

8. Are there organisms in your control dish? yes no

   If the answer is yes, how did they get there, and when and where did it happen?

   If the answer is yes, and if the experimental dish had been opened on Mars or Venus, rather than at your test location, what would that tell you about whether or not there is life on Mars or Venus?

9. There were probably a few organisms that entered the experimental dish that did not grow there. Why not? What might have kept them from growing?

10. Suppose that the dishes were to go to Mars or Venus, and suppose- that somebody on your team says that they couldn't detect Martian or Venusian life because the organisms there can't use the nutrients in your Life Trap. How might you answer them? How might you change this experiment?

Mission 12
Can You “Gas” What’s Happening?

Gas Production in Living and Nonliving Systems

Overview

In mission 12.1, students examine gas production in two soil samples, one seeded with seltzer and one with yeast. They activate the soils with a hot, nutrient solution and observe their gas production. In mission 12.2, students graph their results from their soil samples and discover some of the characteristics of living and nonliving systems. They deduce which of their soils contain life.

Notes

In mission 11, students used Life Traps to collect airborne microbes. If extraterrestrial scientist sent a robotic space to Earth, could they detect life in the soil without collecting the microbes? Living things give off gases, but so do simple chemical reactions A nonliving system will produce gas rapidly until the Limiting reasctant is no longer available. Then gas production ceases. A living system’s gas production begins slowly as the organism’s population increases. This is followed by a period of steady gas production and a long slowdown as space or nutrient supply limits the living system’s growth.

Mission 12.1
Materials

For a Class of 30

- Overhead projector
- “Measuring Gas Production” transparency
- 6 liters of dechlorinated water at about 60” C
- 2 cups of sugar
- 13 seltzer tablets (Alka Seltzer@ works well)
- 16 1/4-ounce packages of yeast
- 2 cups of clean or sterile fine-grained sand
- 2 soil-sample holding bowls
- Small jar of glycerin or liquid soap
- Thermometer
- 250 – ml Erlenmeyer flask
- Clock with the second hand
- Tablespoon

For Each Team

- 2 250-ml Erlenmeyer flasks
- 2 single-holed stoppers (must fit into the Erlenmeyer flasks)
- 2 10-cm glass tubes (must fit into the stopper holes)
- 2 30-cm rubber tubes (must fit onto glass tubes)
- 2 100-ml graduated cylinders
- Water tub (must be large enough to hold 2 Erlenmeyer flasks)
- Ruler
- 2 pencils
- 2 soil-sample carrying dishes
- "Measuring Gas Production" directions

For Each Student

- "It's a Gas!" worksheet
- Pencil

Getting Ready

1. Make a nutrient solution just before class. Use a thermometer and obtain six liters of hot water (approximately 60º C). Mixing two cups of sugar with the hot water will make enough nutrient solution for 15 teams. The ideal temperature for yeast gas-production is 50º C. By the time students transport and introduce a soil sample into the nutrient solution, it will have cooled to about 50º C. Yeast gas-production is not as dramatic alien the nutrient temperature is less than 40ºC, and yeast are killed when the nutrient temperature is above 55º C.

2. Make a demonstration soil sample and two soil sample mixtures as follows. (Two of these soil sample mixtures were used in mission 10. If you made extra of these mixtures or have leftover material, use it now.)

   Demonstration Sample - Crush 5 seltzer tablets and mix with 5 tablespoons of sand. Put this mixture into the 250-ml demonstration flask.

   Earth Sample # 3-Crush the seltzer tablets into fine pieces using the back of a spoon to press on the packets before they are opened. Open the packets and mix the seltzer with 32 tbs (2 cups) of sand. Put the mixture into a bowl and label it "Earth Sample # 3."

   Earth Sample # 4-Mix the yeast with 32 tablespoons (2 cups) of sand. Put the mixture into a bowl and label it "Earth Sample # 4."

3. Because there is the possibility of students breaking the glass tubes and injuring themselves, you should put the glass tubes into the single-holed stoppers yourself.

Use glycerin or liquid soap as a lubricant. Hold the tube at the point where it enters the stopper and gently twist the tube as you insert it into the stopper. Do not use excessive force!

4. Practice Readings. The teacher should practice taking readings before the students take the practice readings. Students may have difficulty reading the levels of gas because the seltzer reaction occurs so fast. You may want to set up inverted cylinders around the room so that students can practice taking readings before they do their experiment. You may sketch a diagram on the board showing how to read the level.

5. Copy the “Measuring Gas Production” directions for each team and the “It's a Gas!” worksheet for each student.

6. Prepare the “Measuring Gas Production” transparency. Set up the overhead projector.

Classroom Action

1. **Discussion**. Divide the class into teams of two students each. Show students the two soil samples. Tell them that their extraterrestrial probes can send back a picture of each soil sample, but that they do not have microscopes to enlarge the view. Have students look at the soil. Ask them to see if they can find life in either sample by direct observation. Could there be dormant life in the samples? Ask students to think of ways to activate the samples. *(Some answers might include addition of water or other liquids, or changes in temperature.)* Tell students that they will use a nutrient solution and heat to activate any dormant life.

2. **Demonstration.** Introduce the warm nutrient solution to the demonstration flask of soil seeded with 5 seltzer tablets (more seltzer than the student sample, for a greater effect). The flask should overflow with bubbles. Ask students if they think that this shows that the soil contains life. Are released gases a sign of life?

3. **Discussion.** Ask students to name some of the gases given off by living things. *(Living things give off carbon dioxide (C02) during respiration, oxygen (02) during photosynthesis, and methane (CH4) and numerous sulfides during flatulence.)* Ask students to name some nonliving things that release these and other gases. *(Nonliving things that release gases include automobiles: NO, N02, C02 and CO; gas stoves: H20, CO2, and CO; baking soda and vinegar: C02; chemical factories: a great variety of gases; fires: COs.)*

   Tell students that they will test their two Earth Sample soils and then decide which one has life in it by examining released gases. Ask students if measuring the release of a gas from an unknown substance is a good way to detect life. How might we be able to tell if a system is living by observing the gases given off? Have students hypothesize how the rate of gas production might differ between living and nonliving systems. For both living and nonliving systems, try to address these issues: Will gas production start quickly or slowly? Will gas production stay constant or fluctuate?

Will gas production stop and, if so, why, when, and how quickly? Which system will give off more gas?

4. **Activity.** Hand out the "Measuring Gas Production!" directions to each team and the "It's a Gas!" worksheet to each student (note that there is no teacher's key for this worksheet because student answers to the questions will vary; all reasonable attempts should be accepted). Have students complete the graph for their hypothesized living and nonliving systems. Distribute soil samples to each team.

5. **Transparency.** Show the "Measuring Gas Production" transparency. Use it to explain the setup. By putting a soil sample into an Erlenmeyer flask and adding a warm nutrient solution, you are trying to cause gas production, either by means of a living metabolic reaction, or from a nonliving chemical reaction. Quickly sealing the flask after the addition of the warm nutrient solution with a single-holed stopper allows you to route any gas formed in the flask through a tube and collect it in a partially submerged and inverted graduated cylinder.

   As gas is produced, it will force water out of the cylinder. If the change in volume is timed and recorded, you will be able to find the rate of the gas production of the sample being tested. The rate is important in determining if life is responsible for the gas production. After testing both samples, a graph of your data will tell you if one of the samples contained dormant life that was activated by the warm nutrient solution.

6. **Demonstration.** After the explanation, do a hands-on demonstration. Choose a student assistant for the last few steps of the demonstration.

Procedure

a. Measure 2 Tbs. of a soil sample into your carrying dish and write down which sample number you are using.

b. Insert a glass tube through a single holed stopper. If students are inserting their own glass tubes, then they should coat one end of the glass tube with glycerin or liquid soap, and put that end of the glass tube into the single-holed stopper. Students should hold the glass tube at the point where it enters the stopper and gently twist the tube as they push it through the stopper. Do not use excessive force!

c. Connect 1 ft. of rubber tube to one end of the glass tube.

d. Fill a water tub halfway with warm water.

e. Place the stopper-tube assembly and the graduated cylinder underwater in the tub. Let any air bubbles escape. While the equipment is still under water, insert the rubber tube 10 cm up into the mouth of the graduated cylinder. Be careful to keep the rubber tube in the graduated cylinder and the mouth of the graduated cylinder underwater throughout the entire experiment.

f. Raise the base of the graduated cylinder until it is inverted (held upside down). Trapped air should be much less than 5 ml; if there is too much trapped air, repeat the procedure. One student must continue to hold the graduated cylinder. This student also holds the rubber tube in the cylinder, keeps track of timing, and will make the readings on gas production.

g. The other student should pour 200 ml of hot nutrient solution into the Erlenmeyer flask and hold the flask on the bottom of the tub. As quickly as possible this student pours the soil flask and seals the flask with the stopper end of the stopper-tube assembly.

h. The first student should take an initial reading of the graduated cylinder by holding it vertical and lowering his or her eye level to the reading level.

i. The second student records all readings on the student worksheet. Readings should be made at 30-second intervals. After three minutes, change the reading interval to every minute instead of every half minute. Stop taking readings after 15 minutes or after the gas level in the cylinder has not changed for two minutes.

- Earth Sample # 3: The seltzer will require two minutes of reading time. It will initiate rapid gas production immediately and then stop producing completely within 30 seconds. In this time, the seltzer will have produced approximately 80 ml of gas.

- Earth Sample # 4: The yeast will require 15 minutes of reading time. Its gas production will start gradually and then steadily increase. Within 15 minutes, the yeast will have produced approximately 70 ml of gas. Gas production will begin slowing after about 20 minutes; it won't completely stop until a few days later.

  Now is a good time for your students to practice reading graduated cylinders. Refer to step 4 in Getting ready.

7. **Activity.** Have teams gather their materials and begin experimenting. Tell students that after they have finished testing one Earth sample, they should test the other Earth sample as well. Have team members switch tasks on their second test. Have students answer their worksheet questions while they are taking readings.

Mission 12.2
Materials

For a Glass of 30

- Projector
- “Gas Production Graphs” transparency

For Each Student

- Sheet of graph paper
- "Gas Analysis" worksheet
- Pencil

Getting Ready

1. Copy the "Gas Analysis" worksheet for each student.

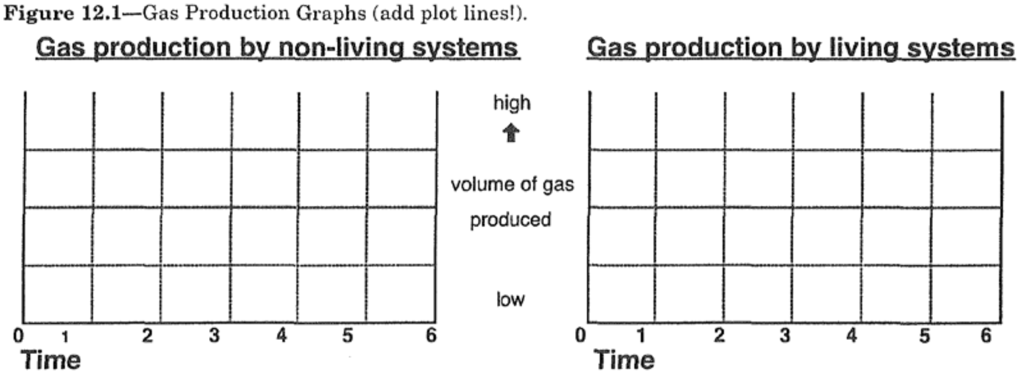
2. Prepare the "Gas Production Graphs" transparency. Set up the overhead projector.

Classroom Action

1. **Activity.** Hand out the "Gas Analysis" worksheet and a sheet of graph paper to each student. Explain to students that they will be graphing the data from their gas production experiment. If necessary, review with the class how to plot a graph. Use the x-axis for time in minutes and the y-axis for volume in milliliters or cubic centimeters (1 ml = 1 cm3). Have each student graph the results of their two tests. Make sure they use a different kind of line for each test.

2.**Transparency.** Show the "Gas Production Graphs" transparency. Plot the class's results onto this transparency or have students come up and plot them as shown in figure 12.2.

Figure 12.1—Gas Production Graphs (add plot lines!).



Invite the class to describe each of the plots. How are the lines the same? How are they different? What does this say about the gas production in the nonliving system? What does this say about gas production in the living system? Focus on different sections of the slope from each plot. Ask the class to interpret what is happening to the reaction rate in each time interval you point out. By observing the graphs, would it be possible to determine which of the soil samples contained life? How could you tell? How could you use this information for detecting the presence of life in an unknown system?

Going Further

Activity: A Better Probe

Imagine an expensive extraterrestrial probe that has a microscope, and imagine that it can send back to Earth images of its microscopic observations. Have students put small amounts of the soil samples onto slides and observe the yeast reaction and the seltzer reaction under a microscope. One student should keep an eye focused on the dried powder while a second student adds a drop of warm nutrient solution to the soil. Then students should switch. Ask them if they observed any differences between the yeast reaction and the seltzer reaction. Could this observation, by itself, prove that life was or was not present?

Activity: Bakers and Brewers
Activity: Fruit of the Vine

The white film that appears on growing grapes is a natural yeast. (Ultra clean supermarket grapes may be stripped of their yeast.) Ask students to gather such grapes and make slides of the yeast to observe its growth under a microscope. Ask students to deduce a way to measure gas production from the yeast. What "warm nutrients" are activating the yeast? How did the yeast get onto the grapes?

Discussion: Confusing Results

Pose a question to students: What if a soil sample that you tested for gas production had life in it as well as nonliving chemicals that were capable of producing gas? Ask students to graph what the gas production of such a sample might look like. Ask students to repeat this experiment with the following soil sample: 2 tablespoons of Earth Sample # 4 mixed with 1 tablespoon of Earth Sample # 3.

Gas production by yeast is essential to the process of making bread and beer. Give students a recipe for a bread that uses yeast and a recipe for an unleavened bread. Ask them to prepare the two doughs and observe them side-by-side: the yeasty dough will rise while the unleavened dough will not. Students bake and eat the two breads, comparing taste and texture. Arrange to have the bread baked in the school cafeteria or have students do it at home with adult supervision. Different varieties of yeast contribute to the difference in breads. Each bakery maintains its own yeast culture, which provides a characteristic taste. Have students visit a bakery or a brewery to observe commercial production of yeast.

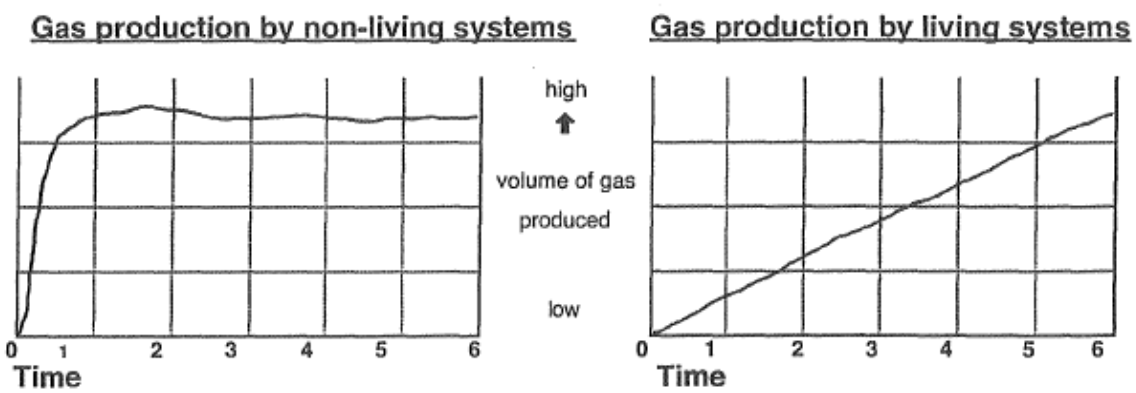
Gas Analysis-Teacher's Key

1. Wow! Earth Sample # 3 produced gas extremely rapidly, and it stopped producing gas within 30 seconds. In this time it produced approximately 80 ml of gas.

2. Earth Sample # 4's gas production started out gradually and proceeded steadily to a production of approximately 70 ml within 15 minutes. (This sample will only show signs of slowing its rate of gas production after 20 minutes.)

3. See the graphs below.

Figure 12.2—Teacher's Key for "It's a Gas" and "Gas Analysis."



4. This looks like a chemical reaction! It began fast, went fast, and ended abruptly, as if one reactant chemical had been used up. It could be that the warm nutrient contained a chemical that reacted with a chemical in the soil.

5. This looks like a living system! Gas production began slowly, built up, and is still continuing. It could be that the warm nutrient activated dormant life, much as water activates dormant brine shrimp eggs in soil.

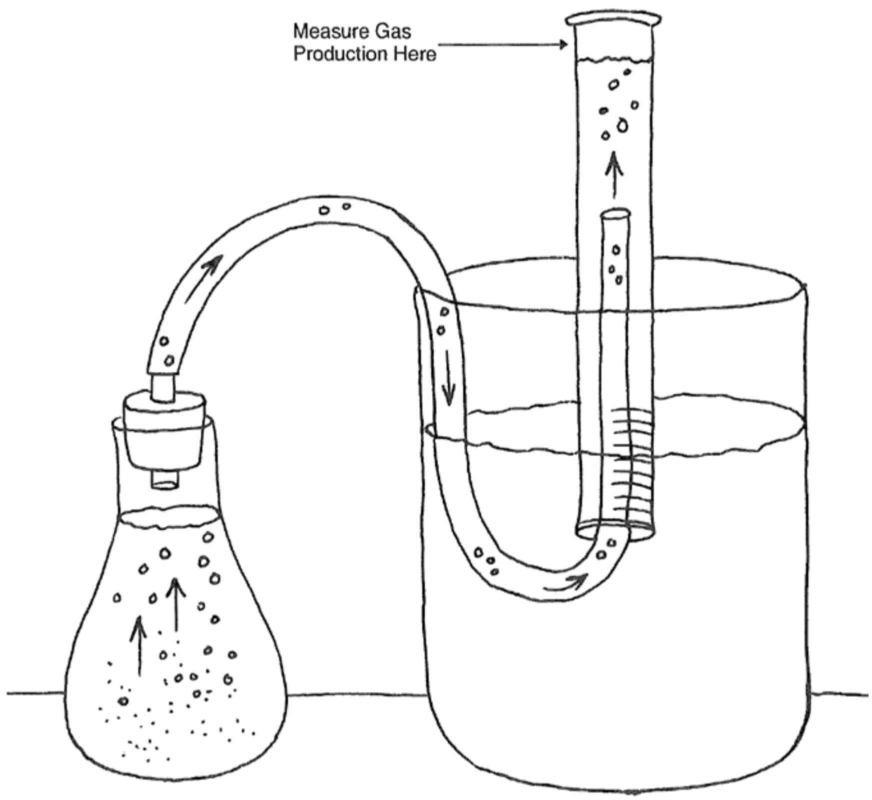
6. Yes! Earth Sample # 4.

7. Student responses will vary. Accept all reasonable attempts.

Can You "Gas" What's Happening
Gas Production in Living and Nonliving Systems

Measuring Gas Production-Transparency

Figure 12.3-Gas Production Setup.



Can You "Gas" What's Happening?
Gas Production in Living and Nonliving Systems

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Gas Production Graphs-Transparency

Figure 12.4-Gas Production Graph, Living Systems.

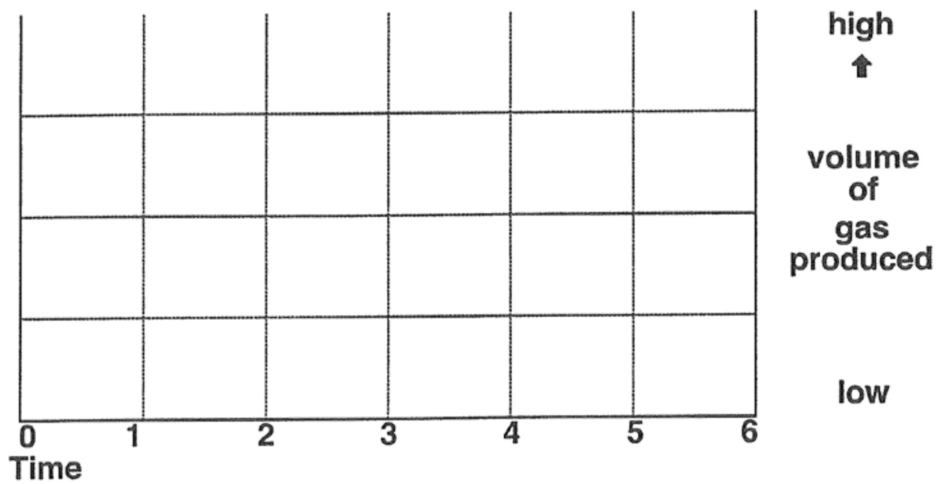
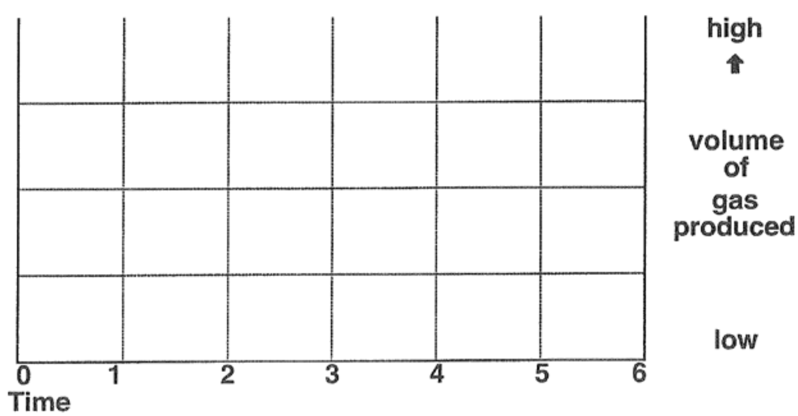


Figure 12.5-Gas Production Graph, Nonliving Systems.



Can You "Gas" What's Happening?
Gas Production in Living and Nonliving Systems

Measuring Gas Production- Directions

1. Measure 2 tablespoons of each soil sample into a carrying dish. Be sure to label each dish.

2. Obtain a single-holed stopper that has a glass tube in it.

3. a. Connect 1 foot of rubber tube to one end of the glass tube.

   b. Fill your water bath halfway with warm water.

   c. Put together the stopper-tube assembly and submerge it in the water bath.

   d. Submerge the graduated cylinder in the water bath.

   e. Put the rubber tube 10 centimeters into the graduated cylinder while holding it under water.

   f. Let any air bubbles escape.

   g. Now invert (turn upside down) the graduated cylinder.

   h. Make sure there is very little air in the cylinder. Be careful to keep the rubber tube in the graduated cylinder and the mouth of the graduated cylinder underwater throughout the entire experiment.

4. One student must continue to hold the graduated cylinder under water. This student also holds the rubber tube in the cylinder, keeps track of timing, and makes the readings of gas production.

5. The other student should pour 200 ml of hot nutrient solution into the Erlenmeyer flask and hold the flask on the bottom of the tub. As quickly as possible, this student should pour the soil sample into the flask and seal the flask with the stopper end of the stopper-tube assembly.

6. The first student should take an initial reading of the graduated cylinder by holding it vertical and stationary and lowering his or her eye-level to the reading level.

7. The second student should record all readings on the student worksheet. Readings should be made at 30-second intervals. After three minutes, change the reading interval to every minute. Stop taking readings after 15 minutes or after the gas-level in the cylinder has not changed for two minutes.

8. Repeat this procedure with the other Earth Sample. Switch roles for holding the flask and taking the readings.

Can You "Gas" What's Happening?
Gas Production in Living and Nonliving Systems

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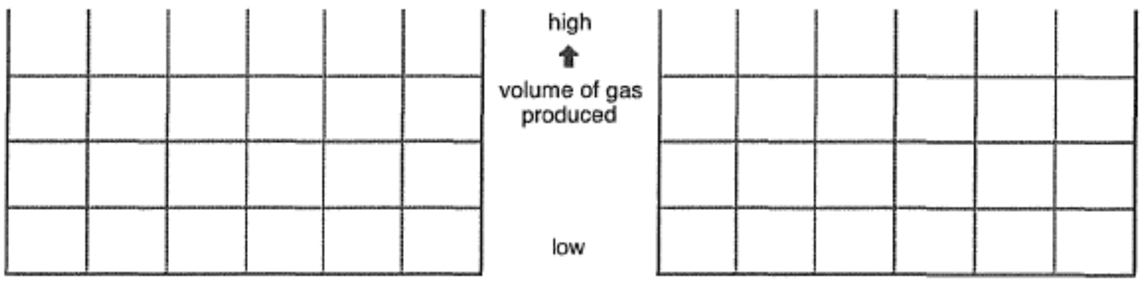
It's Gas! Worksheet

Name: ______________________________ Date: ______________________________

1. What do you think your graphs will look like? Sketch your best guesses below.

Figure 12.6—Gas production Graphs



2. State your hypothesis:

3. Record your data into table 12.1 on **XXXXX**.

Table 12.1—Gas Production Data

Time in Minutes	Sample # 7 Gas Production in ml or cubic cm	Time in Minutes	Sample # 8 Gas Production in ml or cubic cm
0.5		0.5	
1.0		1.0	
1.5		1.5	
2.0		2.0	
2.5		2.5	
3.0		3.0	
4.0		4.0	
5.0		5.0	
6.0		6.0	
7.0		7.0	
8.0		8.0	
9.0		9.0	
10.0		10.0	
11.0		11.0	
12.0		12.0	
13.0		13.0	
14.0		14.0	
15.0		15.0	

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Can You “Gas” What’s Happening?
Gas Production in Living and Nonliving Systems

Gas Analysis – Worksheet

Name: ________________________________ Date: __________________________

1. What were your observations of Earth Sample # 3?

2. What were your observations of Earth Sample # 4?

3. Graph your results. Use the hypothesis graphs as a guide to set up a proper graph.

4. Describe what you think is happening in the graph of Earth Sample # 3?

5. Describe what you think is happening in the graph of Earth Sample # 4?

6. What were the differences and similarities in the gas production of the two soils?

7. Do you think that either of the soils contains a living system? Why or why not?

8. How did the final results differ from your initial hypothesis?

Mission 13
The Viking Search for Life on Mars

Is There Life on Mars?

Overview

In mission 13.1, student teams go on a “Mission to the Schoolyard” to sample “target sites” much in the way Viking landers sampled sites on Mars. In mission 13.2, students analyze the results from Viking's three life detection experiments. Students decide whether or not the Viking mission found proof of life on Mars by solving two “Mysteries of Mars.” They then propose a new mission of their own to Mars.

Notes

Scientists and science fiction writers have always considered Mars the most likely planet in our solar system, other than Earth, to host life. In 1976, two Viking landers arrived on the red planet to investigate. Television cameras revealed a rocky landscape with no obvious plants or animals. The landers were not equipped with microscopes to look for microbes directly, but they did perform three microbial life detection experiments. These were the Gas Exchange (GEX) experiment, the Labeled Release (LR) experiment, and Pyrolytic Release (PR) experiment. The results of all three tests initially came back positive, causing considerable excitement. But the Viking scientists decided that this did not prove that life was present on Mars because the results could have been caused by nonbiological chemical reactions with water.

Mission 13.1
Materials

For a Class of 30

- 6 plastic rings at least 12 inches in diameter
- 6 blindfolds
- 6 plastic cups or scoops
- (optional) Instant film cameras
- (optional) Drawing materials
- (optional) Colored pencils

For Each Student

- “Mission to the Schoolyard” directions
- “Mission to the Schoolyard” worksheet
- Pencil

Getting Ready

1. Find six “target sites” around the schoolyard that students may “sample.” Some should be on grass or bare dirt, but others may be on concrete.

2. Copy the “Mission to the Schoolyard” directions and worksheet for each student.

Classroom Action

1. **Discussion.** Tell students about America's Viking mission to Mars in 1976. With this mission, space scientists were limited to those areas of Mars that they could sample. With only two landers, which were immobile after touchdown, the amount of Martian soil that could be tested was small. Additionally, the landing sites were not optimized for possible biology; it was more important that they be relatively smooth plains, so that the landers would not tip over. The exact touchdown points could not be predicted.

2. **Activity.** Hand out the “Mission to the Schoolyard” directions and worksheet to each student. Divide the class into six teams. Each team will play the role of an extraterrestrial probe sent on a mission to the schoolyard. Assign each team to one of the selected general target sites (*e.g.*, playground, grassy area). Give each team a plastic ring, a blindfold, a collecting scoop (plastic cup), and drawing materials. Set a time limit and launch the teams to their mission landing sites. Read the “Mission to the Schoolyard” directions aloud during this activity.

   (optional) During this activity, visit the teams and document this mission with instant film photographs. Standard cameras and overnight developing can be used to simulate delayed image retrieval, adding a second day to this activity.

3. **The Mission to the Schoolyard.** Lander: Go to your general target site. Choose one student to be the Lander. Blindfold the Lander, and turn him or her around a few times, and then lead him/her a few steps forward. Hand the Lander a sampling ring. The Lander should then gently toss the ring to the ground. This simulates the randomness in the exact touchdown point for Viking (assuming that the Lander is not too much directed by students who are not blindfolded!).

   Photographer and/or Data Recorders: If your team has a camera, photograph the area inside the sampling ring. (Alternatively, the teacher may come and do this.) This is the only view that your Lander has. If your team does not have a camera, then each of you should sketch what you see within the ring. This simulates the pictures of the landing site made by Viking, and sent to Earth.

   Soil Sampler: Another student should be the Soil Sampler. Give him or her a sampling scoop (the plastic cup). He or she must take a sample from the center of the ring and bring it back to class. If it is not possible to actually collect any soil (*e.g.,* if the target site is the cafeteria floor), sample anything that is present inside the ring that can be scooped up by the cup (*e.g.*, dust or crumbs). This simulates the collecting of soil for Viking's life detection experiments.

4. **Discussion.** Have each team present its observations to the class and discuss them in terms of a search for life. A concrete surface, for example, is not a living thing, but is it a sign of life? Could it be a hard clay surface left by evaporating water? Could it be very smooth rock? Based upon the sampling and observation, did your team detect any life or signs of life on Earth? Or would your mission lead you to believe that Earth is a dead planet? If there are no obvious signs of life, are there any tests that you could perform on a sample to detect unseen life? Recall the tests your class has done on other soil samples.

   (optional) Perform one or more tests from previous missions on students' samples. Ask students to decide which tests to use.

   (optional) If photographs were taken, put them on display and ask students to guess where they were taken. This may be particularly puzzling for close-up photographs.

Mission 13.2
Materials

For a Class of 30

- Overhead projector
- “The Viking Mission” transparency (2 pages)
- “Mystery of Mars # 1” clue cards

For Each Student

- “Viking's Life Detection Tests” (1 page)
- “Mysteries of Mars” worksheet
- “A New Mission to Mars” worksheet

Getting Ready

1. Copy the “Viking's Life Detection Tests,” the “Mysteries of Mars” worksheet, and the “A New Mission to Mars” worksheet for each student.

2. Copy a set of clue cards for “Mystery of Mars # 1.” Cut them apart into individual clues.

3. Prepare “The Viking Mission” transparency. Set up the overhead projector.

Classroom Action

1. **Transparency.** Show the overhead transparency. Briefly explain Viking's three life detection experiments. In the actual Viking mission to Mars, three life detection tests were made on random soil samples taken at two sites. Each test used a different detection method. We will look at the strange, and unexpected, results of these three tests. All the tests initially gave

positive readings. Of course, a positive result should indicate the presence of life. But when the Viking scientists looked at the tests again, they concluded that the results did not prove the existence of life on Mars.

Pose a mystery question to the class (“Mystery of Mars # 1”):

Why did Viking scientists conclude that their detection tests did not prove the existence of life on Mars even though all three tests initially gave positive readings?

Discuss the concept of a “false positive” result, in this case the idea that positive readings may not always mean what you think they mean.

2. **Activity.** Divide the class into teams of two students. Hand out the “Viking's Life Detection Tests” and the “Mysteries of Mars” worksheet to each student. Ask teams to examine the Viking experiments as described on their fact sheets and then brainstorm as to why the Viking scientists concluded that they could not prove that life was present on Mars, despite the positive results from their tests.

   If a team is completely lost, give them one of the four clue cards. These should be given out randomly; their order is unimportant, as each clue relates to every experiment. Challenge students to solve the mystery with as few clues as possible!

3. **Discussion.** After students have done all they can with the first mystery, hold a class discussion. Have students contribute ideas until all students see the answer: Each of the three positive results could have been caused by nonliving chemical reactions, specifically a reaction from adding water to the dry Martian soil. Make the point that not even trained scientists can foresee every possibility. Much thought went into designing the three life detection experiments, but even more thought must go into designing future life detection techniques!

   Pose a second mystery question to the class (“Mystery of Mars # 2”):

   Could it be that life is present on Mars and Viking failed to detect it?

4. **Activity.** Have teams brainstorm about the second “Mystery of Mars.” Introduce any information you feel is appropriate. (There are no associated clue cards.)

5. **Discussion.** After students have done all they can with the second mystery, hold a class discussion. Have students contribute ideas until all students see the answer. There are at least two reasons why Viking could have failed to detect life even if it does exist:

   Insufficient sample. Viking's landers may have landed at lifeless locations. Only a tiny part of the Martian surface was actually sampled. The selected Viking landing sites were not optimized for possible biology. However, some scientists believe that planet-wide dust storms would probably distribute microscopic life over the entire surface of Mars.

Biochemical bias. Viking's experiments, like many of those that we are conducting in these missions, were all based upon the assumption that any life on Mars would be life as we know it on Earth. Viking's tests were designed to detect life with metabolisms similar to the metabolism of Earth life. But Martian life could be metabolically different than Earth life. However, based on our theories of the origin of life, most scientists believe that any life on Mars would be metabolically similar to Earth life.

6. **Activity.** Hand out "A New Mission to Mars" worksheet to each student. Tell students that future missions to the red planet may reveal new and surprising facts. What should we do differently next time to discover any life that is there? Have students answer the questions in class or as homework.

Going Further

Research: The Exobiologist's Nightmare

The Viking landers only sampled a tiny portion of the Martian surface. What if life existed everywhere on Mars except for the two little spots where we looked? This is the exobiologist's nightmare! Could this happen on Earth? Are there spots on our planet where there is no life? A desert? The ice sheets of Antarctica? Freshly fallen snow? Have students find out where the landers touched down on Mars. Were there indications that it was a good spot to look for life? What would have been a better location? In the canyons? Under the surface? Near the polar ice caps? What if microbial life was present on Mars four billion years ago (when running water probably existed) but then disappeared? How could we find evidence to support this hypothesis?

Research: More Missions to Mars

There are new missions to the red planet being planned now. In the late 1990s, Russia is scheduled to launch a Mars mission that will include orbiters, landers, and penetrating darts to take samples beneath the planet's surface. Future American missions will be using miniature rovers to scout the Martian landscape. Have students make posters showing the missions, the information scientists hope to gather, and when they will occur.

The *Viking* Search for Life on Mars
Is There Life on Mars?

Mission to the Schoolyard--Teacher's Key

1. Student responses and drawing ability will vary. Accept all reasonable attempts. Look for precision and careful observation.

2. Student responses will vary. Accept all reasonable attempts. You should have an idea of the physical characteristics of each site so that you may check on their accuracy.

3. Student responses will vary. Accept all reasonable attempts, depending upon the sample seen by the student. Look for logical patterns of response.

4. Such tests include looking for water in the samples, charring substances, iodine testing for starch, and so on.

5. Student responses will vary. Accept all reasonable attempts. In cases where life was found (*e.g.*, ants) or detected (positive iodine test on fragments in soil) it must be concluded that Earth has life. In cases where only dust and other lifeless materials were seen, it must be concluded that no life wasn't found, but students should not conclude that the entire planet is lifeless from one (or a few) random samples that turned out to be lifeless.

6. Student responses will vary. Accept all reasonable attempts. Consider that random sampling, in theory, may not be the most effective way to search for life on a planet, but in reality it is the only way to search for life. Scientists need to consider where the lander will set down on a planet's surface and how many samples can be taken.

The Viking Search for Life on Mars
Is There Life on Mars?

Mysteries of Mars—Teacher's Key

Mystery of Mars # 1

1. and 2. In the first two cases, the GEX and the LR, the initial positive results could be explained by nonliving chemical reactions caused when the chemicals in the dry soil of Mars reacted with the water that was added as part of the experiment. Water is a very reactive compound, and the chemical-rich soil of Mars is completely dry. This should remind students of mission 12, where gas production was caused by the addition of a warm nutrient solution (which was water-based) to their seltzer-containing soil sample. Purely chemical reactions can mimic the chemical actions of life.

3. In the Pyrolytic Release experiment, two of the soil samples were heated to a degree that should have destroyed any organisms. One wouldn't expect Martian organisms to be resilient to high temperatures in view of the fact that it never gets warmer than 0” Celsius at these landing sites. Instead the results were again positive, giving rise to the suspicion that some chemical reaction was responsible for the result. This should remind students of the results of the Venus Plates and Mars Jarsthe *Penicillium notatum* survived the freezing conditions in the Mars Jar but not the heat the Venus soil sample was exposed to.

4. In all three cases, the positive results can be explained by nonbiological processes. It is also possible, though highly unlikely, that contamination by some materials brought from Earth could be an explanation. The fact that many other tests run by *Viking* were clearly negative indicated that the positive results were far less likely to have been caused by life. Tests of the Martian soil showed no organic compounds. Tests of the Martian air showed no compounds

that would indicate the presence of life (such as oxygen or methane). The cameras saw no signs of life on the Martian surface and detected no movement of living things. The presence of life is unlikely given these negative results.

Mystery of Mars # 2

1. There are at least two reasons why Viking could have failed to detect life even if it does exist:

   Insufficient sample. Viking's Landers may have landed at lifeless locations. Only a tiny part of Mars' surface was sampled. Life may exist at other locations on Mars. The selected Viking landing sites were not optimized for possible biology. However, some scientists feel that planetwide dust storms would probably distribute microscopic life over the entire surface of Mars.

   Biochemical bias. Viking's experiments, like many of those that we are conducting in these missions, were all based upon the assumption that any life on Mars would be life as we know it on Earth. Viking's tests were designed to detect life with metabolisms similar to the metabolism of Earth life. But Martian life could be metabolically different. However, based on our theories of the origin of life, most scientists believe that any life on Mars would be metabolically similar to Earth life.

The *Viking* Search for Life on Mars
Is There Life on Mars?

A New Mission to Mars-Teacher's Key

1. The Viking scientists did not consider the possibility of water reacting with chemicals in the dry soil. Also, they were not able to exclude all sources of contamination.

2. Any chemical experiments must take into account the possibility of nonliving chemical reactions and be able to tell them from those reactions caused by living things. Measures such as sterilization and containment barriers are needed to prevent contamination.

3. As many as possible! It would be best to have a “rover” on the lander so that many random samples could be taken. It would also help to pick the sites with the best chances for the presence of life, and to sample from all possible habitats.

4. Student answers will vary. Accept all reasonable attempts.

Mission 13 Logbook
The Viking Search for Life on Mars

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Is There Life on Mars?

Mission to the Schoolyard – Directions

Your team will play the role of an extraterrestrial probe being sent to a specific landing site on that mysterious third planet from the Sun, Earth. At the landing site, you will randomly select a sample of Earth "soil" for analysis. You will also make a drawing of your sample area and take a photograph if a camera is available.

Procedure

1. Go to the general target site assigned to your team.

2. Choose one student to be the lander. Blindfold the lander and turn him or her around a few times. Lead your lander forward a few steps. Hand the lander a plastic ring. The lander should then gently toss the ring to the ground. (This simulates the randomness in the exact touchdown point for your probe.)

3. If your team has a camera, photograph the area inside the sampling ring. This is the only view that your lander can see!

4. Whether or not your team has a camera, everyone should sketch what they see within the sampling ring. (This simulates the pictures of the landing site taken by your probe and sent to your extraterrestrial world.) Be as precise as you can in indicating the number of objects and the size, shape, and color (if you have colored pencils) of objects.

5. After everyone has sketched the area, have one student be the soil sampler. This student should use a sampling scoop (plastic cup) to take a sample from the center of the ring and bring it back to class. If it is not possible to actually collect any soil, sample anything present inside the ring that can be scooped up by the cup (e.g., dust, gravel). (This simulates the collecting of soil for your probe's life detection experiments.)

6. Return to the classroom. Each team will present its observations to the class, including photos and sketches, and discuss them in terms of a search for life. A concrete surface, for example, is not a living thing, but is it a sign of life? Could it be a hard clay surface left by evaporating water? Could it be very smooth rock? Based upon the sampling and observation, did your team detect any life or signs of life on Earth? Or would your mission lead you to believe that Earth is a dead planet?

7. If there are no obvious signs of life, are there any tests that you could perform on your "soil" sample to detect unseen life? Recall the tests your class has done on other soil samples. What do you think the results of these tests would be when performed on your "soil" sample?

The Viking Search for Life on Mars
Is there Life on Mars?

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Mission to the Schoolyard – Worksheet

Name: ______________________________ Date: ______________________________

1. On the back of this paper, draw your sampling site.

2. Describe your "soil" sample in detail. Include information about its color, texture, and moisture.

3. Did you detect any life or signs of life? What observations lead you to this conclusion? Can you be sure of this conclusion? Why? Why not?

4. Are there some further tests that you could do to tell if your landing site contained living organisms? Describe these tests.

5. If you were an extraterrestrial scientist and this was your only sample of the surface of Earth, what would you conclude about life on Earth?

6. Do you think that this type of random sampling is an effective way to search for life on a planet?

The Viking Search for Life on Mars
Is There Life on Mars?

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The Viking Mission- Image

Figure 13.1—*Viking* Life Detection Tests.

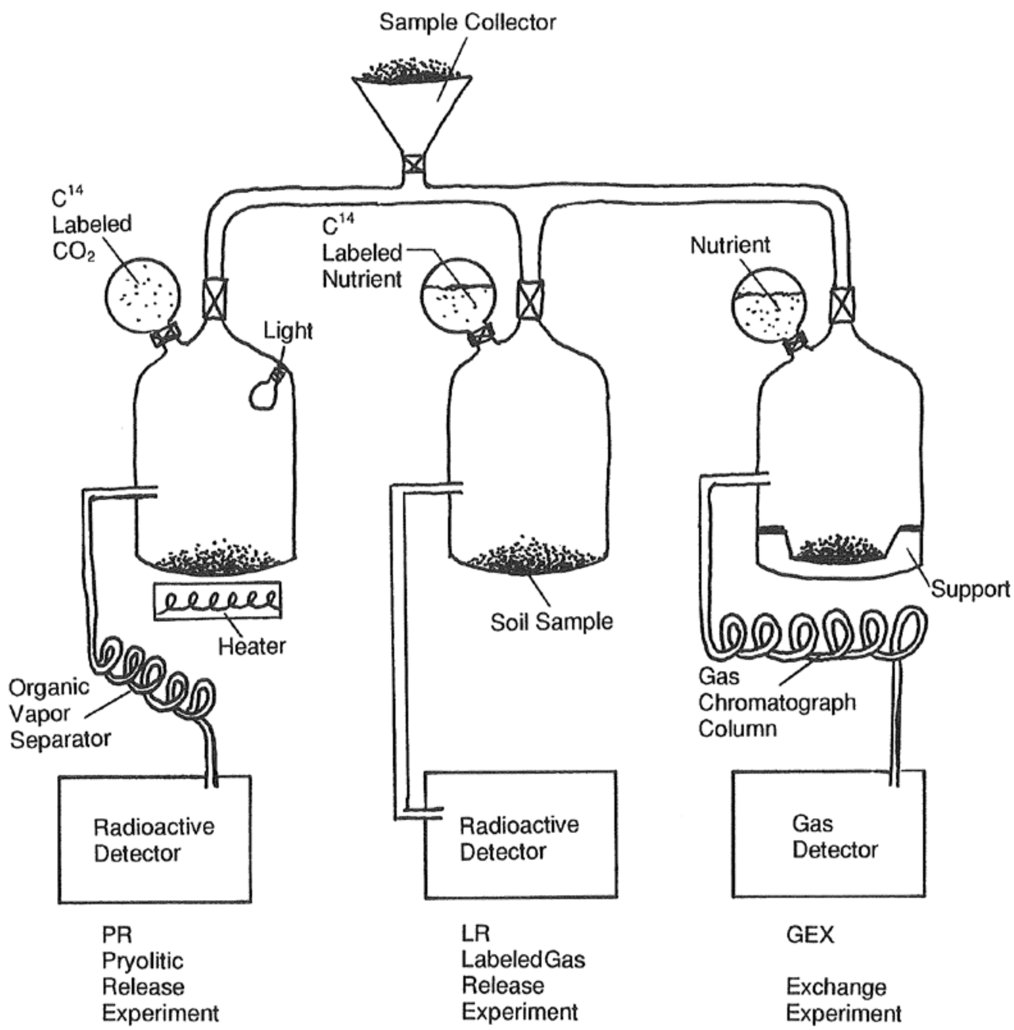

Table 13.1—Life Detection Tests Used by *Viking* Landers

Name of Test	**How It Works**
The Gas Exchange (GEX) Experiment	Measures changes in the gas composition above a soil sample after a warm, liquid nutrient, or plain water is added.
The Labeled Release (LR) Experiment	Relies on the detection of labeled (radioactive) carbon compounds released into the gas above a soil sample after adding a labeled (radioactive) liquid nutrient.
The Pyrolitic (PR) Experiment	The detection of labeled carbon compunds in “roasted” soil sample after exposure to those radioactive compounds in the air above the sample.

The Viking Search for Life on Mars
Is there Life on Mars?

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Viking's Life Detection Tests- Image

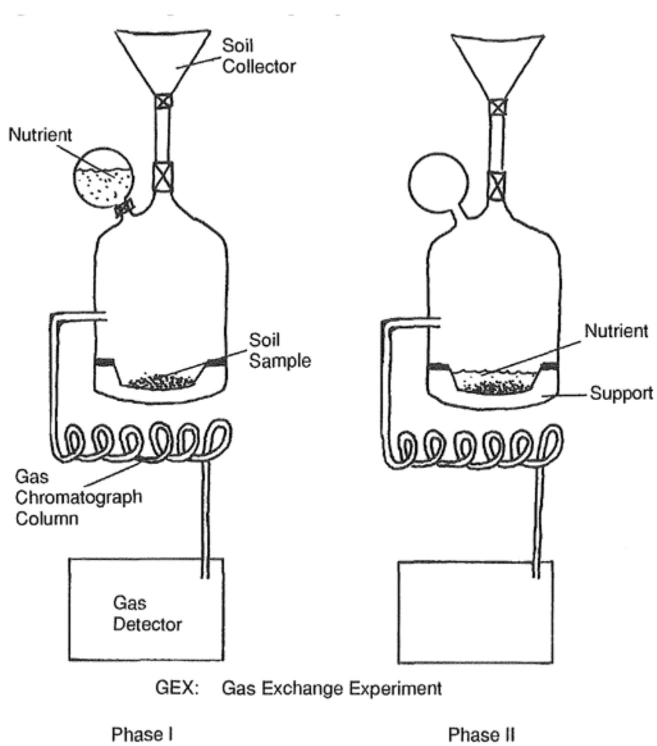
The Gas Exchange (GEX) Experiment
(or the "Chicken Soup" Experiment)

Phase One

1. The Lander scoops soil into a container. (See figure 13.2, left side.)

2. The soil is exposed to water vapor rising from the nutrient solution. (See figure 13.2, right side.) Note that there are no nutrients in this vapor, just water. If the soil contains bacteria that need only water to grow, they may use up gas by absorbing it into their bodies or produce gas.

Figure ***13.2-****Viking Gas* Exchange Experiment.



3. The gas chromatograph indicates if gas has been used or produced.

Phase Two

1. Ten days after phase one, the soil is covered with nutrient solution. The newspapers called this nutrient solution “chicken soup.” If the soil contains bacteria that can use these nutrients to grow, they may use up or produce gas.

2. The gas chromatograph indicates if gas has been used or produced.

Results

The results of phase one of the GEX experiment were positive. Oxygen (0^2) and carbon dioxide (Cog) came out of the soil as soon as the sample came in contact with the water vapor.

At first, some scientists concluded that this indicated life on Mars. However, as they thought about it more, they decided that this did not prove that there was life on Mars. What could have changed their minds?

Discussion

The GEX is similar to the test you conducted in mission 12, “Can You 'Gas What's Happening?” Viking scientists expected that water or a nutrient solution would allow any microbes in the Martian soil to grow. As they grew, they would use up or produce gas. The gas chromatograph would show if the gas mixture in the container had changed.

The Viking Search for Life on Mars
Is there Life on Mars?

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Viking's Life Detection Tests

The Labeled Release (LR) Experiment

Description

The LR experiment, like the GEX experiment, tried to feed any possible Martian life with a liquid nutrient that was dripped over the soil sample. However, the usual carbon-12 atoms in the nutrient were replaced with radioactive carbon-14 atoms. Chemically, carbon- 14 atoms behave the same as carbon-12 atoms. If there were living microbes in the soil, they would take in the labeled compounds, use them, and release them (as carbon dioxide, for example) into the air above the sample. The telltale carbon-14 atoms could be detected by Viking instruments sensitive to radiation.

Results

The original test results for the LR experiment were positive. Gas (carbon dioxide) containing the radioactive carbon-14 atoms appeared above the sample. Again, scientists at first concluded that this indicated life on Mars. Scientists were even more convinced after sterilization of a second soil sample by a heater prevented the reaction. But once more, after thinking about it, scientists were not so sure. What caused them to doubt their initial conclusion?

The Pyrolitic Release (PR) Experiment

Description

Essentially, this was a test for photosynthetic organisms. Once again, radioactive carbon-14 atoms were used as "tracers," but this time the labeled compounds were put into the air above the soil sample and a lamp was turned on to simulate solar illumination. Any potential Martian microbes were given the chance to use the air and incorporate the labeled compounds into their bodies. Finally, the soil sample was heated enough to pyrolize (or "roast") any potential microbes. ("Pyrolize" comes from the Greek word for fire, and means to decompose with heat.) This would release the labeled compounds, producing a radioactive signal. Ten tests were made. In two of the tests, the samples were heated to Temperatures that should have destroyed any organisms in the soil before they were exposed to the compounds in the air. The results of the tests made on these two samples were virtually the same as the results of the tests made on the unsterilized samples.

Results

For the third time, most of the original test results were positive. Compounds containing the carbon-14 atoms were detected, and scientists now had another reason to believe they had found life on Mars! And, for the third time, they soon began to doubt this conclusion.

The Viking Search for Life on Mars
Is there Life on Mars?

Mysteries of Mars – Worksheet

Name: ________________________________ Date: _________________________

Mystery of Mars # 1

Why did *Viking* scientists conclude that their tests did not prove the existence of life on Mars even though all three tests initially gave positive results?

There are four clue cards available. Try to solve this Mystery with as few clues as possible. Can you solve it with no clues? If you are stuck, ask for one clue, and then try again. Good sleuthing!

1. Why might the GEX experiment give a “false positive” result?

2. Why might the LR experiment give a “false positive” result?

3. Why might the PR experiment give a “false positive” result?

4. Why might all three experiments give “false positive" results?

Mystery of Mars # 2

1. Could it be that life *is* present on Mars and *Viking* failed to detect it?

The Viking Search for Life on Mars
Is There Life on Mars?

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Mystery of Mars # 1 – Clue Cards

Clue—The soil on Mars is composed of chemical. Can some nonliving chemical reactions mimic the metabolic reactions of living things?

______

______

______

Clue—Mars today is a dry planet. Liquid water has not existed on Mars for many, many years. The "chicken soup" nutrients used in the test were dissolved in water. Is water involved in any chemical reactions here on Earth?

______

______

______

Clue—The *Viking* lander came from Earth. Could *Viking* have brought something with it that might have caused chemical reactions that mimic the metabolic reactions of living things? Could it have brought chemicals from Earth? Leaky fuels? Some other form of contamination?

______

______

______

Clue—Other tests done by *Viking* were negative. Tests of the soil showed no organic compounds. Tests of the air showed no compounds that would indicate the presence of life (such as oxygen or methane). The cameras saw no signs of life and detected no movement of living things/ Is it likely that life exists on Mars, given these negative results?

______

______

______

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The Viking Search for Life on Mars
Is There Life on Mars?

A New Mission to Mars–Worksheet

Name: ________________________________ Date: __________________________

1. Now that you are aware of the problems exobiologists experienced because of the way they designed the *Viking* lander, you should be able to design a better mission to Mars! What basic mistakes did the *Viking* scientists make?

2. If you were designing a spacecraft and lander to search for life, how would it be different than the *Viking* spacecraft and landers? Why would you make these changes?

3. How many samples would you take?

4. Do you think that the United States should send another spacecraft and lander to Mars to search for life? Why do you think so?

Mission 14
Final Spacecraft and Lander Design

Exobiology Instruments and a Final Analysis

Overview

In mission 14, students redesign their original spacecraft and landers from mission 5, improving them based on what they have learned throughout these missions. In mission 14.1, students begin to understand payload constraints and mission limitations when they are allowed to include only three life detection instruments as part of their final spacecraft-lander. In mission 14.2, students receive simulated data from the successful deployment of their spacecraft and landers to the extraterrestrial landing sites. Based upon these communications, students issue a statement on the presence or absence of life at their landing sites.

Notes

In mission 13, students saw a spacecraft and lander that actually went to Mars to look for life. Comparative planetologists and exobiologists work closely with spacecraft engineers to optimize a spacecraft-lander system's scientific performance while minimizing its weight and expense. Scientists must understand as much as possible about each instrument they use-how it works and what information it will send back. This and the anticipation of what can be learned from information sent back to Earth are key components in successful spacecraft design.

Mission 14.1
Materials

For Each Student

- Pages from mission 5:
- “Initial Spacecraft Design” worksheet
- “Designing a Spacecraft and Lander” optional directions
- “Landing Site Environment” data sheet
- “Design Conference” worksheet
- “The Viking Lander”
- “The Final Design” worksheet
- Pencil

Getting Ready

1. Assemble the pages from mission 5, “Initial Spacecraft and Lander Design.”

2. Copy the “The Final Design” worksheet for each student.

Classroom Action

1. **Preliminary.** Have students regroup into their six landing-site teams from mission 5. Hand out “The Final Design” worksheet to each student. Return to each student their pages from mission 5.

2. **Discussion.** Tell the class that because they have learned much about searching for signs of life on alien worlds, they should be able to improve the designs of their composite spacecraft and landers from mission 5. Remind teams that they are in charge of a mission to detect life or signs of life at their landing site. They must prepare a spacecraft and lander with instrument that will gather information that they will use to decide whether life is present at their landing site. Explain that they cannot send any people because of cost and weight constraints! Each test must be automated. In addition, each spacecraft-lander system is limited to a total of three instruments. This will force students to choose the best and most reliable tests for their landing sites. (There are no “right” answers for this selection of tests.) Make sure students consider all their options! To do this they need a list:

   - Hold a class discussion and create a list on the chalkboard.

   - Have each team or student compile a list from their worksheets and notes from previous missions.

   - Hand out a copy of the provided “A Summary of Life Detection Tests” to each team or student.

   - Post “A Summary of Life Detection Tests” on a wall for class reference.

   - Make and show an overhead transparency of “A Summary of Life Detection Tests.”

   - The following life detection tests are used in this guide.

Table 14.1

Test	Test Question	Mission
Still camera photographs	Appearance of life?	1, 2, 4
Video camera to look for movement	Movement on site?	1, 2, 4
Microscopic camera	Appearance of life?	1, 2, 4, 6
Plate soil on nutrient gelatin	Growth in Petri dish?	3, 6
Identify water by its freezing point	Liquid water on site?	7
Identify water by its boiling point	Liquid water on site?	7
Expose soil to water	Movement in soil?	9
Burn or char a substance	Carbohydrate present?	10
Iodine test for starch	Starch present?	10
Ninhydrin test for protein	Protein present?	10
Expose Life Traps to air	Growth in Petri dish?	11
Analyze gas production of soil	Graph indicates life?	12

3. **Activity.** Have the teams develop and improve the instruments that conducted the experiments and tests throughout their missions. Explain that the instruments must carry out their intended tasks without human intervention. The instruments must be realistic, given current technology. Tell students that they may develop a different type of life detection instrument for their spacecraft or lander if they can come up with a better test than any that were discussed in the missions.

   All plans should be reviewed by the team and it should decide which instruments to include on their spacecraft and lander. Toward the end of this activity, encourage students to complete the overall designs of their spacecraft lander systems. Have each team hand in its completed designs for review. Post them in a display.

   Teacher's Note: *There are special considerations for the Venus sites. On the surface, Venus is like a pressure cooker. No soil tests are possible in the atmosphere. However, soil samples can be tested inside an insulated and refrigerated lander (if the lander is equipped with a scooping device). Also, if any solid material is collected from the air, it can be tested (inside the lander) by charring, Ninhydrin, or iodine, or by analyzing its gas production when submerged in water. If a cold plate is exposed to the atmosphere, liquids might condense upon it; these could be tested for water and life.*

Mission 14.2
Materials

For Each Team

- 1 "Instrument Results" data printout
- Completed spacecraft-lander design from mission 14.1

For Each Student

- "Interpretation of Data" worksheet
- "Summit Notes" worksheet
- Pencil

Getting Ready

1. Make one copy of each “Instrument Results” data sheet. Cut the sheets in half so each team receives only the data for its landing site. There is one data printout provided for each of the six landing sites.

   (optional) Blank “Instrument Results”sheets are also provided if you wish to create the data for your students.

2. Review each teams' spacecraft-lander design and prepare the “Instrument Results” data printout for each teams' instruments. Each printout contains the results of all 12 life detection tests used in this guide. Because each team is limited to three tests, you must black out the lines on the printouts that correspond to tests not performed. If a team included a novel instrument or a test of their own design, be creative and make up the results. Malfunctions are always possible!

3. Copy the worksheets “Interpretation of Data”and “Summit Notes” for each student.

Classroom Action

1. **Discussion.** Reassemble the six student teams. Hand back their spacecraft-lander designs from mission 14.1. Tell students that, after many months of interplanetary travel, their spacecraft and landers have all made it to their landing sites. Responses have just been received from their instruments. Most test results are given as “positive” or “negative.” In some cases, if there was no clear positive or negative result, are listed as “inconclusive.” Note that a “positive” result in the “analyze gas production of soil” test is listed as a “quick release” or a “slow release” of gas, while a “negative” result is listed as “no release of gas.”

2. **Activity.** Hand out the “Interpretation of Data” worksheet to each student and the appropriate “Instrument Results” data printout to each team. Tell each team to consider the instrument data and decide whether or not life was detected. This conclusion should not be obvious, and team members may disagree. This is a complicated problem in logic. Students must decide whether a “positive” result, such as growth on a Petri dish exposed to the air, is caused by microscopic extraterrestrial life; or by a contamination; or by soil blowing into a container, which could have looked like “growth” to a camera; and so on! Some results may appear contradictory. Encourage students to think; there are no “right” answers. After the team reaches a conclusion, they should record their data and write down their conclusions for the upcoming “Summit Meeting.” Each team should choose at least three presenters for this meeting.

3. **Activity.** Hand out the “Summit Notes” worksheet to each student. Hold the “Summit Meeting.” Invite teams to share their findings. Designate a strict time limit for presentations and cut students off when their time is up to give the sense of a high-pressure science meeting. Tell students to complete their “Summit Notes” worksheets as the delegations make their presentations.

4. **Homework.** Have students write a press release for their local papers or science institutions.

Going Further

Activity: All the Data!

Give each team the entire “Instrument Reading” data printout for their landing site, with the results of all 12 tests instead of just **3.** Ask students if the extra data changes their opinions or conclusions. In deciding what tests to include, do they feel that they chose wisely or poorly? Would they change anything if they could design their spacecraft lander system again?

Give each student the entire data printouts for all six sites. Tell students that two sites show signs of alien life! Have them determine which ones. Have students rank each site, from “most likely for life” to “least likely for life”; or have students compare the results of the same test at all six sites.

Research: Analogous Earth Environments

Have each team research an Earth location that is analogous to their extraterrestrial landing site. Then have them design experiments to conduct on Earth that might help clarify the results from their spacecraft and lander. What could they expect to find at their Earth site that would indicate the presence of life? Would some of the tests yield inconclusive results?

Table 14.1

Landing Site	Earth Equivalent
# 1—Mars, Utopia Planitia Desert	Desert valleys of Antarctica or Death Valley, California
# 2—Mars, Olumpus Mons Volcano	Summit of Mauna Kea, Hawaii or Summit of Mt. Penatuba, Philippines
# 3—Mars, North Pole	Great ice sheet of Antarctica
# 4—Venus, Aphrodite Terra Continental Plate	None
# 5—Atmosphere of Venus	None
# 6—Venus, Rhea Mons Volcano	None

Activity: Now Where Do We Go?

Ask students to propose a mission for NASA. Have them decide where they should go, how they should get there, and what they should look for.

What factors will give the mission the best chance to detect the presence of life? Why?

Give a lecture entitled "How to Write a Grant Proposal," and discuss how scientists (and science writers!) often get money to do their work. Have each team write a grant proposal and submit it to a review panel of their peers. Give some Monopoly money to the panel and have them give out their "awards" to the most worthy projects. Require written justification of their choices!

Discussion: Is It Worth It?

Ask students how they feel about NASA missions to Venus and Mars. Are they worth the cost? Could the money be better spent? What kind of spin-offs might benefit mankind? How would the discovery of alien life affect us as a people?

These topics may be handled as debates or as simulated "talk shows" with students playing the roles of experts in the detection of alien life.

Final Spacecraft and Lander Design

Exobiology Instruments and a Final Analysis

Interpretation of Data-Teacher's Key

The following answers are based upon a knowledge of the incoming data from all 12 tests. Because students are limited to only three pieces of information, their conclusions and reasoning may vary.

1. **Mars, Utopia Planitia Desert.** The data suggest that there is no life here. The only positive test was the detection of movement after the addition of water to soil. Perhaps particles in the soil are buoyant and are floating around. The quick release of gas from soil is what we would expect from a nonliving chemical reaction. With so many other tests being negative, it is logical to conclude that there is no life here.

2. **Mars, Olympus Mons Volcano.** Things growing on nutrient gelatin, in the Life Traps or in soil, suggest that there is life here. (These may be two different ways of showing the same thing; something in the soil that also gets blown into the air may be giving this positive result.) However, many negative outcomes of direct tests for the components of life are too compelling to be ignored. A best guess based on all the data: there is no life here.

3. **Mars, North Pole.** The most logical conclusion is that there is no life here. Water is present; however, its mere presence does not prove that life exists here. The quick release of gas from soil is what we would expect from a nonliving chemical reaction. Many other negative outcomes make it logical to conclude that there is no life here.

4. **Venus, Aphrodite Terra Continental Plate.** After scooping the soil sample into the lander (and drawing cooled air over Life Traps in the lander), several interesting positive results are seen. The test found water and growth of something in the air. The

tests for organic materials are negative, however, as is a test for growth of objects in a soil sample. The most logical conclusion is that there is no life here.

5. **Atmosphere of Venus.** This example has been crafted to give the most promising indications of life of the six sites. Water was detected. Airborne particles tested positive for carbon, protein, and starch; they slowly released gases when given nutrients. Growth was seen in a Life Trap. All this is consistent with the presence of life as we know it. A conclusion based only on these tests would have to be a tentative one, but the evidence suggests that there is life here.

6. **Venus, Rhea Mons Volcano.** After scooping the soil sample into the lander (and drawing cooled air over Life Traps in the lander), several interesting positive results are seen. Water (which was vapor before it was sampled) is present. Something appeared to grow in the Life Trap. The quick release of gas by soil inoculated with a nutrient is what we would expect from a nonliving chemical reaction. With so many other tests being negative (and considering the environment), it is logical to conclude that there is no life here.

Mission 14 Logbook
Final Spacecraft and Lander Design

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Exobiology Instruments and a Final Analysis

The Final Worksheet

Name: ________________________________ Date: __________________________

Title of spacecraft or lander instrument:

1. Purpose of the instrument:

2. Major steps in the instrument's experiment or test:

3. Expected results:

Positive Indicator:

Negative Indicator:

4. What would these results indicate about the presence of life at the landing site?

Final Spacecraft and Lander Design
Exobiology Instruments and a Final Analysis

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A summary of Life Detection Tests

Table 14.3.

Test	Test Question	Mission
Still camera photographs	Organism-like objects	No such objects
Video camera to look for movement	Movements of organism-like objects	No such movement
Microscopic camera	Organism-like objects	
Plate soil on nutrient gelatin	Growth in Petri dish	No growth
Identify water by its freezing point	Liquid water on site	No liquid water
Identify water by its boiling point	Liquid waster ion site	No liquid water
Expose soil to water	Growth or movement of organism-like objects	No such growth or movement
Burn or char a substance	Blackening	No blackening
Iodine test for starch	Blue color	No color change
Ninhydrin test for protein	Blue color	No color change
Expose Life Traps to air	Growth in Life Trap	No growth
Analyze gas production of soil	Release of gas	No release of gas

Final Spacecraft and Lander Design
Exobiology Instruments and a Final Analysis

Instruments Results—Data Printouts

Attention Earth!
Incoming Data from the Mission to Mars
Landing Site # 1-Mars, Utopia Planitia Desert

Table 14.4

Test	Result
Still camera photographs	Inconclusive
Video camera to look for movement	Negative
Microscopic camera	Negative
Plate soil on nutrient gelatin	Negative
Identify water by its freezing point	Negative
Identify water by its boiling point	Negative
Expose soil to water	Motion
Burn or char a substance	Negative
Iodine test for starch	Negative
Ninhydrin test for protein	Negative
Expose Life Traps to air	Negative
Analyze gas production of soil	Quick release of gas
Other:	

Attention Earth!
Incoming Data from the Mission to Mars
Landing Site # 2-Mars, Olympus Mons Volcano

Table 14.5.

Test	Result
Still camera photographs	Inconclusive
Video camera to look for movement	Negative
Microscopic camera	Inconclusive
Plate soil on nutrient gelatin	Positive
Identify water by its freezing point	Positive
Identify water by its boiling point	Positive
Expose soil to water	Motion
Burn or char a substance	Negative
Iodine test for starch	Negative
Ninhydrin test for protein	Negative
Expose Life Traps to air	Positive
Analyze gas production of soil	Slow release of gas
Other:	

Attention Earth!
Incoming Data from the Mission to Mars
Landing Site # 3-Mars, North Pole

Table 14.6

Test	Result
Still camera photographs	Negative
Video camera to look for movement	Negative
Microscopic camera	Inconclusive
Plate soil on nutrient gelatin	Negative
Identify water by its freezing point	Positive
Identify water by its boiling point	Positive
Expose soil to water	Negative
Burn or char a substance	Negative
Iodine test for starch	Negative
Ninhydrin test for protein	Negative
Expose Life Traps to air	Positive
Analyze gas production of soil	Quick release of gas
Other:	

Attention Earth!
Incoming Data from the Mission to Mars
Landing Site # 3-Mars, North Pole

Table 14.7

Test	Result
Still camera photographs	Inconclusive
Video camera to look for movement	Negative
Microscopic camera	Inconclusive
Plate soil on nutrient gelatin	Negative
Identify water by its freezing point	Positive
Identify water by its boiling point	Positive
Expose soil to water	Motion
Burn or char a substance	Negative
Iodine test for starch	Negative
Ninhydrin test for protein	Negative
Expose Life Traps to air	Positive
Analyze gas production of soil	Quick release of gas
Other:	

Attention Earth!
Incoming Data from the Mission to Venus
Landing Site # 4-Venus, Aphrodite Terra Continental Plate

Table 14.8

Test	Result
Still camera photographs	Inconclusive
Video camera to look for movement	Positive
Microscopic camera	Inconclusive
Plate soil on nutrient gelatin	Positive
Identify water by its freezing point	Positive
Identify water by its boiling point	Positive
Burn or char a substance	Positive
Iodine test for starch	Positive
Ninhydrin test for protein	Positive
Expose Life Traps to air	Positive
Analyze gas production of soil	N/A This is a test on atmosphere
Other:	

Attention Earth!
Incoming Data From the Mission to Venus
Landing Site # 6-Venus, Rhea Mons Volcano

Test	Result
Still camera photographs	Inconclusive
Video camera to look for movement	Negative
Microscopic camera	Inconclusive
Plate soil on nutrient gelatin	Negative
Identify water by its freezing point	Positive
Identify water by its boiling point	Positive
Expose soil to water	Negative
Burn or char a substance	Negative
Iodine test for starch	Negative
Ninhydrin test for protein	Negative
Expose Life Traps to air	Positive
Analyze gas production of soil	Quick release of gas
Other:	

Attention Earth!
Incoming Data From the Mission to Mars
Landing Site

Table 14.10

Test	Result
Still camera photographs	
Video camera to look for movement	
Microscopic camera	
Plate soil on nutrient gelatin	
Identify water by its freezing point	
Identify water by its boiling point	
Expose soil to water	
Burn or char a substance	
Iodine test for starch	
Ninhydrin test for protein	
Expose Life Traps to air	
Analyze gas production of soil	
Other:	

Attention Earth!
Incoming Data From the Mission to the Surface of Venus
Landing Site

Table 14.11

Test	Result
Still camera photographs	
Video camera to look for movement	
Microscopic camera	
Plate soil on nutrient gelatin	
Identify water by its freezing point	
Identify water by its boiling point	
Expose soil to water	
Burn or char a substance	
Iodine test for starch	
Ninhydrin test for protein	
Expose Life Traps to air	
Analyze gas production of soil	
Other:	

Final Spacecraft and Lander Design
Exobiology Instruments and a Final Analysis
Interpretation of Data - Worksheet

Name: ________________________________ Date: __________________________

Landing Site:

Test # 1:

Result:

Conclusion:

Test # 2:

Result:

Conclusion:

Test # 3:

Result:

Conclusion:

Is there life at your test site? Explain why or why not.

Final Spacecraft and Lander Design
Exobiology Instruments and a Final Analysis
Summit Notes—Worksheet

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Name: ________________________________ Date: ____________________________

1.Landing site # 1:

Is there life there? Why or why not?

2. Landing site # 2:

Is there life there? Why or why not?

3. Landing site # 3:

Is there life there? Why or why not?

4. Landing site # 4:

Is there life there? Why or why not?

5. Landing site # 5:

Is there life there? Why or why not?

6. Landing site # 6:

Is there life there? Why or why not?