The Evolution of a Planetary System

SETI Academy Planet Project

SETI Institute
Mountain View, California

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Scope and Sequence
Life in the Universe Curriculum

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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 the number of civilizations with this ability is sufficiently large, then there is an opportunity for us to find them by "eavesdropping" on their communications. 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.

Carl Sagan

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 (National Aeronautics and Space Administration) 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) and NASA 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.

The ***SETI Academy Planet Project*** consists of three books, each of which is a teacher's guide for grades 5-6. ***The Evolution of a Planetary System*** examines an important aspect of the search for intelligent life: the evolution of stars and planets. Students visualize how our Sun and its family of nine planets have formed and evolved into the solar system we know today. By applying what they have learned about the evolution of Earth, students imagine how planets might have formed around other stars, how individual planets might have evolved through similar processes, and what such planets might look like today. They explore how Earth has changed over time, how tectonic forces deep inside our planet brought about these changes, and how geographic locations and geologic landforms influence climate. Students use the results of their research to design planetary systems that contain habitable planets, “evolve” individual planets into life-sustaining worlds, and create continental and climate maps of their planets.

How Might Life Evolve on Other Worlds? focuses on the vast expanses of time during which plant and animal life evolved on Earth. Students participate in a series of multidisciplinary activities to analyze the origin and evolution of life on Earth. Students discover that life evolved through interaction with the environment and that some life evolved from simple to complex forms. By applying what they have learned about the evolution of life-forms on Earth, students imagine realistic scenarios for how life might evolve on another planet.

The Rise of Intelligence and Culture emphasizes how intelligence and culture helped humans to form a civilization that now has the technology to detect and communicate with possible extraterrestrial civilizations. Students learn about indications and characteristics of intelligence, about the evolutionary increase in the size of the human brain, about survival needs, and about the stages of human culture. They examine the possibility of sending messages through space and the social issues related to the search for extraterrestrial intelligence. By applying what they have learned, students contemplate how an extraterrestrial civilization might have evolved.

The ***SETI Academy Planet Project*** provides an exciting, informative, and creative series of activities for elementary students, grades 5-6. In these activities, each student plays the role of a cadet at the SETI Academy, a fictitious institution. Each book of the *SETI Academy Planet Project* is designed to be a complete unit in itself as well as a subunit of a three-unit course. The use of these guides rests with each teacher.

In the first book of the project, students will

- see an introductory show of video or slide images that describe the formation of Earth and the evolution of life;
- make a scale model of our solar system;
- simulate the formation of our solar system using oats, puffed rice, and tea;
- make a timeline of the formation of our solar system and the development of Earth;
- do a laboratory experiment that examines the different types of stars and their related temperatures and colors;
- measure the life zones of different star types;
- design an imaginary, but scientifically plausible, planetary system;
- search for habitable planets within this planetary system;
- evolve planets of their own, to the point at which the planets become suitable for life;
- put together the Pangaea Puzzle to show the single large continent that once existed on Earth;
- make a filmstrip that shows how the continents on Earth have drifted;
- make models of different geologic formations that occur where the Earth’s tectonic plates come together;
- study how Earth’s landforms affect its weather and climate; and
- make a map for their imaginary planet, laying out its continents and climate zones.

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Mission 13: Creating a Map of Planet X	Dr. John Marshall-SETI Institute; NASA-Ames Research Center, Moffett Field, CA
Mission 14: Mission Completed!	None (no science content)

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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:

- Components of the solar system and their relative sizes and distances.
- Modern theory about formation of the solar system and other planetary systems.
- The timeline of Earth's formation.
- Different types of stars, their colors, temperatures, and lifetimes.
- The concept of a "habitable zone," where planets with liquid water may be found.
- The theory of plate tectonics, continental drift, and the supercontinent of Pangaea.
- Climate zones and the relationship between landforms and climate.

Skills

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

- Using simulations.
- Making scale models.
- Performing controlled experiments.
- Making laboratory measurements and analyzing them.
- Making graphs and interpolations from them.
- Designing simulations that reflect current scientific knowledge.
- Creating maps.
- Working in teams and working alone.
- Revising ideas to include new information.

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 group 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 part of a mission is designed to take one class period. Teachers may want to take two or even three class periods with some parts.

Mission 1: Welcome Aboard!

Mission 1.1: Students share pictures and discuss their ideas about UFOs and extraterrestrials. Students learn that real scientists are searching for real ETs.
Mission 1.2: Students "register" at the SETI Academy.
Mission 1.3: Students see a PowerPoint slide show, "Life Story of the Earth."

Mission 2: Our Solar System

Mission 2.1: Students select tiny objects to represent the eight planets plus a dwarf planet in a scale model of the solar system.
Mission 2.2: Students take their scale planets outside and make a model solar system.

Mission 3: Formation of Planetary Systems

Mission 3.1: Students simulate the formation of a planetary system using oatmeal, puffed rice, and tea.
Mission 3.2: Students see a PowerPoint slide show, "Birth of the Solar System and Formation of Our Planet."
Mission 3.3: Students create a timeline showing the geologic history of Planet Earth.

Mission 4: Types of Stars

Mission 4.1: Students use a radiometer to measure infrared radiation coming from the three types of "stars," which are represented with a variable light bulb.

Mission 5: Habitable Zones of Stars

Mission 5.1: Students use a radiometer to measure the habitable zones around the three types of stars.

Mission 6: Building a Model Planetary System

Mission 6.1: Students select types of stars and design systems of rocky planets and gas giant planets that orbit their stars.

Mission 7: Searching for Habitable Planets

Mission 7.1: Students add life zones to their planetary systems and search for habitable planets within these life zones. Students choose one "Planet X" to evolve and map in later missions.

Mission 8: Evolving Planet X

Mission 8.l: Students play a game to determine the early events in the geologic evolution of their chosen planets.

Mission 9: 200 Million Years Ago

Mission 9.1: Students solve the Pangaea Puzzle, learning how Earth's continents were united 200 million years ago.

Mission 10: Drifting Continents

Mission 10.1: Students make a flipbook showing the breakup of the supercontinent Pangaea and the formation of the modern continents.

Mission 11: Changes on Planet Earth

Mission 11.l: Students build a simple clay model of Earth, showing the core, the mantle, and the crust. Students cut their Earth models in half and observe the interiors.
Mission 11.2: Students model and record four types of plate tectonic interactions. Students observe and record convection currents in water and draw the convection cells that drive the continents.
Mission 11.3: Students search for signs of plate tectonics in a PowerPoint slide show, "Changes on Planet Earth," and in images of Earth throughout time.

Mission 12: Climate Zones

Mission 12.l: Students color the wet and dry regions on diagrams, showing the relationship of these regions to mountains and to latitude.

Mission 13: Creating a Map of Planet *X*

Mission 13.l: Students create plausible maps of Planet *X*, showing continents and other geologic features.
Mission l3.2: Students refine their maps of Planet *X* by developing climate zones that reflect the effects of mountains and latitude.

Mission 14: Mission Completed!

Mission 14.l: Students review all they have learned in this unit.

Preparation

SETI Institute and "SETI Academy"

The SETI Institute is a real scientific organization, but the SETI Academy is pure *fiction.* It is a device to increase student involvement in this material. The people who are listed in each mission as members of the "SETI Academy Team" are real scientists and science educators, but most of them have never met one another!

Assessment

The projects in this book are designed to help teachers assess students' learning and understanding. The planetary systems and planet maps that students create, along with their responses on worksheets, will reflect their grasp of concepts and skills presented in the lessons, experiments, and projects. Teachers can use the student logbooks and the projects themselves to make portfolio-based assessments, and use evaluations of student participation to assign grades and provide appropriate feedback.

Planning

Classroom trials show that the activities in this book require about four weeks, if science is taught every day. Time spent on the ***SETI Academy Planet Project*** can be counted for credit in language arts and mathematics, because skills in these areas are emphasized alongside science skills.
When students have completed this book, teachers may want to proceed directly into ***How Might Life Evolve on Other Worlds?*** in which students evolve oceans and life-forms on an ideally

habitable planet similar to the planets created in this book. In ***The Rise of Intelligence and Culture***, students endow a given life-form with intelligent capabilities and evolve cultures for that life-form. Each book is based on the detailed study of life as it has evolved on Earth and on the scientific observation of our neighborhood in space. Each book of the ***SETI Academy Planet Project*** contains an exciting, informative, and creative series of integrated science activities for upper elementary students.

Expanding or Compressing the Unit

If long on time, create a variety of activities to add richness to this unit, such as "star parties" and performing analyses of moon rocks, or activities that expand on concepts presented in each mission. There are ideas in the "Going Further" section at the end of each mission. If short on time, consider cutting some of the less crucial activities, such as those in mission 9, "200 Million Years Ago," or those in Mission 12, "Climate Zones." Or perhaps simplify the activities that involve creating planetary systems and planet maps by requiring less detail.

SETI Academy Cadet Logbooks

Masters for "mission briefings," student worksheets, and student handouts, all of which should be included in the student logbooks, are provided following the details of each mission. A master for the logbook cover is provided in Mission 1, "Welcome Aboard!" Also make a copy of the two-page glossary (found at the end of this book) for each student logbook. Paper is a limited resource both environmentally and at some school sites, so the following options for reproducing the masters are included.

Option One

Ideally, it is best to make copies of each master and assemble them into packets, one for each student. This option really captivates students by allowing each their own SETI Academy Cadet Logbook. This option involves reproducing about 50 pages. The reproduction can be done using a two-sided copier, but note that some of the student logbook pages are consumable, so be sure to copy those particular pages one-sided. When reproducing pages for the student logbooks, use three-hole-punched paper so students can keep their logbook papers in binders alongside other papers. Papers may be collated and handed out as complete logbooks or kept in folders to be handed out one or two sheets at a time as students are ready for new missions.

Option Two

Save on materials costs by producing one copy of the student logbook for every group of two or three students.

Option Three

For those schools that have a limited supply of paper, teachers might try making transparencies of the mission briefing masters and using them on an overhead projector. Save the transparencies and reuse them each year. Have students copy and answer the pre-activity *"What Do You Think?"* questions and the post-activity *"What Do You Think, Now?"* questions onto their own binder paper, which should be placed in their logbooks. Reproduce student worksheets and handouts from each mission and distribute them as needed.

Helpful Procedures

In a typical mission, a teacher will

- hear a Mission Briefing and ask students to answer pre-activity *"What Do You Think?"* questions;
- perform a lab experiment or simulation, or make a model that gives students more information on the topic of discussion;
- use the results of this experiment or simulation, or the model built to further consider the possibilities of extraterrestrial intelligence; and
- ask students to answer the post-activity *"What Do You Think, Now?"* questions, either in class or as homework.

Prerequisite Skills

To complete the activities in this guide, students will need to be able to do the following:

1. Fill out an application that asks them questions about their interests and opinions.
2. Follow written directions for a series of lab experiment steps after the experiment has been demonstrated.
3. Understand "big" numbers: million, billion.
4. Compare models and simulations to real objects and processes.
5. Make measurements using meter sticks (or yard sticks) and clocks.
6. Place points on a graph (which will not involve setting up a graph).
7. Follow a flowchart for a dice game. (Example: If you roll a 1, 2, or 3, go to section A; if you roll a 4, 5, or 6, go to section B.)
8. Label a diagram.
9. Most importantly, *apply* what is learned about our solar system to create realistic models of planetary systems.

Cooperative Learning

The ***SETI Academy Planet Project*** is well suited to the use of cooperative learning groups. Each group can have a materials monitor, a recorder, a speaker, and so forth. Successful cooperative learning groups should have a mix of learning abilities and be balanced in sex and ethnicity. It is best if groups last at least several class periods so students have a chance to work together long enough to get comfortable. If two or all three of the *Project* books will be taught, new groups can be formed for each unit so that students have opportunities to work with different peers.

Preparation of Special Materials

PowerPoint Images: *Evolution of a Planetary System*

A set of full-color images was produced by artist Jon Lomberg specifically for the Life in the Universe series. This set of images is used in several missions in this book, as well as in missions in

How Might Life Evolve on Other Worlds? Each time the images are used, they are accompanied by different text—"scripts" in the missions. Both the images and the scripts are in the PowerPoint files.

Bulletin Board

Student groups will produce colorful, creative materials throughout this unit. Teachers will want to display the work somewhere in the classroom area. A lot of space will be required to display the students' timelines, drawings of planetary systems, Pangaea Puzzles, and planet maps. If possible, set aside one entire wall of the classroom for this purpose.

Mission 1
Welcome Aboard!

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The Mission Begins at SETI Academy

Overview

This unit is designed around a naturally exciting topic: the search for life beyond Earth. In Mission 1.1 of this introductory mission, students share pictures and discuss their ideas about UFOs and extraterrestrials. Students learn that real scientists are searching for real ETs. (Note: No actual ETs have been detected [circa 2010.])

In Mission 1.2, students are greeted and briefed by Chief Project Scientist Jill Tarter, who invites them to become a part of the "SETI Academy," a fictitious institution. Then Tom Pierson, Chief Executive Officer of the SETI Academy, asks them to fill out a questionnaire, "registering" them as cadets in the SETI Academy. This gives students an opportunity to express their interests and experience in the topics that will be covered. This is a good time to evaluate what students already know and correct any misconceptions. After completing the unit, students will answer the same questionnaire again. Compare their before and after answers to assess how much they have learned.

In Mission 1.3, after registering with the SETI Academy, students attend a PowerPoint Mission Briefing (slide images), after which the class will discuss the formation of our solar system and the formation of Earth as a life-bearing planet. The PowerPoint presentation is an exciting way to spark students' interest in the search for intelligent life in the universe.

Concepts

- SETI stands for Search for Extraterrestrial Intelligence. The SETI Institute in Mountain View, California, is one place where scientists are actively preparing for radio searches that take place on radio telescopes around the world.
- Our solar system formed when a swirling cloud of gas condensed to become the Sun and its planets.
- Our planet, Earth, went through a series of changes as it evolved into a life-bearing planet with oceans and an atmosphere that contains oxygen.

Skills

- Critical thinking

Mission 1.1
Materials

For the Class

- *(optional)* Magazine and newspaper articles about UFOs

Getting Ready

One or More Days Before Class

1. *(optional)* Invite students to bring in newspaper and magazine clippings and posters about alien life-forms.

2. Prepare the student logbooks. (See "SETI Academy Cadet Logbook" on pages xxvi, 4, 16.)

Classroom Action

1. **Introduction.** Tell students about the ***SETI Academy Planet Project.*** Tell students about their place in the galaxy: "We all live on one planet, Earth, which revolves around a star that we call the Sun. The Sun is one of a half-trillion stars in a *very* large galaxy that we call the Milky Way." Discuss large numbers: "What do *thousand, million,* and *billion* really mean?" Perhaps engage students in a mathematical exercise or game that will *show* them such sizes.

2. **Project Briefing.** Instruct students to refer to the "Planet Project Briefing" in their logbooks as one student reads it aloud.

   "Welcome to SETI Academy. I invite you to work with me and other scientists on the Search for Extraterrestrial Intelligence (SETI). Our job is to search for signs of intelligent life in our galaxy. Our home base is in Mountain View, California, where we work closely with scientists from the National Aeronautics and Space Administration (NASA) at Ames Research Center, and with scientists all over the world.

   "As a Cadet at SETI Academy your mission is to study what today's scientists know about how Planet Earth was born and how planets may have formed around other stars. Then, you will apply what you learn to imagine what other star systems and planets may exist in our galaxy. You will design a fictitious star system and check it for habitable planets. You will evolve one planet to make it more suitable for life and design a continent and climate map of your planet.

   "Later, if you choose to continue with SETI Academy, you'll learn about how living things evolved on Earth and consider if there could be life elsewhere in the universe. During your future studies at SETI Academy you'll invent planets, imaginary plants and animals, intelligent life-forms, alien cultures, and send and receive alien messages! As scientists, we will build on what we know to imagine what is possible."

3. **Discussion.** Ask students if they have any questions about what they will be doing over the next few weeks. Discuss the “Planet Project Profile” logbook page. If the students have brought in newspaper or magazine clippings or posters about alien life-forms, hang them up on a bulletin board or wall. Ask the class to comment on how realistic these imaginary ideas might be. Are they reasonable, or are they pure fantasy? How can we be sure? Can we be absolutely sure that something exists just because we see it in a photograph or a movie? (Refer to the special effects regularly used for TV and science fiction films.) How is a photo different than physical evidence, for instance, a radio knob or a bolt from an extraterrestrial craft? Some people believe in ghosts, but what is the evidence that they exist?

Mission 1.2
Materials

For the Class

- Large sheet of butcher paper
- Tape for hanging butcher paper
- Marking pen
- PowerPoint of *History of Earth* images
- *(optional)* Ink pads for making fingerprints

For Each Student

- SETI Academy Cadet Logbook
- Pencil

One or More Days Before Class

1. (*optional*) Some teachers have created SETI Academy ID cards for students to add to the feeling of being part of the Academy. These may include photographs of the cadets. If you have an ink pad available, plan to have students come up one by one to put their fingerprint on their ID cards.

Just Before the Lesson

1. Hang the butcher paper at the front of the classroom.

Classroom Action

1. **Mission Briefing**. Welcome Aboard! Today students will register at SETI Academy. Ask the class refer to the “Mission Briefing” for Mission 1.3 in their logbooks while one student reads it aloud.

2. **Activity.** Ask if there are any questions, and then have students fill out the questionnaire part of the “Mission Briefing.” The questions are to be answered in complete sentences, in as much detail as possible, using extra paper if necessary. (Students may fill these out individually, or groups of two or three students may fill them out together, pooling their knowledge of our solar

system.) This is not a test. The idea is for students to record what they know already about our solar system so they can look back at the end of the unit and see how much they have learned. Give the students 15 to 25 minutes.

(optional) Fingerprint the cadets and/or issue them SETI Academy ID cards. They may use family snapshots to add photographs of themselves at home.

3. **Discussion.** Tell students bring their logbooks to the discussion area. Invite all students who wish to share their drawings and ideas. Do not judge the students' ideas as right or wrong at this point. Let them know that they will be learning a lot more about these things and should expect to change their ideas several times by the end of this unit. Allow the class to brain-storm what objects are in our solar system. Record this list on a sheet of butcher paper. Save it to be amended later.

   (optional) Collect the student logbooks and review them to get an idea of what students already know. Plan and tailor the Missions accordingly.

Mission 1.3
Materials

For the Class

- *Evolution of a Planetary System* PowerPoint file
- Data projector
- "Life Story of the Earth" PowerPoint script

Getting Ready

Just Before the Lesson

1. Set up the data projector. Start the *Evolution of a Planetary System* PowerPoint presentation at "Mission 1." Have the "Life Story of the Earth" PowerPoint script handy.

Classroom Action

1. **PowerPoint Presentation.** Introduce the *Evolution of a Planetary System* PowerPoint presentation of still images. The "Life Story of the Earth" PPT script is in a PowerPoint file under "Notes."

2. **Discussion.** Discuss any portions of the PowerPoint presentation that may have confused students.

Closure

1. **Discussion.** Ask students to share what surprised or interested them the most in the PowerPoint presentation.

2. **Preview.** Tell students that, in the next mission, they will be making a giant model of our solar system.

Going Further

Drama: "War of the Worlds"

Obtain a copy of Orson Welles' *"War of the Worlds"* on DVD from a library. Play parts of this radio show for the class and discuss their reactions.

Research/Literature: Space Aliens!

Research aliens in popular culture, especially Martians and human interaction with the planet Mars and its inhabitants. Read and analyze popular science fiction books.

Math—How Many Seconds?

Challenge students to estimate and then compute the number of days/years it takes for one million seconds to pass. Do the same for one billion. *(It takes about eleven and a half days for one million seconds, about 32 years for one billion seconds!)*

Math--Collect a Million!

Request that students begin collecting small (preferably recyclable) objects. When the objects come in, group them 10 to a bag (clear plastic works best); label each bag "10." When you have 10 bags of 10, group them into a larger bag labeled "100." Group 100 bags of 100 each into a "1,000" bag, and so on. It may not be possible to collect a million objects during one school year but students can extrapolate how much more time it would take to collect a million or how much space a million objects would take up.

Math—A Million Letters

Ask students to find book(s) they think have: 100 letters, 1,000 letters, 100,000 letters, a million letters. (Approximate by counting the number of letters on one "average" page and multiplying by the number of pages in the book.) How many letters might be in a set of encyclopedias?

Mission 1
Script for PowerPoint Slide Show

SETI INSTITUTE

"Life Story of the Earth"

Dr. Jill Tarter mentioned in her briefing that our mission is to learn about Planet Earth, our star the Sun, and other objects in our planetary system, and to use this information to understand other stars and planets in our own Milky Way galaxy. All this will help us in our search for intelligent life in our Milky Way galaxy. Currently, we are unable to photograph planetary systems around other stars. They are simply too far away. It might be possible to imagine what other planetary systems are like if we use the evolution of our own solar system as an example. Let's start with the life story of Earth, according to the best evidence and theories that scientists have formulated so far.

Figure 1.1—Over four and a half billion years ago, the star that we now know as our Sun began to form from a swirling mass of gas and dust.

Figure 1.2—Around this developing star. planetesimals (little lumps that will become planets) began to form from the tiny amounts of dust and gas in a flattened disk formed by the rotation.

Figure 1.3—Eventually, eight or nine planets formed. Pluto may not have formed at this time. The closest planet to the star, or Sun, formed 36 million miles away. The most distant planet formed about 3 billion miles way.

Figure 1.4—A large collision forms our Moon. Other planets also have moons, but some planets, like Venus, do not have any moons.

Figure 1.5—The planets and their moons continued forming for hundreds of millions of years as asteroids and other debris crashed into their hot, partially molten surfaces.

Figure l.6—Earth, the third planet from the Sun, was special. Its orbit was just the right distance from the Sun to allow Earth to have liquid water and to be comfortably warm. Some of the water had been trapped inside the molten Earth and was outgassed (released) by volcanoes and some was brought by comets striking the early Earth.

Figure 1.7—Under these ideal conditions of water and warmth, very simple life appeared in the seas of Earth nearly four billion years ago. How and where did life begin? Was it in volcanic vents at the bottom of the ocean. or was it in tide pools? The question of *where* life formed is one of the continuing great questions of science.

Figure l.8—What is certain is that bacteria, tiny microorganisms, came into existence and dominated the seas. They lived in an atmosphere that consisted mainly of carbon dioxide, not oxygen. The first bacteria could not make their own food, but soon other types of microorganisms, such as the cyanobacteria that are shown here, evolved the ability to make their own food.

Figure 1.9—For two billion years, organisms made their own food through a process called photosynthesis. This process used the carbon dioxide in the atmosphere to produce the food and gave off oxygen as a waste product. The introduction of oxygen gradually changed the atmosphere and led to the atmosphere that we have today.

Figure 1.10—During the first few billion years, the simple one celled organisms, bacteria, reproduced by splitting apart. This is shown in the upper right picture. But about 1.7 billion years ago, some organisms joined together and reproduced a cell that was similar to, but not exactly like, the parent cells. This was the beginning of *sexual reproduction* (pause for embarrassed laughter). This is shown in the lower right. Sexual reproduction added variety to the organisms.

Figure 1.11—Over 500 million years later, some cells failed to separate as they reproduced and formed an organism consisting of more than one cell. These included the first simple "seaweed," or marine algae, like the ones in the foreground. In the background, the more primitive creatures thrive, as they still do today.

Figure 1.12—Some multicelled animals eventually developed the first specialized cells that worked together to form simple nerves and muscles. These animals had some control of their movement, like the jellies ("jellyfish" are *not* fish) and worms that you see here.

Figure 1.13—Another 200 million years went by. Soft-bodied animals and plants in the seas were joined by some fascinating creatures with hard outside shells and skeletons. Examples of these animals are the trilobite and the ancestors of the snail. Animals like these, with no backbones, and soft bodied animals like jellies and worms, are called *invertebrates.*

Figure 1.14—During this time, Earth's atmosphere kept changing as well. The oxygen level had increased to a level that allowed the ozone layer to become sufficiently thick to protect life on Earth from the Sun's harmful ultraviolet light. Plants could not live on land away from the protection of the seas.

Figure 1.15—Some time between 450 and 400 million years ago, jawless fish developed an internal skeleton and later evolved jaws and paired fins. As shown in this image, one fish, the Lobefin, was able to use its strong fins to move on land. About 350 million years ago, certain bodies of water began to dry up. The Lobefin fish responded to this problem by using its strong fins and simple lungs to move over land to another pond. This successful development led to the four footed amphibians.

Figure 1.16—By about 300 million years ago, amphibians, huge insects, giant centipede-like animals, and the first reptiles inhabited a land with giant ferns and other plants.

Figure 1.17—About 225 million years ago, Earth's greatest mass extinction occurred. Was this major loss the result of an asteroid impact?   nearby exploding star? A *big* volcano? Scientists don't know. Whatever the reason, 96% of the sea life, 75% of the amphibians, and 80% of all land species vanished.

Figure 1.18—Several smaller organisms survived the catastrophe and continued to adapt to the environment. Small reptiles evolved into other reptiles, including dinosaurs. Some reptiles also evolved into birds, and other reptiles evolved into mammals.

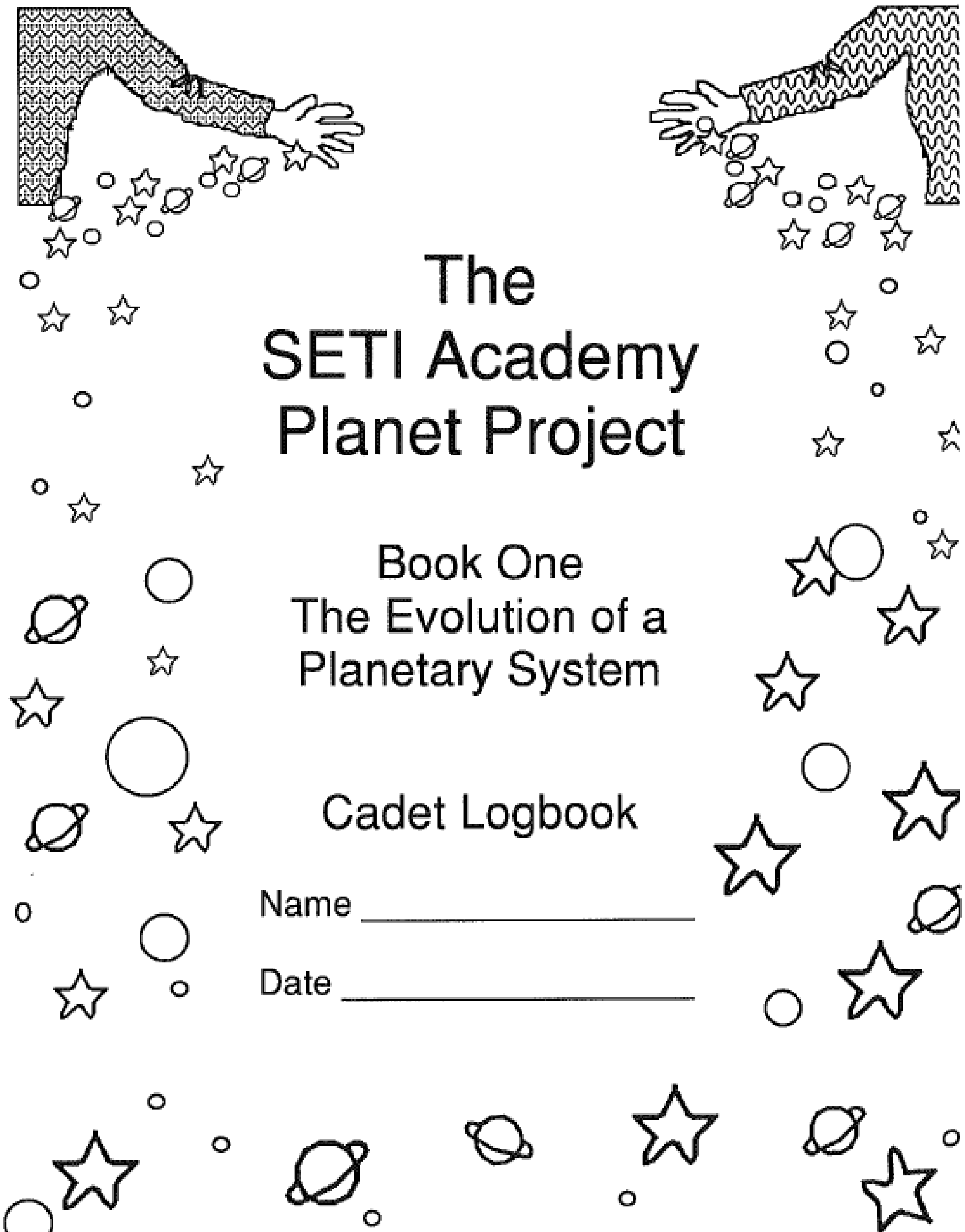
Figure 1.19—Then about 65 million years ago nature delivered another devastating blow. Scientific evidence seems to indicate that an asteroid struck Earth in the Gulf of Mexico. Again the smaller species survived while the larger ones died out. This is the period in which dinosaurs became extinct.

Figure 1.20—Small reptile-like mammals adapted so well to the environmental change and to the absence of large reptiles that they increased dramatically in size, variety, and number. Most of the mammals that exist today can trace their ancestors to this period of time.

Figure 1.21—Only a few million years ago, one branch of mammals, early humans, began to use tools, even to make tools of their own, and to use fire to keep warm and cook food. These major steps allowed early humans—our ancestors—to begin to control their environment, settle in groups, and form communities.

Figure 1.22—From early human communities came a variety of cultures that produced the young people of today. As a member of this group, you are part of a new stage in Earth's development--one that has radio, television, space satellites, and computers as tools that can be used to help people understand one another better and answer questions that humans have been asking for centuries: Are we alone? Or are there other intelligent beings out there somewhere on other planets in other planetary systems who are as eager to find out about us as we are to find out about them?

Figure 1.23—The Unknown Future.



The SETI Academy Planet Project

Book One
The Evolution of a Planetary System

Cadet Logbook

Name ____________________

Date ____________________

Mission 1.2
Planet Project Briefing

Name: ____ Date:___________________

Dr. Jill Tarter, Chief Project Scientist of SETI Academy Team.

Welcome to SETI Academy. I invite you to work with me and other scientists on the Search for Extraterrestrial Intelligence (SETI). Our job is to search for signs of intelligent life in our Milky Way galaxy. Our home base is in Mountain View, California, where we work closely with scientists from the National Aeronautics and Space Administration (NASA) at Ames Research Center, and with scientists from all over the world. As a cadet at SETI Academy, your mission is to study what' scientists know about how planet Earth was born and how planets may have formed around other stars. Then, you will apply what you learn to imagine other stars and planetary systems that may exist in our galaxy. You will design a fictitious planetary system and check it for habitable planets. You will evolve one particular planet—Planet *X*— to make it more suitable for life, and then design continent and climate maps of your planet. If you choose to continue your missions with SETI Academy after ***The Evolution of a Planetary System***, you will learn about how living things evolved on Earth and you will use this knowledge to consider whether there could be life elsewhere in the universe. During these future studies at SETI Academy, you will invent planets, imaginary plants and animals, intelligent life-forms, an alien culture, and send and receive alien messages! As scientists, we will build on what we *know* to imagine what is *possible* elsewhere.

Mission 1

The Planet Project Profile

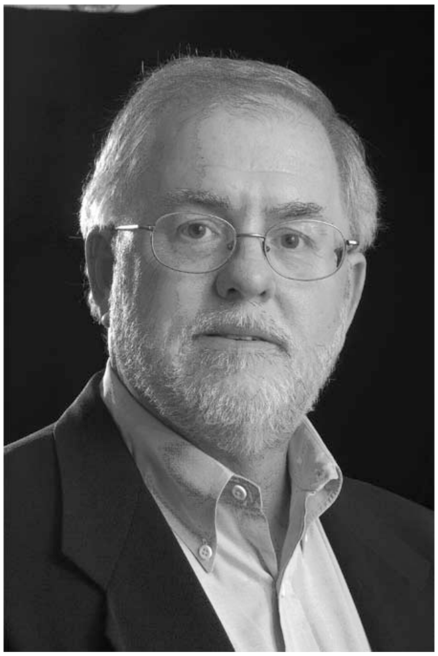
Welcome to the SETI Academy! In *The Evolution of a Planetary System* you will be learning how to create your own scientifically accurate planetary system. To accomplish your mission, you will learn about our Earth, and the solar system. It may be useful for you to jot down your initial impressions and responses to the following questions before starting the activities. Will your ideas change?

- **Mission 1-Welcome Aboard!** What do scientists know about the life story of the Earth?
- **Mission 2-Our Solar System.** How much space is there in space? What does our solar system look like?
- **Mission 3-Formation of Planetary Systems.** How did our solar system form? Would planets form around other stars too?
- **Mission 4-Types of Stars.** Are all stars alike? Why are they different colors? How hot are they?
- **Mission 5-Life Zones of Stars.** Could life exist on *any* planet, or does it have to be a special planet?
- **Mission 6-Building a Model Planetary System.** What kind of a planetary system might exist around another star?
- **Mission 7-Searching for Habitable Planets.** Can we find another planet that life could exist on?
- **Mission 8-Evolving Planet X.** How does a planet develop?
- **Mission 9-200 Million Years Ago.** What was the Earth like when dinosaurs existed, 200 million years ago?
- **Mission 10-Drifting Continents.** How can continents drift across the Earth?
- **Mission 11-Changes on Planet Earth.** What is Earth like inside? Why do we have earthquakes and volcanoes?
- **Mission 12-Climate Zones.** Can we tell what the climate will be like in South America without going there?
- **Mission 13-Creating a Map of Planet X.** What kind of a habitable world would you create?
- **Mission 14-Mission Completed!** What did you learn about the Earth and our solar system?

Mission 1.3
Welcome Aboard!

Mission Briefing

Name: ____ Date: ____________________



Mr. Tom Pierson, Executive Director of the SETI Academy

As a new Cadet at SETI Academy, we would like to know more about you and your interests. After registering you, we'll give you a short briefing on how Earth's solar system formed.

Your Name:

Your Age:

Fingerprint:

School Name:

1. What are your favorite things to do?

2. What are some of the things you have seen in the night sky?

3. What do you think is beyond what you can see?

4. List below as many objects as you can that are parts of our solar system. On the back of this sheet, draw a rough diagram of our solar system.

5. How do you think our solar system formed?

6. How do you think Earth formed?

7. How do you think Earth has changed since its formation?

8. What causes climates on some part of Earth to be rainy while it is dry in other areas? Draw a rough diagram of Earth's climate zones in the space below.

9. If we could get a close look at planetary systems in the years ahead, what should we study about these new planets to decide whether or not they may contain life?

Mission 2
Our Solar System
Eight Planets and One Dwarf Planet Circle One Sun

Notes

In Mission 1, students shared ideas about extraterrestrials, registered with the SETI Academy, and saw a PowerPoint image show about the development of our solar system.

Overview

Many students are surprised at how much *space* there is in space! Posters, T-shirt designs, and other depictions of our solar system always use two different scales, one for the size of the planets and one for the distances between them. This use of two different scales makes a pretty picture, but it gives an unrealistic view of what our solar system is really like. In Mission 2.1, students choose tiny objects to represent the eight planets and one dwarf planet. In Mission 2.2, students use these tiny objects to make a huge scale model of our solar system on the school playground, using the same scale for both size and distance.

Concepts

- Our solar system is composed of the Sun, eight planets, at least one dwarf planet, and other objects such as asteroids, moons, and comets.
- Most of our solar system is empty space.
- The four inner planets are much smaller and in a region much closer to the Sun than the other four planets.
- The outer four planets are very large, and they are much more spread apart than the inner planets.

Skills

- Making a scale model
- Estimating

Mission 2.1
Materials

For Each Group

- 9 index cards
- 9 sticks or tongue depressors (or pencils)
- Roll of transparent tape
- Sheet of black construction paper

- Items to make a set of model planets (store in film canisters):
- Pinch of salt
- 2 large, round, hard sugar cake decorations (see table 2.1)
- 2 small, round, hard sugar cake decorations (see table 2.1)
- Chalk dust
- *(optional)* Magnifying glass or lens and butcher paper

For Each Student

- SETI Academy Cadet Logbook
- Pencil

Getting Ready

One or More Days Before Class

1. Set up the planet models. In this scale model, each centimeter will represent 500,000 kilometers. In Table 2.1, the scale size diameter of the planets is listed, along with a suggested item to represent each planet. Attach the "planets" to index cards with transparent tape. Feel free to substitute other objects of the same size if they are more convenient. With the exception of Mercury, Pluto, and asteroids, teachers may use small balls of clay to represent the planets if they find the suggested items to be too small to work with. Students may make these in a separate activity.

Table 2.1—Scale Models of the Planets in the Solar System.

Planet	**Actual Size Diameter (km)**	**Scale Size Diameter (mm)**	**Suggested Item**
Mercury	4,900	.10	A typical grain of salt is 0.5 mm in diameter. Have your students pick the smallest they can find and tell them the salt grain is about five times bigger than it should be to make this model accurate.
Venus	12,100	.24	Grain of salt/sand.
Earth	12,800	.25	Grain of salt/sand.
Mars	6,800	.14	Tiny grain of salt/sand about half the size of the Earth grain
Asteroid Belt			Chalk dust
Jupiter	143,000	2.9	Cake decoration
Saturn	120,000	2.4	Cake decoration
Uranus	51,800	1.0	Cake decoration
Neptune	49,500	.99	Cake decoration
Pluto	2,300	0.46	A typical grain of salt is 0.5 mm in diameter. Have your students pick the smallest they can find and tell them the salt grain is about ten times bigger than it should be to make this model accurate.

Classroom Action

1. **Review.** Ask students to share one new thing they learned about our solar system in the *Evolution of a Planetary System* images they saw in mission 1. Review Mission 1 with students: the possibility of life in the universe; all the life that we *know* of exists on only one planet, Earth, which is located in our solar system; and, furthermore, most SETI scientists think that life has the best chance of originating and surviving on planets similar to Earth, where water is plentiful. Stars, of course, are flaming balls of gas, and much too hot for life. Introduce mission 2: Students will learn about our solar system and its planets.

2. **Mission Briefing.** Tell students to refer to the "Mission Briefing" for Mission 2 in their student logbooks while one student reads it aloud.

3. **What Do You Think?** Ask students to answer the pre-activity questions on the "Mission Briefing." Then invite them to share their answers in a class discussion.

4. **Activity.** Divide the class into groups. Hand out the sets of model planets and the black paper.

(optional) Provide each group with a magnifying glass, if available.

Show students the 2.8 cm (slightly more than 1-inch) diameter ball. *(Tell them that it represents the Sun.)* Have the groups carefully pour out the model planets onto the black paper and guess which item will represent Earth. Name the other planets one by one; asking the class to guess which item will represent that planet. List the correct items for each planet on the whiteboard or on butcher paper.

Ask each group to write "Earth" on one index card and tape a medium grain of salt to it. Have groups tape a stick to the back of the index card to serve as a stake for putting the card into the ground. *(If the ground is asphalt, students can tape their planets to folders or books that can be stood on end.)* Name the rest of the planets one by one, asking each group of students to tape the correct item to the card and label it with the planet's name. Tell students that a good way to remember the order of the planets is to use the phrase, "**M**y **V**ery **E**ducated **M**other **J**ust **S**erved **U**s **N**ine **P**izzas!"

After students attach the objects to the cards, they will add other useful information to the cards, such as the actual size (diameter) and the actual distance from the Sun. Perhaps have students research the planets and add this information to the cards as well. *(This research could be assigned as homework.)*

Mission 2.2
Materials

For the Class

- Large area outdoors
- 2 meter sticks or a l0-meter measuring tape
- Sphere, 2.8 cm (about 1 inch) in diameter, preferably yellow
- Butcher paper
- Tape for hanging butcher paper
- Marking pen

Getting Ready

One or More Days Before Class

1. Find an area outdoors where the scale model of our solar system can be created. This will require an area 118 meters long. (*If a sufficiently large space cannot be found, leave Pluto out of the scale model and describe to students where it would be. Without Pluto, the model will require an area 90 meters long)* In case of rain, use a long corridor or indoor gym.

   After students attach their model planets to index cards, they will lay out a model of our solar system. Students measure out the distances with a meter stick or measuring tape. It may be easier to measure out and mark the distances ahead of time on a long string.

Just Before the Lesson

1. Hang butcher paper at the front of the classroom.

Classroom Action

1. **Activity.** Take students outside to create a model of our solar system with their finished cards and meter sticks. Place the Sun at one end of the playground on a post for better visibility. Refer to Table 2.2 for the scale distances to use in this model (1 cm = 500,000 km).

   Ask each group to guess how far away Mercury would be from the Sun in this scale model and post their cards into the ground accordingly. When everyone has guessed, use the meter stick to measure a distance 1 meter, 16 centimeters from the Sun's center. Ask students to move their cards to the correct position for Mercury.

Table 2.2—Planet Distances for This Model.

Planet	Actual Distance from Sun's Center	Model Distance from Sun's Center	Distance from Previous Planet
Mercury	58 million km	1 meter, 16 cm	NA
Venus	108 million km	2 meters, 16 cm	100 cm
Earth	150 million km	3 meters	84 cm
Mars	228 million km	4 meters, 56 cm	1 meter, 56 cm
Asteroid Belt	Approx. 400 million km	8 meters	
Jupiter	778 million km	15 meters, 56 cm	11 meters
Saturn	1,430 million km	28 meters, 60 cm	13 meters, 4 cm
Uranus	2,870 million km	57 meter, 40 cm	28 meters, 80 cm
Neptune	4,500 million km	90 meters	32 meters, 60 cm
Pluto	5,900 million km	118 meters	28 meters

Repeat this process for Venus. *(For the rest of the planets, they will be measuring each planet's distance from the previous planet, as this will be much easier than trying to measure from the Sun.)* Ask students to guess where Earth will be, then measure 84 centimeters *from* Venus. Allow students to adjust their cards. Continue this process for the rest of the planets. After Mars, measure the approximate distance to the Asteroid Belt from the Sun. Students should spread a pinch of chalk dust over a wide region at this location. Beginning with Jupiter, round off the distances between planets to the nearest meter. If students run out of space, they estimate where the remaining planets would be (*e.g.*, "in that person's backyard"). Before leaving the school yard, ask students to imagine the planets orbiting in huge circles around the Sun. Ask students where they are located and how big they are on the scale of this model. (*The students would be an invisible dot on a tiny grain of salt, not too far from the Sun.)*

Teacher's Note: *In reality, Pluto is not* always *farther away from the Sun than Neptune, as neither orbit is a perfect circle. (See the Going Further section below.).*

Closure

1. **Discussion.** In the classroom, ask students to add to or amend the list of solar system objects that was made in their logbooks during the first activity. Some possible additions are asteroids, gas giant planets, moons, comets, and lots of empty space. Ask them where these objects would appear in the schoolyard model.

2. **What Do You Think, Now?** Have students answer the post-activity questions on the logbook sheet "What Do You Think, Now?" Invite students to share their responses.

3. **Lecture.** Tell students that the name of our central star is the Sun. It is also called *Sol*. This is why our system of planets, moons, asteroids, comets, and other objects is called the solar system. Ask students what the names would be of planetary systems around other stars such as Arcturus, Vega, Deneb, and Polaris.

Remind students that only a few other planetary systems have been found, because they are so far away. At a scale of 1 cm = 500,000 km, the nearest star would be over 800 km, or about 500 miles away. Ask students to try to imagine seeing a few grains of salt and some cake decorations from a distance of 800 km. They would need a *very* good telescope!

4. **Preview.** Tell students that, in the next mission, they will be simulating the formation of our solar system using supplies from the kitchen!

Going Further

Activity-English and Metric Models

To reinforce students' understanding of what a scale model is, compare a toy car to a real car. Measure the length of the toy car in inches and the length of the real car in feet (or, reinforce the metric system by measuring in meters). Divide the length of the real car by the length of the toy car to find the scale of how many feet of real car each inch of the model represents. To go farther, compare the measurements of the windshield, the door, and so on of both the real car and the toy car. *(Some teachers have done this **Going Further** activity before doing the solar system scale model activity.)*

Research-Solar System Facts

Assign pairs or groups of students to do independent research on different parts of our solar system. Each student should write a paragraph or a page on the object they choose. This information could be added to their index cards.

Discussion: Pluto-Far Out!

Students may be surprised to learn that the dwarf planet Pluto is not *always* farther away than Neptune. It is actually erroneous to say that Pluto is always 118 meters (in the scale model) from the Sun, just as it is erroneous to say that Neptune is always 90 meters from the Sun, because neither planet's distance from the Sun is a constant. In fact, Pluto's orbit is so elliptical, it is occasionally closer to the Sun than Neptune. For the purpose of this mission's static scale model, such a generalization may be made for simplicity's sake; still, it is a common misconception that might interest students. Due to Pluto's orbit and properties, it is now known as a Dwarf Planet.

Activity—Seeing the Solar System

Show astronomical images, PowerPoint slides, or posters of our solar system. Whenever possible, let students share information they already have. Ask students if they think that the visual scale shown in a PowerPoint or on a poster or image accurately portrays both size and distance.

Math—Moons

Students can add scale orbits to the Earth, Mars, Saturn, Jupiter, *etc*. cards to show moon(s) orbits.

Mission 2
Our Solar System
Mission Briefing

Name:____ Date:_____________________

Dr. Janice Bishop, Chemist and Planetary Scientist on the SETI Academy Team.

To search for extraterrestrial intelligence, we must know what we are looking for. We are not yet able to photograph planets around other stars. They are simply too far away. We can, however, *imagine* what systems of planets might exist by using our own solar system as an example. Please answer the two questions below and then make a model with your class of our solar system.

What Do You Think?

1. How would you give directions to an alien from another star system trying to find Earth once the alien has arrived at the edge of our solar system?

2. Why is our system of planets called the *solar system?*

SETI INSTITUTE

Mission 2
Our Solar System

What Do You Think, Now?

Name:____Date:_______________________

After you have completed this mission, please answer the following questions:

1. What was the most interesting thing you learned about our solar system?

2. Which planets would you call the *inner* planets? How are they different from the *outer* planets?

SETI INSTITUTE

Mission 3
Formation of Planetary Systems

Do All Stars Have Planets?

Notes

In Mission 2, students created a scale model of our solar system to help them develop an understanding of the great distances involved.

Overview

How many stars have planets? The answer depends on how planets form. If planet formation is an unusual occurrence, then there are likely to be very few. However, the best current theory for the formation of our solar system holds that it formed as part of the same process that formed the Sun. If we assume that this theory is correct, then we should expect to find planets around many, if not all, stars. NASA's Kepler Mission is seeking Earth-like planets around other stars.

In Mission 3.1, students learn about this theory by creating a hands-on simulation of the formation of our solar system using supplies from the kitchen. They will see the Sun and planets form from a "swirling cloud of gas and dust" represented by oats, puffed rice, and tea. In Mission 3.2, students compare the results of their simulation to PowerPoint images of the formation of our solar system. In Mission 3.3, students make drawings to show how they visualize Earth, from its early days to the present day. They will hang their drawings in a class timeline.

Concepts

- Our solar system was once a swirling cloud of gas and dust. Clumps of material began forming because of gravity.
- A large clump of material (about 98 percent of the total material) formed in the center of the cloud and was surrounded by smaller clumps, which orbited the central clump.
- The central clump ignited to become our Sun. The other clumps became the planets, one of which is our Earth.
- The young Earth was a hot, molten ball, with neither oceans nor atmosphere. Comets hitting Earth brought with them water and organic molecules. Volcanic activity provided an atmosphere and some water.

Skills

- Conducting a simulation.
- Comparing a simulation to an actual process.
- Visualizing.
- Constructing a timeline.

Mission 3.1
Materials

For the Class

- Clear, large round bowl with flat bottom (glass pie pan)
- *(optional)* Strainer for easy cleanup

For Each Group of Students

- Clear, large round bowl with flat bottom (glass pie pan)
- Water to fill bowl 1/2 to 2/3 full
- 1 heaping tablespoon of dried rolled oats *(not* instant oats)
- 2 heaping tablespoons of puffed rice cereal
- Pinch of black tea
- Large wooden spoon or other stirring stick
- Cups for oats, rice, and tea
- Marking pens

For Each Student

- SETI Academy Cadet Logbook
- Pencil

Getting Ready

One or More Days Before Class

1. Try out the simulation. If necessary, adjust the amount of oats, puffed rice, and tea, depending on the bowl size, to achieve the best effect of swirling material forming into one large central clump and several orbiting clumps.

Just Before the Lesson

1. For each group of students, set out the bowls, 1/2 to 2/3 full of water; the stirring sticks; and the dry oats, puffed rice, and tea. Putting the oats and puffed rice together into cups makes them easier to handle.

Classroom Action

1. **Review.** Ask students to tell you what surprised them in the solar system model they made in mission 2.

2. **Mission Briefing.** The class should refer to the "Mission Briefing" for Mission 3 in their student logbooks while one student reads it aloud.

3. **What Do You Think?** Ask students to answer the pre-activity questions on the "Mission Briefing." Invite them to share their answers in a class discussion.

4. **Lecture: Modeling the Cosmic Nursery.** Tell students that they will be using oats, puffed rice, and tea to model the formation of our solar system. The oats and rice represent gas and the tea represents dust. Tell them that this simulation will help them see how scientists think the Sun, planets, and other objects in our solar system formed, beginning about 4.6 billion years ago. These models will be telescoped in size and time: Only a few moments of the activity will represent the 100 million years in which gases and particles come together to form the Sun, Earth, and other cosmic bodies in our solar system.

   (optional): Some teachers have introduced or recapped this activity by using creative imagery in a darkened room, or swirling water on an overhead projector:

   Imagine a swirling cloud of gas in deep space. Gradually, a clump starts forming in the center. Soon, other clumps that are smaller begin swirling around that center clump.

5. **Demonstration.** "Sowing Your Solar Oats"

   - Go over the directions in the student logbook with students, demonstrating each step.
   - Use the largest glass bowl or pie pan possible that will fit on an overhead projector. The bowl should be filled approximately 1 inch deep with water.
   - Dump 1 tablespoon of oats into the water. The intention is to have them all sink, and they will after about a minute.
   - Sprinkle the tea on the surface of the water, and then stir the water. The oats will clump on the bottom in the center, representing the Sun while the tea will clump on the surface, representing planets. Ask students to look for parts of the model that represent the Sun and the forming planets.

6. **Activity.** "Sowing Your Solar Oats": Organize students into groups of three to five. Hand out materials, and allow time for students to conduct the simulation and make their drawings in their student logbooks.

7. **Discussion.** Ask students to analyze what they saw. Ask if they saw a central clump form? Were there other clumps forming that went around the central clump? If they didn't see anything, stir the mixture again, then stop, and watch it swirl and form clumps. This can be repeated a couple of times before the water becomes too cloudy.

   Discuss with the class the questions on the "Sowing Your Solar Oats" logbook sheet.

Possible answers to the
"Sowing Your Solar Oats" logbook sheet.

How is this model similar to solar system formation? *Swirling motion causes material to clump. One clump forms in the center, with several smaller orbiting clumps.*

How might it be different? *Instead of gravity, the stickiness of the oats is causing it to clump together. Because of the temperature gradient in a real solar system, only dust exists close to the Sun, while gas and ice are present further out where it is cooler*.

What do the oats and rice represent? *Gas.*

What does the tea represent? *Dust.*

What does the water represent? *Empty Space.*

8. **Cleanup.** For easier cleanup, the oats and rice can be removed from the water with a strainer or colander.

Mission 3.2
Materials

For the Class

- *Evolution of a Planetary System* PowerPoint presentation
- Data projector, computer, and PowerPoint file.
- *(optional) "Birth of Our Solar System and Formation of Our Planet"* PowerPoint script

Getting Ready

Just Before the Lesson

1. Set up the PowerPoint projector. Begin the *Evolution of a Planetary System* PowerPoint presentation at "Mission 3." Have the *"Birth of Our Solar System and Formation of Our Planet"* PowerPoint script handy.

Classroom Action

1. PowerPoint. Introduce and play the *Evolution of a Planetary System* PowerPoint presentation of still images. The *Birth of Our Solar System and Formation of Our Planet* PowerPoint script is found in the PowerPoint file under "Notes."

2. Discussion. Discuss any portions of the image show that may have confused students. Replay slide show if desired.

Mission 3.3
Materials

For the Class

- Strip of adding machine tape, 5 meters long
- Ruler
- Masking tape

For Each Student

- Sheet of blank paper

Getting Ready

One or More Days Before Class

1. Create a timeline from the adding machine tape. Put the title “Earth’s Timeline” at the top. At the far right edge of the tape, make a large mark and label it “TODAY.” Put a mark every 10 cm along the adding machine tape, working backwards from the TODAY label. Make a large mark every 50 cm. Label the large marks “0.5 billion years ago,” “1 billion years ago,” “1.5 billion years ago,” and so on, ending with “5 billion years ago” on the far left. If students have not yet studied decimals, label the marks as “500 million years ago,” “1,000 million years ago,” “1,500 million years ago,” and so on, ending with “5,000 million years ago.”

Just Before the Lesson

1. Hang the “Earth’s Timeline” adding machine tape horizontally at the front of the classroom.

Classroom Action

1. **Activity.** “Images of Earth’s Formation.” Ask students to make small drawings that represent the various phases in Earth’s development as a life-bearing planet, as indicated in Table 3.1. Add at least one drawing to “Earth’s Timeline” for each of the events listed in Table 3.1. Students can work individually or in groups.

Table 3.1—Images of Earth’s Formation.

	The solar system forms from a swirling cloud of gas and dust.
4.5 bya	Earth is a red-hot, molten blob.
4.4 bya	A solid crust begins forming around the Earth.
4.3 bya	Intense showers of comets bring water, and oceans begin to form.
4.2 bya	The sky begins to clear.
4.1 bya	Volcanoes create new land areas and their gases begin to form an atmosphere.

Students' drawings should be captioned to describe the event and when it happened (*i.e.*, "4.5 bya: Earth is a red-hot, molten blob."). Students should make marks on timeline labeled with the years listed in Table 3.1.

2. **Discussion.** "Formation of a Planet-Earth's Timeline"; Explain to students the blank timeline hung at the front of the classroom. Tell them that Earth had to go through many changes before it was suitable for life. This timeline will be used to show the history of Earth's formation. Students will learn how a planet becomes suitable for life. Tell students and write on the chalkboard that the scale for this timeline is 1 meter = 1 billion years = 1,000 million years.

3. **Activity.** One or more students will put an appropriate drawing of our solar system's formation below the mark that corresponds with the label "4.6 billion years ago." Continue along the timeline, attaching at least one drawing of each event at its proper mark. Tell students that they will be putting more events on the timeline as they complete other missions.

Closure

1. **What Do You Think, Now?** Ask students to answer the post-activity questions on the logbook sheet "What Do You Think, Now?" Invite students to share their responses. Ask students how their opinions have been changed by this mission.

2. **Review.** If there is time, allow another class period for students to do the simulation again, now that they have a better idea of what to look for. They can make new drawings or amend the ones they have.

3. **Preview.** As more activities are finished, especially in *How Might Life Evolve on Other Worlds?* and *The Rise of Intelligence and Culture* of the Life in the Universe series, students can add more events to their timeline. The primary objective of the "Earth's Timeline" is for students to grasp the tremendous, yet finite, amount of time that has passed since the formation of Earth, and the comparatively insignificant amount of time that has passed since people "recently" evolved.

Going Further

Writing: In the Beginning

Some teachers have combined this lesson with a study of creation mythology. Students of different cultural groups may share the stories told in their cultures. They may write their own creation myths and then read the stories to the class.

Discussion: Twin Stars?

Discuss the concept of *binary* stars and the possibility that planets exist around them. In the activity ask if anyone's oats formed a binary system and if planets are likely to form around binary systems? Ask what would a planet be like in such a system?

Mission 3

Script for PowerPoint Slide Show

"Birth of Our Solar System and Formation of Our Planet"

Watch for any relationship between the experiments and the theory of the formation of our solar system shown in these images.

Figure 3.1—Over four and a half billion years ago. a giant cloud of dust and gas that had been swirling slowly in space began to contract, possibly as a result of the explosion of a nearby star. As the cloud, or nebula, became smaller it began to spin faster and faster, as does an ice skater who spins faster when she pulls her arms in. As it spun faster the spherical cloud began to form a flattened disk.

Figure 3.2---ln the center of the disk that formed as the nebula continued to spin gases clumped together into a huge ball that became hotter and hotter as the gases became more tightly packed together. Close to this hot clump gas and ice were evaporated. Only rocky dust grains survived. Further out gas and lee and dust all could survive. The remaining particles of dust and gas continued to spin around the disk colliding and forming increasingly larger clumps of orbiting matter.

Figure 3.3—Finally the ball of gas in the center of the spinning disk became so hot and dense that its hydrogen was transformed into another, heavier element: Helium. The transformation of hydrogen to helium produced so much energy that the ball of gas began to glow, generating the heat and light of our star, the Sun. The clumps orbiting the Sun also continued to get larger, forming the planets, moons, asteroids, and other objects that make up our solar system. Because they formed in a rotating disk, all of the planets today have orbits that lie roughly in a plane. The temperature differences across the disk produced small rocky planets close to the Sun and large gas giants farther out.

Figure 3.4—The early solar system was a shooting gallery for rocks left over from its birth. Some of these rocks were the size of small planets. The young Earth became a target when an object the size of Mars crashed into it. The careening rock was destroyed, and the force of the collision tore material loose from the surface of our planet. The remains of this cosmic catastrophe were flung into Earth's orbit, and soon clumped together to form our Moon. While other planets have moons, most of these are simply asteroids captured by the planet's gravity. The dramatic birth of our Moon may be unique in our solar system.

Figure 3.5—A close look at the third planet from the Sun finds the hot, rocky surface seething and bubbling with volcanic eruptions. The asteroid and comet bombardment of Earth's surface continues as this leftover debris from the formation of our solar system is attracted toward the Sun by gravity. The Earth's surface hardened somewhat as it cooled but then melted again when hit. This hardening and melting period churned the material into three distinct layers, sending the heaviest materials, iron and nickel, to the center of the planet. Basalt was lighter and made up the next layer, called the mantle, while the lightest rock, granite, was deposited on the thin outer crust.

Figure 3.6—Intense volcanic activity began forming an atmosphere. As numerous volcanoes erupted, large amounts of gas and water vapor that had been trapped in the molten rock beneath the crust were ejected into the atmosphere. As the planet cooled, this steam fell back to Earth in the form of rain. Eventually, water covered much of the surface of Earth. Volcanic action continued and began to form the first island land masses. Comets also delivered water when striking Earth.

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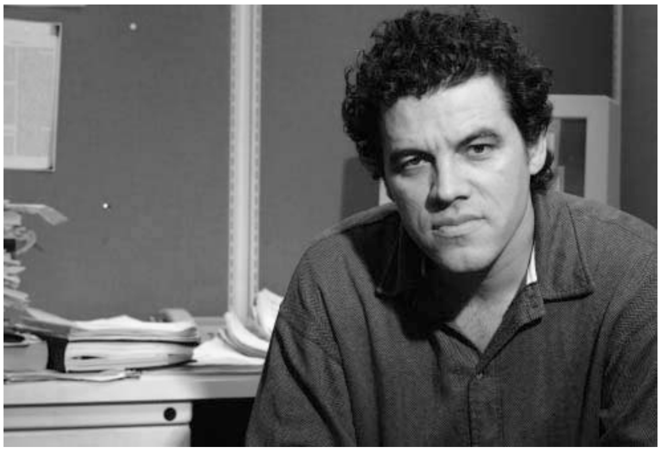
Mission 3
Formation of Planetary Systems

Mission Briefing

Name:____ Date:__________________



Dr. Ignacio Mosqueira, Astrophysicist on the SETI Academy Team.

Are there planets around other stars? How are they formed? Give us your opinion on the two questions below, and then please do the experiment that we call "Sowing Your Solar Oats." It will show you the way many scientists believe that the planets were formed. Next, please make some drawings that show the stages our solar system went through in its formation. Hang them on the "Earth's Timeline." We will add other items to this timeline as you complete future missions. On the timeline, 1 meter = 1 billion years.

What Do You Think?

1. Do other stars have planets going around them? Why or why not?

2. How did our solar system form?

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Mission 3
Formation of Planetary Systems

Sowing Your Solar Oats

Name:____ Date:_________________

What to Do

Student 1: Begin stirring water quickly and evenly. Stop stirring after a few moments.

Student 2: Quickly sprinkle oats and puffed rice into water.

Student 3: Quickly sprinkle tea into water.

All students: Observe and record by drawing and labeling all three pictures (inside *and* outside rings of oatmeal and tea.

Record your observations below.

1. As oats, puffed rice, and rest.

2. As oats, puffed rice, tea, *tea enter water.*

3. Oats, puffed rice, tea, and water at and water swirl.

After you have performed this experiment, please answer the following questions:

1. Describe what happened.
2. How is this model similar to the formation of our solar system?
3. How is it different?
4. What is represented by the oats and the puffed rice?
5. What is represented by the tea?
6. What is represented by the water?
7. Do you think that other planetary systems may exist in our galaxy? Why or why not?

Mission 3
Formation of Planetary Systems

What Do You Think, Now?

Name:____Date:_________________

After you have completed this mission, please answer the following questions:

1. Do other stars have planets going around them? Why or why not?

2. How did our solar system form?

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Mission 4
Types of Stars

Is Our Sun Unique?

Notes

In Mission 3, students performed an experiment in which they simulated the formation of our solar system, watched a PowerPoint presentation about the formation of our solar system, and created a timeline for the geologic history of Earth.

Overview

Is the bright, yellow Sun the only kind of star that might have planets orbiting it? How would a planetary system be different if it formed around another color, or type, of star? In Mission 4.1, students experiment to find that a star's color is determined by its temperature; that white stars (A-type) are hotter than yellow stars (G-type), and red stars (M-type) are the coolest; that white stars burn up the fastest, yellow stars burn up slower, and red stars live the longest; and that if two stars are the same size, the hotter one will radiate more energy than the cooler one. Students use a radiometer to measure infrared radiation coming from these three types of stars.

Concepts

- There are many different colors, sizes, and temperatures of stars.
- The largest, hottest stars are white *(and the hottest of these burn blue)*; but some large stars are cooler and red. Medium-sized stars are cooler than large, white stars; medium stars are yellow or orange. The smallest, coolest stars are red. Even the coolest stars are hot!
- Star types are catalogued according to spectral type by the letters ***O, B, A, F, G, K,*** and ***M***, which can be remembered by the sentence, "**O**h **B**e **A** **F**ine **G**irl (or **G**uy), **K**iss **M**e!" These star types span the range of star temperatures. Spectral type is determined strictly by temperature: O type stars are the hottest, and M-type stars are the coolest. *(Students will study A-type, G-type, and M-type stars.)*
- The larger, hotter stars such as O-type, B-type, and A-type stars, use up their hydrogen fuel quickly and burn out faster. Smaller, cooler stars burn slower and live longer. O, B, and A-type stars probably do not live long enough for life to evolve (as it has on Earth) on any planet near that star.

Skills

- Measuring with a radiometer.
- Timing an experiment.
- Calculating averages.
- Comparing models and simulations to real objects.

Mission 4.1
Materials

It is ideal if a Star Center station can be set up for every group of five to six students. However, if budget factors prohibit a station for each group, arrange other projects to engage the groups of students that are waiting for their turn.

For Each Station

- Clear, 200-watt lightbulb
- Ceramic lightbulb socket
- Rotary-dialed dimmer switch (one that can be installed into lamp wire)
- Electrical tape
- 3-6 feet of lamp wire
- Electrical plug
- Wire cutters
- Wire strippers
- Blade screwdriver
- Phillips screwdriver
- Fine-point permanent marker
- 30-cm ruler or meter stick
- New radiometer (radiometers lose their vacuum seal with time)
- Stopwatch
- *(optional)* Clear plastic box to protect radiometer

For the Class

- Butcher paper
- Marking pens
- *(optional)* Calculator

For Each Student

- SETI Academy Cadet Logbook
- Pencil

Getting Ready

One or More Days Before Class

1. **Build the Star Center.** Refer to figure 4.1 for the Star Center assembly. First consider where to locate the Star Center. Use enough lamp wire to span the distance from the Star Center to a wall socket with plenty of slack. Attach the ceramic lightbulb socket to one end of the lamp wire, following the directions on the box. Then use electrical tape to cover any exposed wire and/or metal on the bottom of the socket. Splice in the dimmer switch about a foot from the socket,

using the directions on the package. Attach the plug at the end of the lamp wire. Use electrical tape to cover any exposed wire and/or metal.

2. **Calibrate the dimmer switch.** Screw the clear 200·watt bulb into the socket, and plug in the Star Center. Set out the 30-cm ruler (or meter stick) and place the radiometer at the end of it as shown in figure 4.2. Use the permanent marker to draw an arrow on the body of the dimmer as shown in figure 4.3. The arrow will show students where to set the dial for each of their measurements (A-type, G-type, and M-type stars).

Figure 4.1—Star Center Assembly.

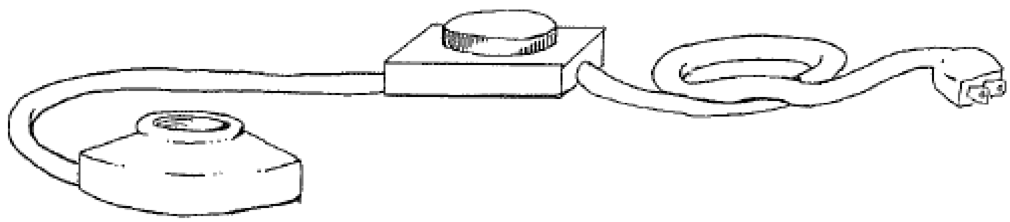


Figure 4.2—Star Center Setup.

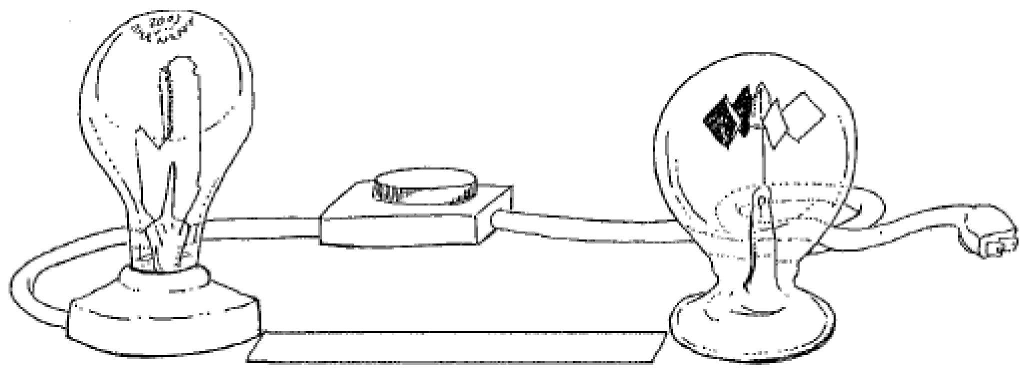
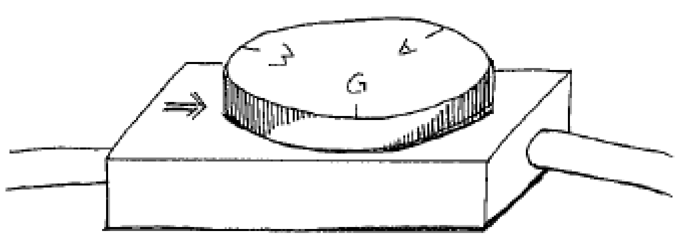


Figure 4.3—Calibrating the Dimmer Switch.



Calibration for the A-type star: Turn the dimmer up to its highest setting. Make a mark on the dial that lines up with the arrow. Label this mark "A."

Calibration for the M-type star: Slowly turn the dimmer down to a point where the filament glows orange/red. When the light bulb is at such a low setting it will flicker. Turn it up until the flicker is less noticeable. Test the radiometer to see if its vanes turn at this setting. If not, turn the dimmer up until the vanes do turn, or replace the radiometer (if the vanes do not turn, the radiometer may be too old). Make a mark at the lowest setting that will turn the radiometer's vanes and label it "M."

Calibration for the G-type star: Turn the dimmer up to its highest point and then slowly turn it down until the bulb glows yellow. This should be about midway between the A mark and the M mark. Make a mark and label it "G."

3. *(optional)* Radiometers are made from very thin glass and therefore are breakable. Some teachers have found it useful to glue their radiometer into a small, clear plastic box.

Teacher's Note*: Starting from the lowest setting and turning toward the highest gives widely varying readings. Encourage students to use a consistent method to collect this data (e.g., starting from the highest setting and turning toward the lowest).*

Just Before the Lesson

1. Set up one or more Star Centers as shown in Figure 4.2. Put the Star Centers in places that have *no* other source of heat (Star Centers cannot be near a sunny window, an incandescent light, a heater, *etc*.).

2. Before each use of a completed Star Center, try the radiometer with each dimmer setting to be sure that its vanes will still turn at the 30-cm distance. An older radiometer will turn more slowly if air has leaked into it. If necessary, shorten the distance at which students make their measurements, but make sure the measurements for all bulbs are made at the same distance.

3. Draw a chart like table 4.1 on butcher paper for students to complete with their data. Hang the chart at the front of the classroom.

Table 4.1—Radiometer Turns in 10 Seconds.

Star Types	A (White)	G (Yellow)	M (Red)
Group 1			
Group 2			
Group 3			
Group 4			
Group 5			
Average			

Classroom Action

1. **Review.** Ask students to restate from Mission 3 how planets may form around a star. Ask students if they think that all stars are the same. Tell them that, in this mission, they will study how stars can vary in color and temperature, as well as the star types, which were first invented to identify stars with different colors. *(For example, our yellow Sun is a G-type star.)*

   Tell them that star types are catalogued according to spectral type by the letters ***O, B, A, F, G, K,*** and ***M***, which can be remembered by the sentence, "**O**h **B**e **A** **F**ine **G**irl (or **G**uy), **K**iss **M**e!" Explain that these star types span the range of star temperatures. Star type is determined strictly by temperature: *(O-type stars are the hottest stars and M-type stars are the coolest.)* Students will study three types of stars: white (A-type), yellow (G-type), and red (M-type).

2. **Mission Briefing.** Ask the class to refer to the "Mission Briefing" for Mission 4 in their student logbooks as one student reads it aloud.

3. **What Do You Think?** Ask students to answer the pre-activity questions on the "Mission Briefing." Then invite them to share their answers in a class discussion.

4. **Demonstration.** Show students the Star Center set up at the front of the classroom. Explain that a single bulb can represent three different star types by using a dimmer switch at three different settings. The three bulb settings represent stars that are white (A-type), yellow (G-type), and red (M-type). Tell students that the lightbulb they see in the Star Center represents a star *(a burning ball of gases)* very far away. Students will observe how the color changes as the temperature of the bulb changes.

   Turn the lights off in the classroom and turn the bulb on to its highest, brightest setting. Ask students what color the bulb is. *White.* Begin dimming. *(The color will become noticeably more yellow.)* Continue slowly dimming the bulb, stopping each time the change in color becomes noticeable to ask students what color they see. At the end, ask students to name all the colors they saw. *White, yellow, and reddish.* Point out that white, yellow, and red are three types of stars: A-type, G-type, and M-type, respectively. The student logbook has a chart on the "What Do You Think, Now?" page that gives facts about each of the basic types of stars. Refer to this chart if desired.

   Tell students that their job is to measure the heat *(infrared radiation)* produced by the simulated A-type, G-type, and M-type stars. A radiometer is used to measure heat (infrared radiation). The faster the radiometer spins, the more heat is being radiated by the bulb. (For an explanation of how a radiometer works, see the appendix.)

   Go over the "Star Center Instruction Sheet" in the student logbook, demonstrating each step. Emphasize that students cannot begin counting until the radiometer reaches full speed, which takes about 30 seconds. Tell them that it is important not to bump the radiometer, since it is *very* fragile, and in order to stop the radiometer vanes between measurements, tilt the radiometer slightly for a few seconds and then *gently* let it down again. Mention the following safety considerations:

- **No more than one group at the Star Center at one time.**
- **Do not touch the bulbs.**
- **Handle the radiometers *very* carefully.**
- **Do not remove the radiometers from the Star Center.**

5. **Activity.** Allow students time to complete their observations and data-taking. Provide other activities for early finishers. When groups finish, they should record their data on the class data chart that has been drawn on butcher paper or the whiteboard.

Closure

1. **Data Manipulation.** Let a student or teams of students use a calculator to average the results from the various groups. Ask students for the conclusions that they can draw from this experiment. Go over the data on the class data chart. The students will find that the A-type star is hottest *(gives off the most infrared radiation)* and the M-type star is coolest *(gives off the least infrared radiation).*

2. **Lecture.** Emphasize that all stars are hot. Even the coolest M-type star, at 3,300C, is at least 13 times hotter than the hottest kitchen oven. Also, tell students that the temperatures listed are for *surface* temperatures of stars. Temperatures at the centers, or cores, of stars are much hotter.

3. **Discussion.** Ask students to read question 3 on the “What Do You Think, Now” page of their logbooks. Invite discussion. Ask students to suppose that our Sun is an A-type star and Earth is the same distance from that A-type star as it is from our G-type Sun. Point out that it would be too hot to live on Earth. Explain that Earth would have to orbit at a greater distance from an A-type star, much farther than its current distance from our Sun, to be suitable for life, and that sunlight would be white, not yellow.

4. *(optional)* **PowerPoint Presentation.** Using PowerPoint slides, quickly review the image show, emphasizing the timeline, to provide students with compressed information of the over three *billion* years it took for complex life to appear on Earth. Use information about the lifetimes of stars of different types from table 4.2. Direct students’ attention to the “Earth’s Timeline” that they created during their last mission. Ask students how long it took for complex life to evolve on Earth. Let students compare this time span of three billion years to the time spans in the “lifetime” column in Table 4.2. Ask them what would happen if Earth orbited an A-type star at a distance where the temperature on Earth was just right for life to begin. Explain that an A-type star only lives 100 *million* years, so complex life could never have evolved on our planet, and an A-type star would have “burned out” long before complex life could get started, and the planet would have become too cold for life at all.

Table 4.2—Star Type Data.

Type	Color	Temperature in ^{o}C	Lifetime
O	Blue	35,000	10 million years
B	Blue-White	21,000	40 million years
A	White	10,000	100 million years
F	Yellow-White	7,500	5 billion years
G	Yellow	6,000	10 billion years
K	Orange	4,700	50 billion years
M	Red	3,300	100 billion years

5. **What Do You Think, Now?** Ask students to answer the post-activity questions on the logbook sheet “What Do You Think, Now?” Invite students to share their responses.

6. **Preview.** Tell students that, in the next mission, they will be finding out how a life-bearing planet orbiting other star types, such as A-type and M-type stars, could still be at a comfortable temperature. *(The completed radiometer table on the “Star Center Instruction Sheet” will be needed in the next mission.)*

Going Further

Demonstration: Lifetimes of Stars

Set up three Star Centers where they can be seen clearly from all points in the classroom. Announce that you are going to begin a demonstration on the comparative lifetimes of A-type, G-type, and M-type stars. Turn the dimmer on the first lightbulb to the A-type star setting, the second dimmer to the G-type star setting, the third to the M-type star setting. Set a timer for five minutes. Explain that the time scale for this demonstration is five minutes = 100 million years (0.1 billion years). At this scale, a white, A-type star will live for five minutes; a yellow, G-type star will live for 8 hours; and a red, M-type star will live for almost a week (80 hours). Mark the class calendar and/or appoint a student to be in charge of turning off the “stars” at the appropriate times. (If there is only one Star Center, demonstrate the lifetimes in series.)

Activity-More Radiometer Stuff!

Ask that students use the radiometer to measure infrared radiation from various things: our Sun, other lights, fluorescent lights, heaters, and so forth. Ask them to interpret the data and draw comparative conclusions about temperatures and distances.

Activity-Colorful Stars at Night

Do some observations of the night sky; try to find stars that are red, white, yellow, or blue, classifying them as they are found by type. Use a star chart to get the star’s name and look it up in a stellar atlas. *(Differences in star color are subtle when viewed with the naked eye. Allow time for dark adaptation and encourage students to look for stars that are “slightly” red or “slightly” blue.)*

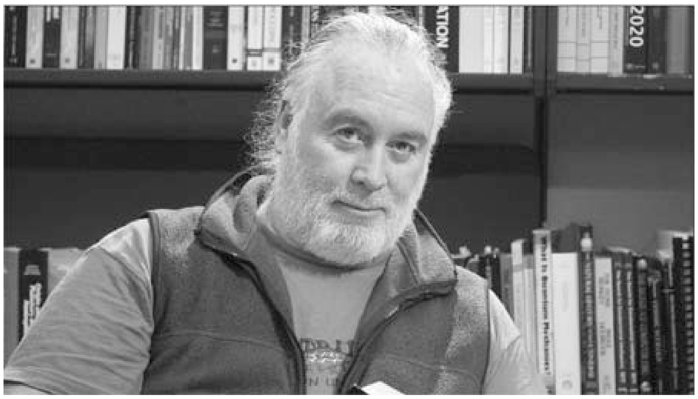
Activity-Astrophotography

Make a long photographic exposure (at least a few seconds) of a familiar constellation from a very dark area. Make sure the lens aperture is at its widest setting (lowest f-stop). Move the camera while taking the picture to "streak" the images of the stars onto the film. This way, their *colors* will be easier to see. From the developed picture, determine the star types.

Mission 4
Investigating Types of Stars

Mission Briefing

Name:____________________________________ Date:______________



Dr. Laurance Doyle, Stellar Astronomer on the SETI Academy Team.

To help us decide which types of stars to search first for planets that could have life, we would like you to conduct experiments to determine some of the ways that stars are different.

What Do You Think?

1. From Earth, stars appear to be different colors: blue, white, yellow, orange, and red. What might cause one star to be a different color than another star?

2. What other ways might stars be different?

3. Earth orbits a yellow star. What things would be different on Earth and in our solar system if our star was red?

SETI INSTITUTE

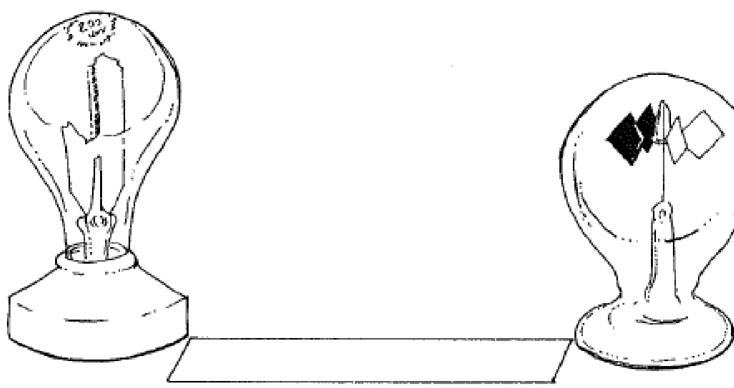
Mission 4
Investigating Types of Stars

Star Center Instruction Sheet

Name:____Date:________________

1. Turn the dimmer switch off. Place one end of the ruler or measuring stick at the base of the socket. Place the radiometer at the other end so it is 30 cm from the light bulb.

Figure 4.4—Proper Distance of Radiometer from the Light bulb.



2. Stop the radiometer's vanes. Turn the dimmer switch to the "A" mark (the light bulb now represents an A-type "star"). Wait 30 seconds. Looking from the top, follow one blade around with your finger. Have your partner time 10 seconds, saying "Start" and "Stop." Count how many times the vanes go around during the 10 seconds. Record the number of turns in Table 4.3.

Table 4.3—Record of Number of Turns in 10 Seconds.

A-type Star	__________ in 10 seconds	Color _____________________
G-type Star	__________ in 10 seconds	Color _____________________
M-type Star	__________ in 10 seconds	Color _____________________

3. Turn the dimmer switch to the "G" mark (the light bulb now represents a G-type "star"). Stop the radiometer's vanes. Wait 30 seconds. Time, count, and record the turns of the radiometer vanes just like you did for the A-type star.

4. Now take the measurements again with the dimmer switch set at the "M" mark (the light bulb now represents an M-type "star"). Don't forget to stop the radiometer completely, waiting 30 seconds for it to once again reach full speed. Record your data. Add all your data to the class chart.

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Mission 4
Investigating Types of Stars

What Do You Think, Now?

Name:____Date:____________________

After you have completed this mission, please answer the following questions:

1. From Earth, stars appear to be different colors: blue, white, yellow, orange, and red. What causes one star to be a different color than another star?

2. What other ways are stars different?

3. Earth orbits a yellow star. What things would be different on Earth and in our solar system if our star was white? (Consider what you learned from the image show about how much time passed before complex life appeared on Earth.)

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Mission 5
Habitable Zones of Stars

Not Too Hot, Not Too Cold, But Just Right

`

Notes

In Mission 4, students explored some properties of three different types of stars.

Overview

The *habitable zone* is the range of distances from the star wherein water can exist in its liquid form on the surface of a planet. Liquid water is necessary for life processes, as we know them, to occur. If a planet is too close to the star, all water will evaporate. If it is too far away from the star, all water will freeze.

In Mission 5.1, students find the relative habitable zones for simulated A-type, G-type, and M-type stars using equipment from Mission 4. In this simulation, the distance from the star at which water freezes is defined as the distance at which the radiometer no longer turns. The distance from the star at which water boils is defined as the distance at which the radiometer's vanes turn 10 times in 10 seconds.

Concepts

- The chemical reactions necessary for life, as we know it, require liquid water.
- For each star type, there is a range of distances from that star wherein water can exist in liquid form on the surface of a planet. This range is called the *habitable zone.*
- Planets orbiting a cool M-type star can have liquid water only if they are relatively close to the star, otherwise the water would freeze. Planets orbiting a hot A-type star can have liquid water only if they are relatively far away from the star, otherwise the water would boil away. The habitable zone depends on the star's temperature.
- Using a graph containing temperature measurements of several stars, the habitable zone can be found (by extrapolation or interpolation) for a star type for which there are no temperature measurements.

Skills

- Making measurements using a radiometer.
- Comparing a model to a real system.
- Graphing and using a graph to get information.
- Interpolating data.
- Using a calculator.
- Calculating averages.

Mission 5.1
Materials

For Each Station

- Star Center from Mission 4
- Star Center Life Zone Directions
- Meter stick

For the Class

- Life Zones of Stars Data Chart large enough for class (or a PowerPoint slide)
- Life Zone Graph large enough for the class (or a PowerPoint slide)
- Data projector and computer
- Colored markers

For Each Group of Students

- Calculator
- Marking pen

For Each Student

- SETI Academy Cadet Logbook
- Pencil

Getting Ready

One or More Days Before Class

1. Make a “Habitable Zones of Stars Data Chart” for summarizing the data, as shown in Table 5.1. Make it large enough for the class to read from their seats, or, make a transparency.

2. Make a Habitable Zone Graph large enough so the class can read it from their seats by preparing a transparency or PowerPoint slide.

Just Before the Lesson

1. Hang both charts at the front of the classroom, set up an overhead projector or data projector, and prepare the transparencies or PowerPoint slides.

2. Set up the Star Center(s) as in Mission 4, but use meter sticks instead of 30-cm rulers. Hang the Star Center Habitable Zones directions at each Star Center.

Table 5.l— Habitable Zones of Stars Data Chart.

	A-Type Star (White		G-Type Star (Yellow)		M-Type Star (Red)	
	Water Freezes	Water Boils	Water Freezes	Water Boils	Water Freezes	Water Boils
Group 1						
Group 2						
Group 3						
Group 4						
Group 5						
Total						
Number of Groups						
Average						

Classroom Action

1. **Review.** Using a Star Center, review the star types and their corresponding temperatures from the last activity. Ask students which colors of stars are the hottest and the coolest. Ask students how Earth would be different if it were orbiting an A-type star instead of a G-type star.

2. **Mission Briefing.** Ask the class refer to "Mission Briefing" for Mission 5 in their student logbooks while one student reads it aloud.

3. **What Do You Think?** Ask students to answer the pre-activity questions on the "Mission Briefing." Invite them to share their answers in a class discussion.

4. **Activity.** Tell students they will be using the Star Center in a simulation to find the habitable zones for different star types. Explain that the point at which the radiometer vanes just begin to turn represents the distance from the star beyond which all water on a planet will freeze and the point at which the radiometer vanes turn 10 times in 10 seconds represents the distance from the star at which all water on a planet will boil and turn to vapor.

5. **Demonstration.** Go over the Star Center Habitable Zones directions, demonstrating how to make the measurements. Students will first set their dimmer dials to the setting for an A-type star and, starting at the end of the meter stick, slowly move the radiometer toward the bulb until its vanes just begin to revolve. This represents the distance from an A-type star at which water would freeze. Then students will move the radiometer closer to the bulb until its vanes revolve 10 times in 10 seconds. This will be repeated for the G-type and the M-type star settings.

Mention the following safety considerations:

- **No more than one group at a Star Center at one time.**
- **Do not touch the bulbs.**
- **Handle the radiometers very carefully.**
- **Do not remove the radiometers from the Star Center.**

6. **Activity**. Allow time for each group to work at the Star Center. Instruct students to record their data into their student logbooks, and then transfer it to the class data chart or transparency.

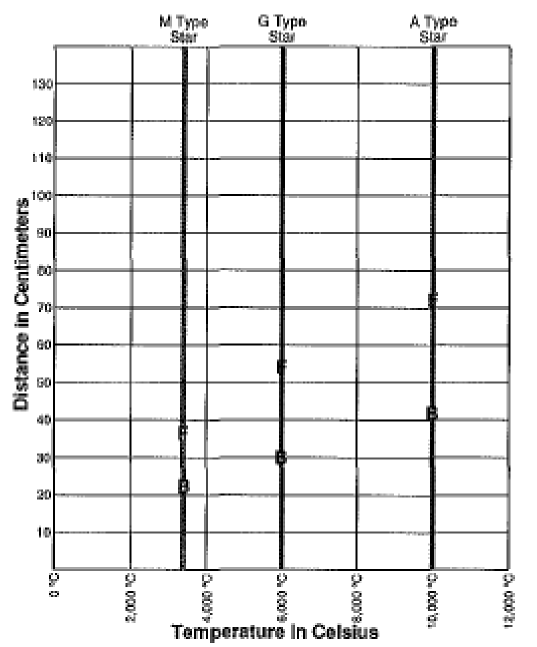
7. **Data/Discussion.** Check to be sure that all groups have taken their life zone measurements and recorded their data on the class data chart. Put the data chart on a wall at the front of the classroom (or put the PowerPoint slide on the data projector) and direct the students' attention to it. Point out that there is a great deal of information on the chart. Ask students to offer ideas about how to summarize the data from the chart. If students do not suggest "finding averages for each column," mention this yourself. Explain that an *average* would be one good way to summarize the data. Hand out calculators and have a few students add up the "water freezes" distances for the A-type star as you read them off. Model this adding process for them on the whiteboard, if necessary. Write the answer in the "total" row on the chart or on the transparency.

8. **Activity.** Ask students to work individually or in groups to find the totals for the other five columns. Explain that the next step in finding the averages is to divide the totals by the number of groups that participated. Do the first one together. Then have students work individually or in groups to find the other averages. Complete the "average" row on the chart or on the transparency.

   ***Teacher's Note*:** *Radiometers can vary greatly in their performance. Do not expect students to get the same results if more than one radiometer is used.*

9. **Activity.** Instruct students to transfer the class averages for life zones onto the table at the bottom of their Habitable Zones of Stars Data Chart. Use the class-sized Habitable Zone Graph (or the transparency or PowerPoint slide of the graph) to demonstrate how to graph the data. Point out that the first step is to find where each type of star falls on the graph, which is shown in figure 5.1, and that the three star types (A, G, and M) are indicated by three vertical lines.

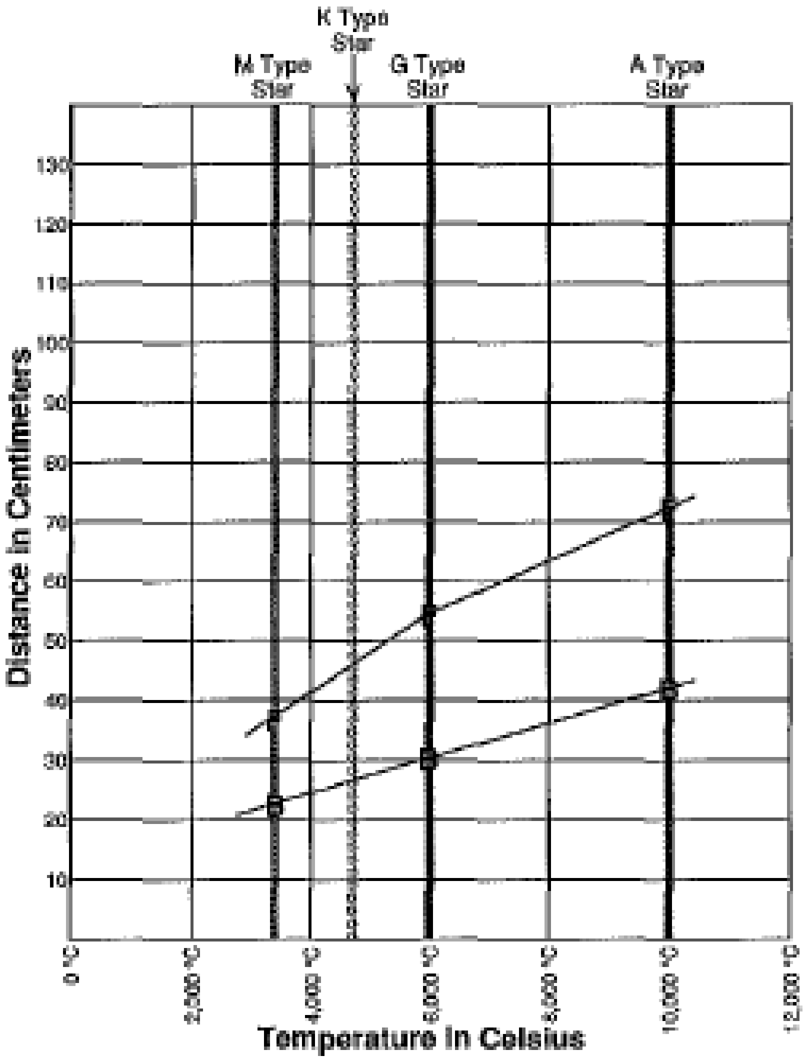
Figure 5.1—Life Zone Graph: Step One.



For the M-type star, tell students to mark the *average* freezing- and boiling-point distances on the temperature line for that star (see page 72) and put a *B* near the boiling-point distances and an F near the freezing-point distances. Do the same for the other two stars. Next, draw a line connecting the data points. There should be one line for the three average freezing-point distances, and another for the three average boiling-point distances. For each of the two lines, have students use a ruler to draw a straight line that comes as close as possible to all three letters.

Ask students how they could use the graph to predict the habitable zones for other types of stars. Instruct students to make a vertical line for the temperature of a K-type star (4,700 °C) as in Figure 5.2. Students should look on the graph to see where the lines they drew for the average freezing- and boiling-point distances cross the vertical line for the K-type star. Tell them that this is an *interpolation* of the freezing- and boiling point distances for planets circling a K-type star. Ask students to color in the habitable zones (see page 72).

Figure 5.2—Life Zone Graph: Step Two.



Closure

1. **What Do You Think, Now?** Encourage students to discuss their ideas, and answer the post-activity questions on their logbook sheet "What Do You Think, Now?" Invite students to share their responses. Students should realize that Earth, Mars, and Venus might not fall within the habitable zone of our central star if the Sun were a different type of star.

2. **Lecture.** The last "What Do You Think, Now?" question asks if all planets within a habitable zone would necessarily develop life. The following information can be added in a lecture:

   No evidence of life has been found on Venus so far. Venus is on the *edge* of a habitable zone (some scientists put it *outside* the Sun's life zone) and it once had liquid water, but it also has a very thick carbon dioxide atmosphere. This caused the surface of the planet to become very hot, and all the water evaporated. No evidence of life has been found on Mars so far. Even though Mars is on the *edge* of a life zone, it has a very thin atmosphere. This means that the surface of the planet is not protected from ultraviolet radiation from the Sun. However, evidence indicates that Mars once had liquid water and a thicker atmosphere. Even if Venus and Mars did have liquid water, there is no guarantee that life would evolve there. We know very little about how life was formed. Some scientists believe that all planets having conditions suitable for life will develop life quickly, while others believe that the appearance of life is a chance occurrence.

3. **Preview.** Tell students that they now have the background they need to create their own planetary systems.

Going Further

Activity-Water-Solid, Liquid, or Gas

Put some ice into a pan and melt it on a hot plate. As water forms, measure its temperature. Ask students if this temperature could be considered the temperature that ice turns into liquid water. Continue heating the water until it starts to steam. Take another temperature measurement and ask students if this temperature could be considered the temperature at which water turns into a gas. Ask student how these measurements compare to measurements made by placing a radiometer 30 cm from the hot plate as the water reaches its melting point and steam point?

SETI INSTITUTE

Mission 5
Habitable Zones of Stars

Mission Briefing

Name: ____ Date: _______________

Dr. Pascal Lee, Planetary Scientist on the SETI Academy Team.

Life as we know it requires liquid water to evolve and survive. The chemical reactions necessary for life cannot happen without liquid water. If a planet orbits too close to its central star, all the water exposed to high temperatures will evaporate. If it is too far from its central star, it will be so cold that all the surface water will freeze and will never be liquid. Please conduct a laboratory simulation to determine these distances from a star that are not too close and not too far for the existence of surface, liquid water. This range of distances from a star is called the star's *habitable zone.* Water on planets inside the habitable zone will, at least at times, be in liquid form, so life might evolve on these planets.

What Do You Think?

1. If Earth were closer to the Sun, what might happen to its liquid water? What planet(s) in our solar system is (are) closer to the Sun than Earth?

2. What would happen to liquid water if Earth were farther away? Which planet(s) in our solar system is (are) farther from the Sun than Earth?

3. Our Sun is a G-type (yellow moderate-sized) star. If our Sun were an A-type (white, more massive) star, where would Earth have to be for its temperature to be not too hot and not too cold?

4. What other factors could complicate the star's habitable zone?

Mission 5
Habitable Zones of Stars

SETI INSTITUTE

Star Center Habitable Zone Directions

1. To find the distance from a star where water will freeze, do the following:

    a. Place the radiometer at the far end of the meter stick.
    b. Make sure the radiometer's vanes have stopped.
    c. Set the dimmer switch to the setting for a star type (A-type, G-type, and M-type, in that order).
    d. Gently move the radiometer toward the lightbulb.
    e. When the vanes begin to spin slowly, stop moving the radiometer.
    f. Record the distance from the bulb to the radiometer on your Life Zones of Stars Data Chart.

2. To find the distance from a star where water will boil, do the following:

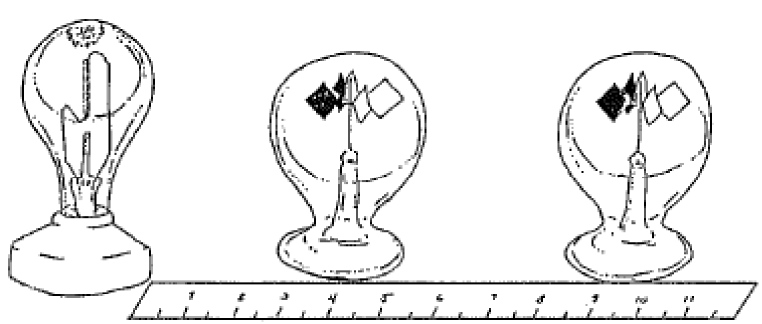
    a. Continue moving the radiometer toward the light bulb.
    b. Stop moving the radiometer every 10 cm and count the number of times the vanes turn in 10 seconds.
    c. When you find the point where the vanes turn 10 times in 10 seconds, record the distance from the lightbulb to the radiometer on your Habitable Zones of Stars Data Chart.

3. To find the life zone, subtract the boiling-point distance from the freezing-point distance. The answer is the width of the life zone. Record this number on your Habitable Zones of Stars Data Chart.

4. Repeat these measurements for each "star."

5. When you are finished, record your data on the class data chart.

Figure 5.3—Positions for Lightbulb and Radiometer.



Mission 5
Habitable Zones of Stars

Habitable Zones of Stars Data Chart

Name:____ Date: ______________________

Follow the directions at your Star Center to measure the distance where water freezes and the distance where water boils for each type of star. Record your data here.

After your class finds the *average* freezing-point distance and the *average* boiling-point distance for each type of star, record them in this table.

Table 5.2—Life Zones of Stars Data Chart

Star Type and Bulb Color	**A-Type Star (White)**	**G-Type Star (Yellow)**	**M-Type Star (Red)**
Distance to Where Water Freezes			
Distance to Where Water Boils			
Width of Life Zone			

Table 5.3—Life Zones of Stars Data Chart

A-Type Star (White)		**G-Type Star (Yellow)**		**M-Type Star (Red)**	
Water Freezes	Water Boils	Water Freezes	Water Boils	Water Freezes	Water Boils

Now you will graph this data!

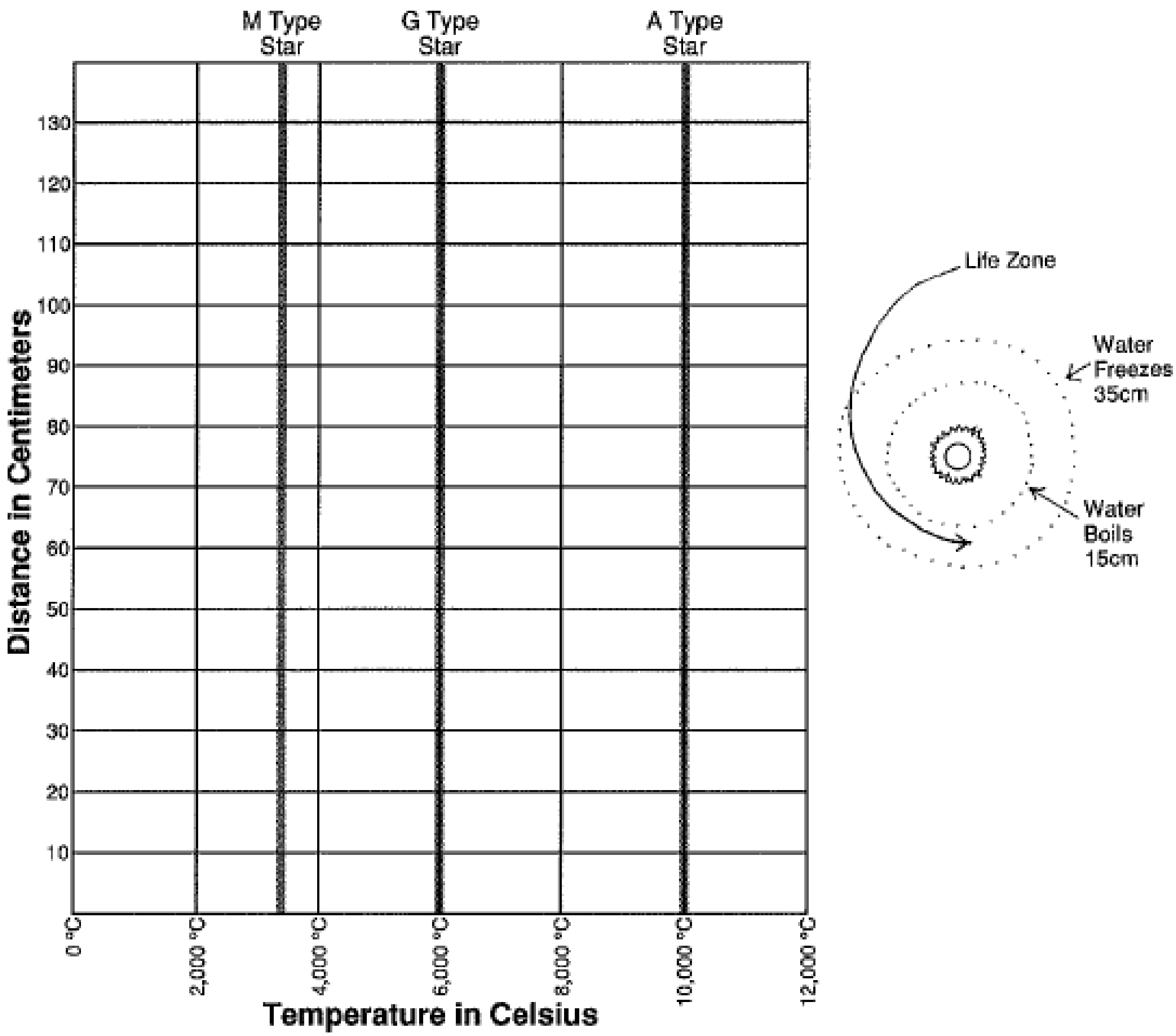
Mission 5
Habitable Zones of Stars

Habitable Zone Graph

Name: ____ Date: ____________________

On this graph, mark the average freezing-point distance for each type of star with an F. Mark the average boiling-point distance for each type of star with a *B.*

Figure 5.4—Habitable Zone Graph.



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Mission 5
Habitable Zones of Stars

What Do You Think, Now?

Name: ____ Date: ______________________

After you have completed this mission, please answer the following questions:

1. Describe how the habitable zone of our solar system would be different if the Sun were an M-type star.

2. Describe how the habitable zone of our solar system would be different if the Sun were an A-type star.

3. In your opinion, should all planets in a habitable zone necessarily develop life? Why or why not? Give some evidence from our own solar system to support your opinion.

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Mission 6
Building a Model Planetary System

SETI INSTITUTE

Creating Your Own "Solar" System

Notes

In Mission 5, students performed experiments to determine the habitable zones of certain star types.

Overview

In Mission 6.1, students select an A-type, G-type, or M-type star and design a system of rocky planets and gas giant planets to orbit that star using a strip compass. This activity involves a wide variety of creative design skills and requires students to synthesize what they have learned so far about Earth's solar system. This is primarily an *art* activity, and precise scales are not required. Creating individual planetary systems is also highly motivating. Allow time for each group to describe their creations before the rest of the class. Post these planetary system designs on the wall, as they will be needed for the next activity.

Concepts

- A planetary system includes a star, the planets, dwarf planets and other objects, which are held in their orbits around the star by gravity.
- Planets can be small and rocky, or giant and gaseous.
- Asteroids are very small chunks of rock left over from the formation of planets that orbit the star.
- The region where solid planets form is called the *rocky planet zone.* Giant gaseous planets form in a zone far from the central star, in a region called the *gas giant zone.*
- Planets in the "habitable zone" circle more closely around cool stars than around warm stars
- *(optional)* Moons are rocky or icy objects that orbit a planet.
- *(optional)* Comets are icy bodies that travel in long, oval-shaped orbits around a star.

Skills

- Making circles of a measured size with a strip compass.
- Drawing a model and applying experimental results to a model.

Mission 6.1
Materials

For the Class

- Masters of star cutouts (M-type, G-type, and A-type)
- 1 sheet each of red, yellow, and white copy paper (or red and yellow markers and white copy paper)
- Box to hold paper stars
- Masking tape

For Each Group of Students

- 30-cm ruler or meter stick
- Sheet of black construction paper, 45-by-60 cm
- Scissors
- Bottle or stick of glue

For Each Student

- Strip of tagboard, 26-by-2.5 cm
- Push pin
- Piece of cardboard (or use the back of a notebook)to protect table from push pin
- Marking pens or crayons
- SETI Academy Cadet Logbook
- Sharp pencil

Getting Ready

One or More Days Before Class

1. Cut a strip of tagboard (or file folder) for each group.

2. Copy the masters of star cutouts on colored paper: 1 sheet of M-type stars on red paper, 1 sheet of G-type stars on yellow paper, 1 sheet of A-type stars on white paper. If colored paper is not available, use markers to give the copied star cutouts their correct colors.

3. Cut the stars apart from each other with a paper cutter and then ask a few students to help cut out the circles. Put the stars into a box and stir them up.

4. Make a strip compass, as described in the student logbook handout for this mission, to show students as an example.

Classroom Action

1. **Review.** Ask students what objects a planetary system would have in it. Review how a planetary system with a red or white star would be different than a planetary system with a yellow star.

2. **Mission Briefing.** Instruct the class to refer to "Mission Briefing" for Mission 6 in their student logbooks while one student reads it aloud.

3. **What Do You Think?** Ask students to answer the pre-activity questions on the "Mission Briefing." Invite them to share their answers in a class discussion. Answer students' questions about planetary systems.

4. **Demonstration.** Tell students that each group will need to start by making a strip compass for drawing circles. Go over the directions in the student logbook for making a strip compass. Demonstrate each step.

5. **Activity.** Make and test the strip compasses. Each student creates their own strip compass.

6. **Demonstration.** Hold up the box full of "stars." Ask one member of each group to select one "star" without looking. These will be the central stars in their planetary systems. Tell students that they should be able to tell what kind of star it is from its color, or they can refer to their logbooks for a reminder. Go over the instructions for designing a planetary system.

   Demonstrate a simple system in front of the class. Glue a star onto a piece of black construction paper. Demonstrate how to use the strip compass to draw the circle for the beginning of the rocky planet zone and the beginning of the gas giant zone, as indicated on the "Designing a Planetary System" logbook pages. The rocky planet zone ends where the gas giant zone begins.

7. **Activity.** Provide paper, stars, push pins, scissors, and glue so students may begin creating their systems once they complete the "Information Sheet" for building a planetary system. Ask each group to invent a name for their central star and write the name of their star and the name of their planetary system on the poster. (The name of the system should reflect the name of the star. For example, if the star is called Arcturus, the star and its orbiting planets together would be called the *Arcturean* system.) They can write the name on a piece of white paper, cut it out, and glue it to the front of the black poster.

Closure

1. **Discussion.** It is important to point out that stars and the planet zones are not drawn to the same scale. Each group presents a short verbal report on their planetary system. What kind of central star does it have? How many planets of each type does it contain? On which ones might life be evolving?

2. **What Do You Think, Now?** Instruct students to answer the post-activity questions on the logbook sheet "What Do You Think, Now?" Invite students to share their responses.

3. **Preview.** Save student's planetary systems. Put them up on the bulletin board for future use.

Going Further

Activity: Outdoor Models

Create outdoor models of students’ new planetary systems.

Activity: Making Tables

Ask students to make a table showing the sizes and distances of the planets in their systems, and a drawing showing the relative sizes of the planets and other objects in their systems. Suggest that students refer to the table of information about planets in our own solar system to judge appropriate sizes (see table 2.1 on page 35).

Figure 6.1—M-type Star Cutouts. (Print on red paper or use red markers to color in.)

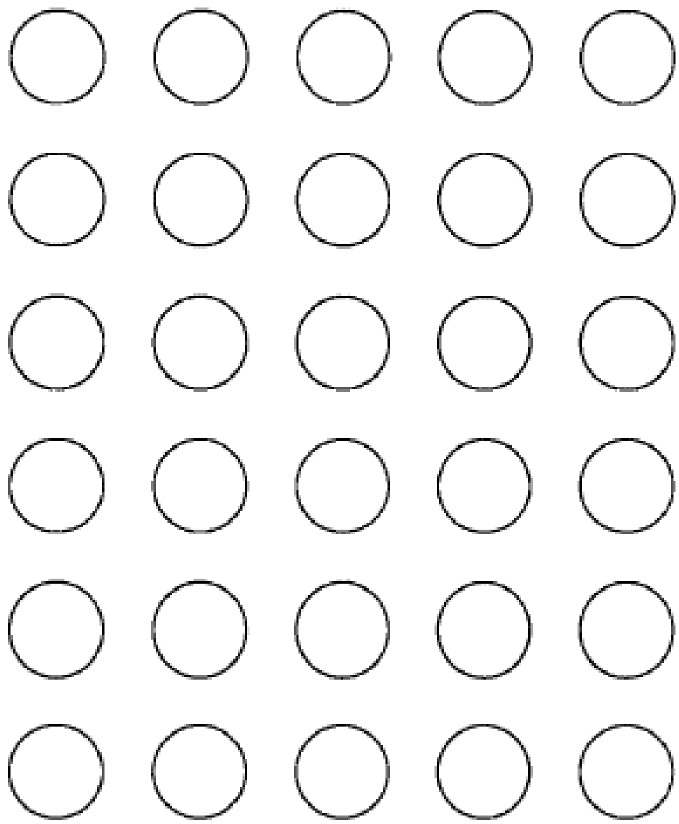


Figure 6.2—G-type Star Cutouts. (Print on yellow paper or use yellow markers to color in.)

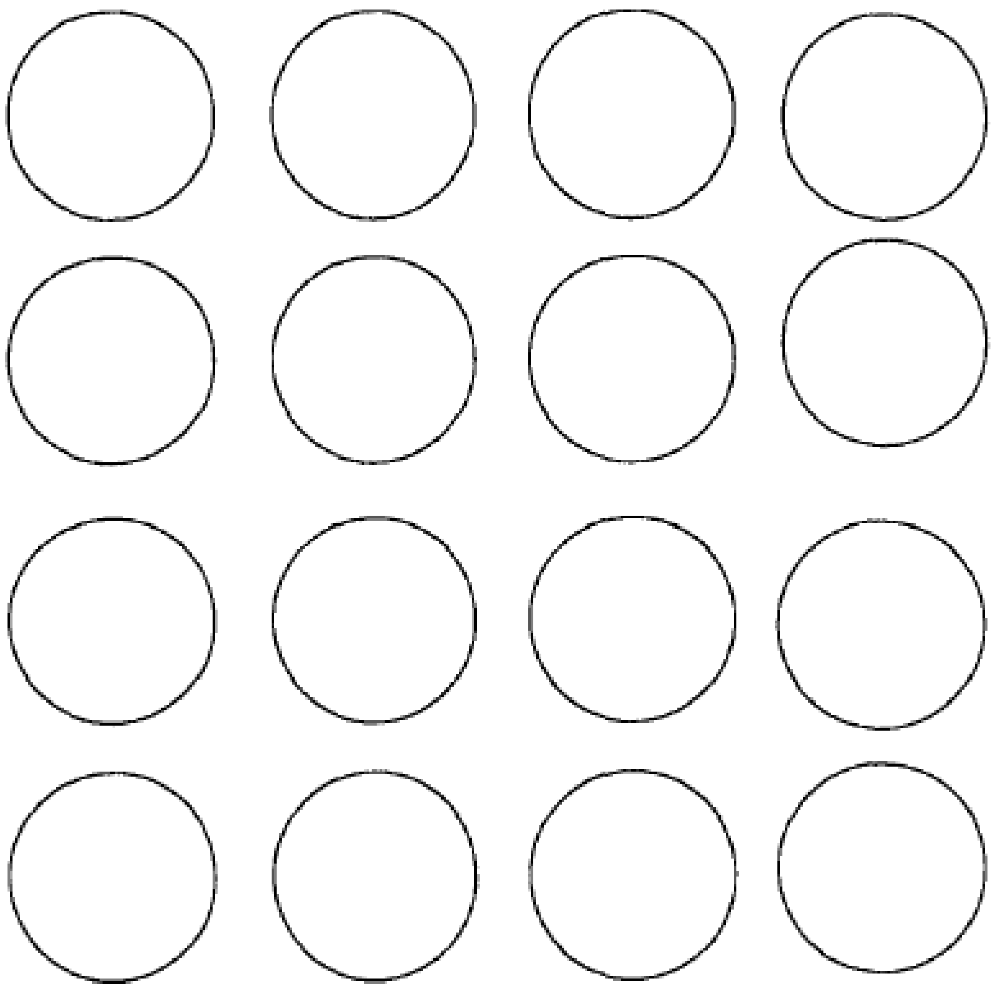
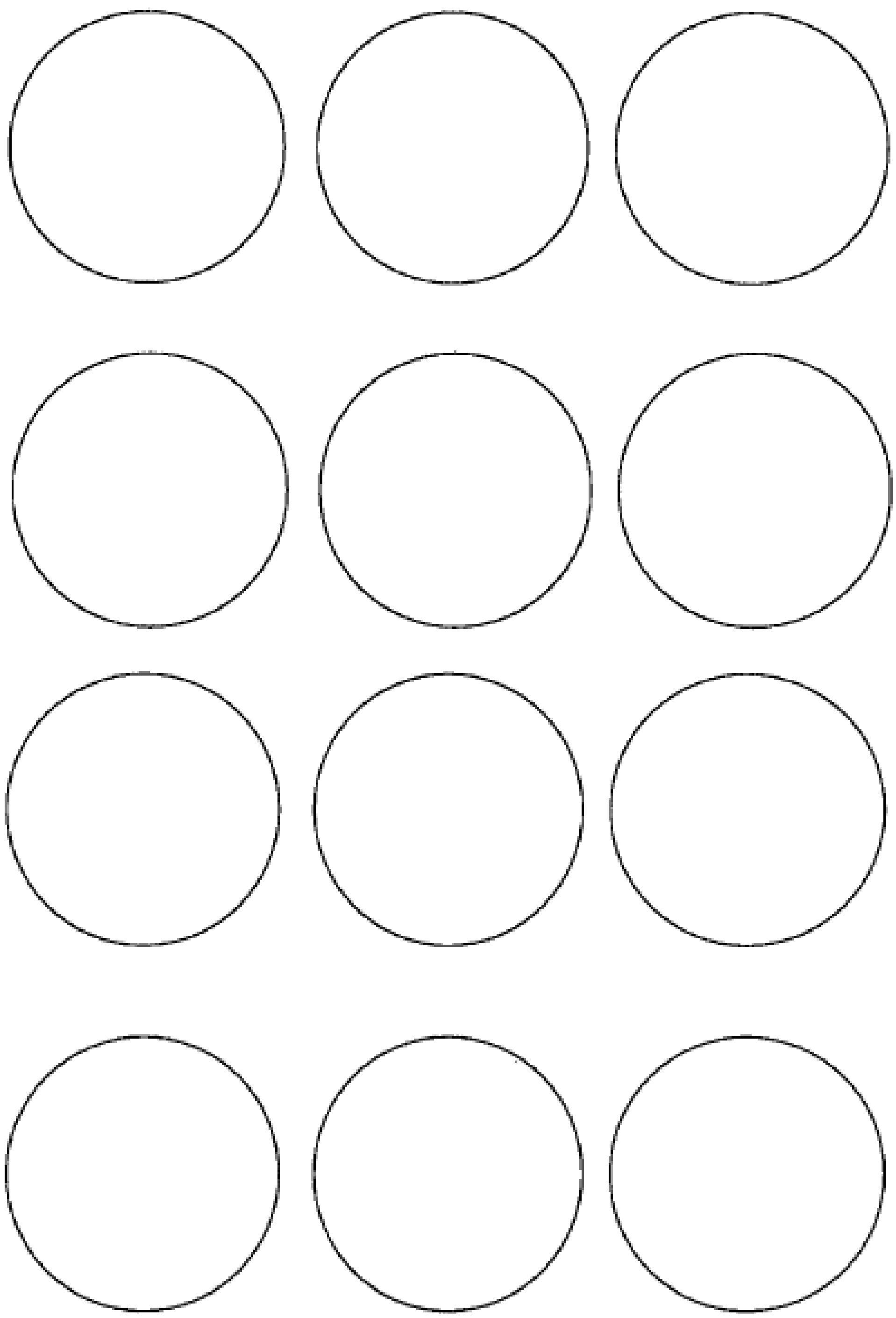


Figure 6.3-A-Type Star Cutouts. (Print on white paper.)



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SETI INSTITUTE

Mission 6
Building a Model Planetary System

Mission Briefing

Name:____ Date: __________________

Dr. Jean Chiar, Astronomer on the SETI Academy Team.

You have now completed your Basic Training and are ready to design an assortment of planetary systems that might be found in our galaxy. Please work in teams to design possible planetary systems. It is our goal to investigate a wide range of systems that *might* exist in our galaxy, including some that contain habitable planets and some that do not.

What Do You Think?

1. What objects might another planetary system have in it?

2. In what ways might a planetary system around another star be different from our solar system?

SETI INSTITUTE

Mission 6
Building a Model Planetary System

Directions for Making a Strip Compass

A strip compass can be used to make circles.

1. Make a pin hole in one end of the strip of tagboard and label it O.
2. Line up your ruler with the O and copy the marks onto your strip. Make a line for every centimeter and a dot for every .5 centimeter. Number each line.
3. Decide what the radius of your first trial circle will be. Remember that the distance across the circle is twice the radius. Make a hole in your strip compass at the distance that is the radius of your circle.
4. Practice making circles with your strip compass.
   a. Put cardboard under the paper so the tack doesn't poke into the table.
   b. Anchor the strip compass at the 0 mark with a push pin.
   c. Poke the pencil through the mark of the radius you want.
   d. Rotate the strip and draw a circle on the paper.

Figure 6.4—Making a Strip Compass.

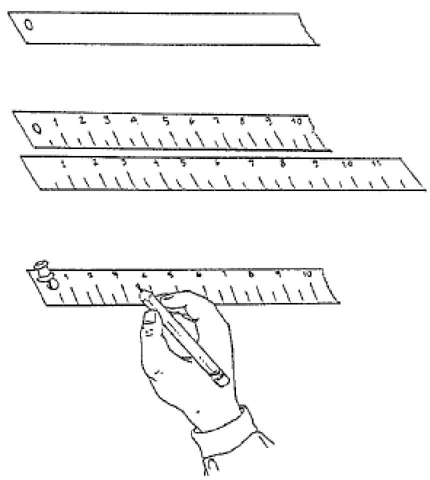
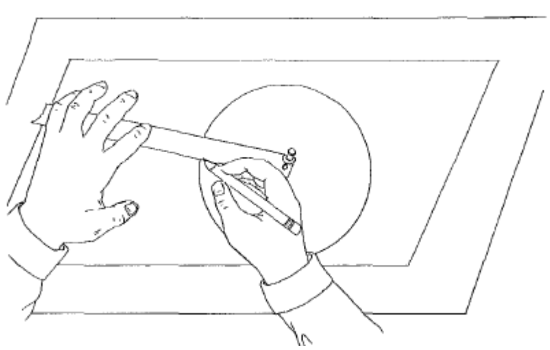


Figure 6.5—Using a Strip Compass,



Mission 6
Building a Model Planetary System

SETI INSTITUTE

Designing a Planetary System

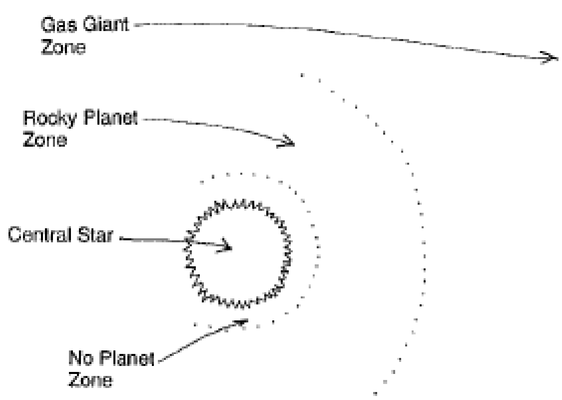
Your job is to design a model planetary system using what you have learned in the previous missions.

1. Choose your star. Check your "Investigating Types of Stars" logbook sheet from Mission 4 for information about colors, temperatures, and lifetimes.
2. Glue your star near the left edge of the black construction paper.
3. Mark the "no planet zone," the "rocky planet zone," and the "gas giant zone." Use the chart below and your strip compass. Measure from the *center* of the star.

Table 6.1—Rocky Planet and Gas Giant Zones.

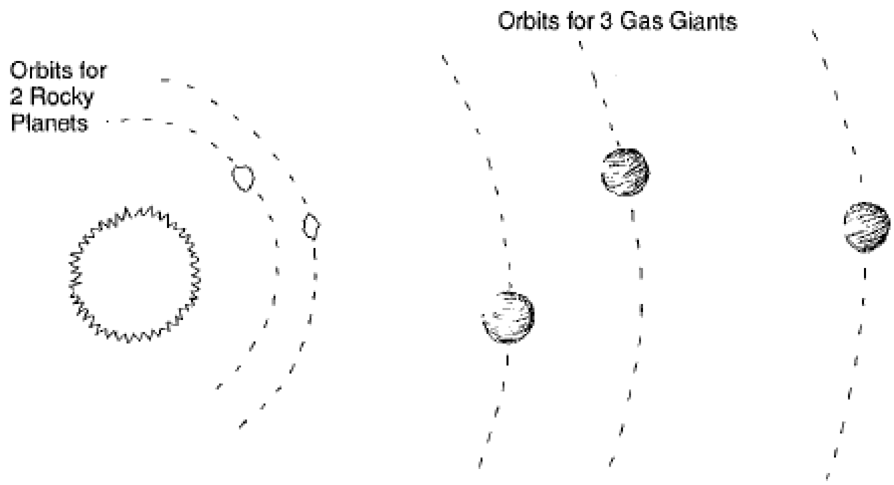
Star Type	Beginning of Rocky Planet Zone	Beginning of Gas Giant Zone
M	2.5 cm	7.5 cm
G	3.0 cm	10.0 cm
A	10.0 cm	20.0 cm

Figure 6.6—Planet Zones.



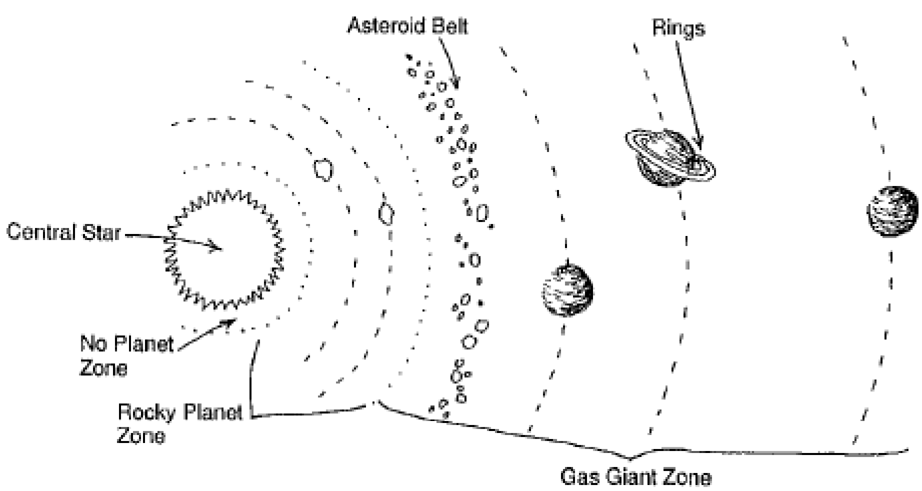
4. Decide how many rocky planets and gas giants you would like to have in your planetary system. Using your strip compass, draw in the orbits for your rocky planets and gas giants as shown below. Measure from the center of the star. Be sure the orbits are placed far enough apart to avoid planets crashing into each other!

Figure 6.7—Placing Planets.



5. Make the planets for your planetary system. This model is not to scale by planetary size or distance, so remember that the rocky planets are many times smaller than the gas giants. Glue your planets onto the black paper. Be sure the center of the planet is on the orbit line.

Figure 6.8—Completing Your Planetary System.

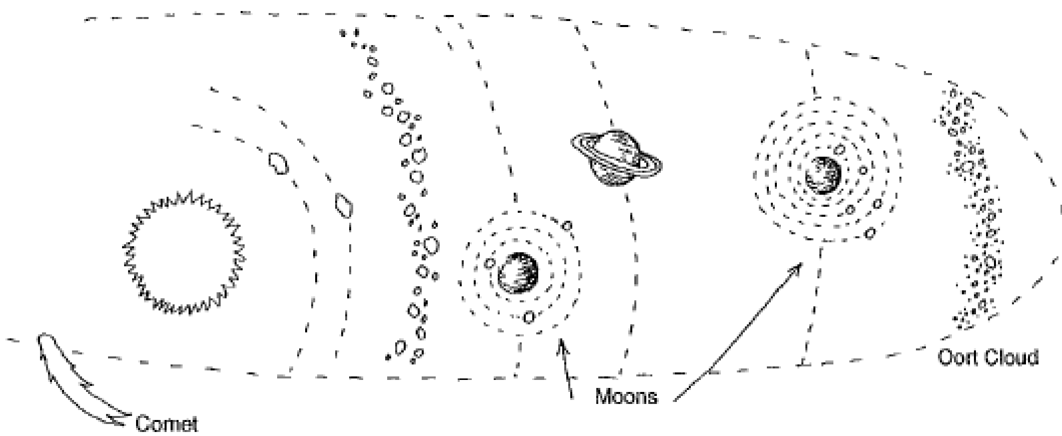


6. Add any of the objects listed below to your planetary system model. (If you add moons to your planets, use your strip compass to draw in their orbit lines, measuring from the center of planets.)

Asteroids, also called *minor planets* or *planetoids*, are chunks of rock and metal that are probably left over from planet formation. In the solar system, asteroids form a belt between Mars and Jupiter. Sometimes large asteroids collide with planets, and on Earth can cause planet-wide earthquakes, tidal waves, fires, and clouds of dust that block out the Sun for months.

Moons are bodies that revolve around planets. They usually have been pulled into orbit by the planet's gravity or have broken off the planet. Rocky planets have very few moons; gas giants have many.

Figure 6.9—Adding Asteroids, Moons, Rings, and Comets.



Rings are made of billions of small lumps of ice and dust held by gravity in thin disk-like orbits around gas giants.

Comets appear as bright heads with long tails. The head consists of a lump of rock, dust, and ice. The tail only appears when the comet comes near the Sun and the ice evaporates. Water vapor and dust that make up the tail are lit up by the Sun. Sometimes large comets collide with planets, causing planet-wide destruction similar to that caused by an asteroid collision.

Comet cloud, also called a *Dart cloud*, consists of billions of lumps of rock, dust, and ice orbiting around the Sun on the outer edge of our solar system, beyond Pluto. Occasionally, some of the lumps from the Oort cloud leave their orbit and become comets, pulled by the gravity of the Sun. When comets come into the inner part of our solar system, near the Sun, they form tails.

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Mission 6
Building a Model Planetary System

Information Sheet

Name: ____Date: ____________________

1. Star type: ____

2. Number of rocky planets: _______________________________________

3. Number of gas giants: ____

4. Number of dwarf planets ____

5. Our planetary system includes:

   _____ asteroids rings

   _____ moons comets or comet cloud

6. If you have chosen to have a comet cloud or asteroids in your planetary system, explain how they have influenced the system's planets and moons.

7. If you have chosen asteroids, moons, rings, and/or comets for your planetary system, explain how these objects might influence the possibility of life on the planets in your system.

Mission 6
Building a Model Planetary System

What Do You Think, Now?

Name: ____Date: ________________

1. In your opinion, might any of the planets in your system have life-forms on them?

2. Why or why not?

3. What kind of life might it be?

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Mission 7
Searching for Habitable Planets

Which of Your Planets Could Support Life?

Notes

In Mission 6, students used a strip compass to design planetary systems that may exist in the neighborhood of our Sun.

Overview

The first step in searching for life is deciding where to look. In Mission 7.1, students add habitable zones to their planetary systems and search for habitable planets in all the students' systems to determine which planets are the most likely homes for extraterrestrial -forms. Students choose one "Planet X" to evolve and map in later missions.

Concepts

- A planet is not likely to develop life if it is too close or too far from its star, because there will be no liquid water *(it will not be within the habitable zone).*
- An A-type star does not live long enough for complex life as we know it to develop on an orbiting planet.

Skills

- Using a strip compass to make circles.
- Using graphics to indicate regions in a diagram.
- Using criteria to eliminate items from a set.

Mission 7.1
Materials

For the Class

- Model planetary systems from Mission 6
- Butcher paper
- Tape
- Marking pen

For Each Group

- Thin-tipped colored markers or crayons

For Each Student

- Scratch paper
- SETI Academy Cadet Logbook
- Pencil

Getting Ready

Just Before the Lesson

1. Label the butcher paper “Conditions for a Life Supporting Planet” and hang it at the front of the classroom.

Classroom Action

1. **Mission Briefing.** Instruct the class to refer to the “Mission Briefing” for Mission 7 in their student logbooks while one student reads it aloud.

2. **What Do You Think?** Have students answer the pre-activity questions on the “Mission Briefing.” Then invite them to share their answers in a class discussion. Ask students how to decide which planets in their systems might be suitable for life. If they do not recall, give them the hint that each star has a habitable zone around it.

3. **Review.** Discuss the concept of zones. Encourage students to explain the concept. Write guidelines on the whiteboard for students to find the habitable zones in their planetary systems. List the habitable zones in Table 7.1, explaining that these represent the potential habitable zones around different types of stars.

Table 7.1—Habitable Zones Around Star Types.

A-type star (white) Life expectancy of a star	Habitable zone = 12.5 cm to 16.5 cm 100 million years
G-type star (yellow) Habitable expectancy of star	Habitable zone = 4.0 to 7.5 cm 10 billion years
M-type star (red) Life Expectancy of star	Habitable zone = 3.5 cm to 5.0 cm 100 billion years

Activity. Students draw in the habitable zone circles for their planetary systems. The inner circle shows the closest a planet can be to the star and still have liquid water. *(The outer circle shows the farthest a planet can be and still have liquid water.)* Students should use the strip compass they made in the last mission, with a colored marker or crayon to differentiate the habitable zone from the planets' orbit lines. Measure from the center of the star. Ask students to use the guide-lines just written on the whiteboard.

5. **Discussion.** Ask students to brainstorm conditions that a planet requires to support habitable . Record the students' ideas on the butcher paper hung at the front of the classroom labeled "Conditions for a Life-Supporting Planet."

   Add ideas if necessary, such as the following:

   - should be within a star's habitable zone *(have liquid water)*
   - the planet's central star should live long enough for complex life to evolve *(it took three billion years on Earth)*
   - no major interference from meteorites or large comets
   - an orbit that is reasonably circular, so the temperature on the planet does not vary too much
   - preferably a solid, rocky surface
   - planet should be massive enough to have an atmosphere and hold onto it *(the early atmosphere on Mars was lost in part because Martian gravity was not strong enough to keep it from escaping)*

6. **Activity.** Regroup students into the groups that designed the planetary systems.

   - Students carry out their SETI mission by searching all the planetary systems that we know of (indicate the posters on the bulletin board).
   - Students select the planetary system (s) and the planet(s) that they think are the most likely to have conditions suitable for life.
   - Each group appoints a recorder to keep track of the systems visited, the planets selected, and the reasons for selection.
   - Student teams to choose one of the likely planets. This will be the planet they "evolve" in future missions.

Teacher's Note: *It is okay if groups all select the same planet, or if different groups select different planets. They can select a planet from any system they want, and this will be their Planet X. In the unlikely event that no planets are suitable for life, build a new planetary system with the help of the entire class. Put up a black poster, select a central star, and draw in planetary orbits and habitable zones. Or have each team add a potentially life-bearing planet to their own model planetary system.*

Closure

1. **What Do You Think, Now?** Instruct students to answer the post-activity questions on the logbook sheet "What Do You Think, Now?" Invite students to share their responses.

2. **Preview.** Tell the students that, in the next few missions, they will imagine how their selected Planet X changes over time, based on the evolution of our own planet, Earth.

Going Further

Mathematics: “Real” Habitable Zones

Scale from “real” (Earth's) habitable zone to find M-type and A-type habitable zones in actual measurements in kilometers. Consider Earth's habitable zone to extend from Venus to Mars. Use the relative sizes of habitable zones for A-type, G-type, and M-type stars as determined in the radiometer mission.

Mission 7
Searching for Habitable Planets

Mission Briefing

Name: ____ Date: ________________

Dr. Hiromi Kagawa, Molecular Biologist on the SETI Academy Team.

You will now investigate each of the model planetary systems to determine which systems have planets that are likely to support life. The planet most suitable for life to begin will be called Planet X. In later missions, you will evolve Planet X, creating its geography and determining its climate.

What Do You Think

1. What things would make it possible for a planet to develop life?

2. What kind of a planet would probably *not* develop life?

Mission 7
Searching for Habitable Planets

What Do You Think, Now?

Name: ____ Date: ____________________

After you have completed this mission, please answer the following questions:

1. Now that you have selected your planet, explain *why* you selected that planet.

2. What kind of life do you imagine might exist on your planet?

Mission 8
Evolving Planet X

Your Planet Begins Its Childhood

Notes

In Mission 7, students explored their planetary systems for habitable planets and chose Planet X.

Overview

In Mission 8.1, students begin creating a history for the planet they selected. This history will show its evolution from a molten ball to a planet with liquid water that is able to sustain life. Students play a simulation game to determine the volcanic activity and encounters with comets and asteroids that their planet was subjected to in its early history, before it formed a stable crust and liquid oceans.

Concepts

- Earth went through a series of changes before it was suitable for life.
- When Earth was first formed, it was a molten body of hot rock, with no liquid water or atmosphere.
- Over time, Earth cooled. The outer surface formed a crust, and oceans formed from water brought by comets that impacted Earth. Periods of intense volcanic activity contributed to the oceans and the formation of the atmosphere.
- Random events, such as asteroid and comet impacts, contributed to Earth's evolution. It is possible that a planet could evolve to become similar to Earth, with slight differences, depending on its volcanic activity and the number and timing of asteroid and comet impacts.

Skills

- Following a flowchart.
- Using dice to simulate random events.
- Constructing a timeline.

Mission 8.1
Materials

For the Class

- “Earth's Timeline” from Mission 3
- Scissors or paper cutter

For Each Group of Four Students

- 2 dice
- Marking pens or crayons
- Glue stick or transparent tape
- 20 3-by-5-inch index cards (or small squares of construction paper)
- *(optional)*5 meters of adding machine tape
- *(optional)*Scissors

For Each Student

- SETI Academy Cadet Logbook
- Pencil

Getting Ready

Just Before the Lesson

1. Mount the “Earth's Timeline” at the front of the classroom. Make space below it for the student groups to display the timelines of their planets.

2. Trim the index cards to 10-cm long with a paper cutter, or have students do it themselves.

Classroom Action

1. **Mission Briefing.** Instruct the class to refer to the “Mission Briefing” for Mission 8 in their student logbooks while one student reads it aloud.

2. **What Do You Think?** Ask students to answer the pre-activity questions on the “Mission Briefing.” Then invite them to share their answers in a class discussion.

3. **Discussion.** Show the “Earth's Timeline” that the class began in Mission 3. Ask students to come up and point out various events in Earth's formation. Ask them how long ago the events happened. The small marks on the timeline each represent 0.1 billion years *(100 million years)*. Ask students if they think that these events might occur at different times in the evolutions of different planets. For example, if a planet were bigger, would it take more or less time for the hard surface and the oceans to form?

4. **Demonstration.** In this mission, students will play a game where they use dice to determine the chance impacts by large asteroids and the appearance of volcanoes and oceans on their planets. Demonstrate the game, following the “Timeline Directions” in the student logbook. Each time the dice are rolled, 100 million years go by. The number rolled on the dice determines the most important event that occurs on the planet during those 100 million years. Follow the flowchart on the directions to find out what happens next.

5. **Activity.** Students cut out the six cards with their captions from the “Planet Evolution Event Descriptions” sheet in their student logbooks. Tell students in each group to use the l0 cm wide trimmed index cards to make six drawings, one based on each event description. Students make an index card drawing of a mass of hot, solid rock to represent the early state of their planet.

   The index-card drawings should have the following labels:

   Hot Rock

   Asteroid Strikes on Molten Surface

   Crust Forms

   Asteroid Impact

   Comet Impacts

   Volcanic Activity

   Seas and Continents Form

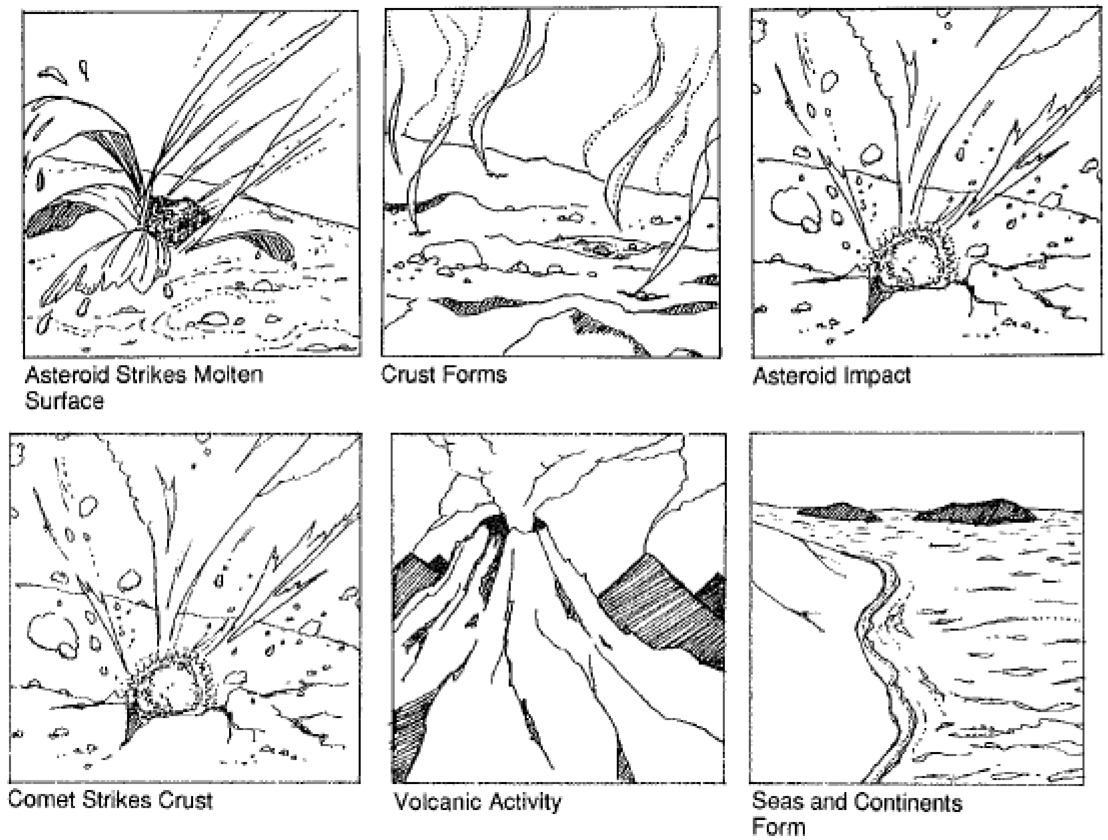
   Use the remaining blank cards for additional drawings, as needed. *(The needed number of drawings will depend on the numbers that students roll.)* In each group, students turn the description cards upside down and place them into a pile. They can then select cards blindly as a method of deciding who will make each drawing.

   Playing the Game: Tell students that each roll of the dice is worth 100 million years *(0.1 billion years)*. This length of time is represented by one card *(10 cm by 10 cm)*. They start by putting down a “Hot Rock” card, which shows how their planet starts out. After each roll, they should look at the flowchart in the directions to see what happens during that 100 million year time period. Next, they should read the appropriate event card and add the appropriate index-card drawing onto the timeline. (*They will be taping together the drawings into a very long strip, from left to right. Or, cards may be taped onto a long strip of paper.)* Go over directions and demonstrate each step. Begin an example timeline like the one shown in Figure 8.1 as students watch.

6. **Activity.** Pass out one strip of adding machine tape, 5-meters long, to each group.

   - Ask them to mark the tape “Today” at the right end, and put a small mark every 10 cm along the tape.
   - Students make a large mark every 50 cm, labeling these large marks with “0.5 billion years ago,” “1 billion years ago,” “1.5 billion years ago,” and so on, ending with “5 billion years ago” for the last large mark.
   - Students attach their strip of index-card drawings to the timeline, aligning the strip so the rightmost card is above the “Today” label.
   - Groups invent a name for their planet and make a name label for their timeline. It should include the students' names.

Figure 8.1—Sample Timeline.



Closure

1. **Discussion.** Tape Planet X's Timelines under the Earth's Timeline. Invite each group to report to the class on what occurred during their planet's history.

2. **What Do You Think, Now?** Ask students to answer the post-activity questions on the logbook sheet "What Do You Think, Now?" Invite students to share their responses.

3. **Lecture.** Point out to students that so far they have learned about the history of their planets for only the first half-billion years. Scientists think that complex, intelligent life will take several billion years to develop on any planet, as it did on Earth, but they do not know for certain. In some cases, intelligent life might form in only three billion years, while in other cases it might take seven billion years. With only one sample to study, Earth, we cannot know whether our evolution was "typical" or very unusual.

4. **Preview.** Tell students that, in the next mission, they will learn about "recent" Earth history *(the period about 200 million years ago, at the beginning of the age of dinosaurs.)*

Going Further

Research-Timelines

Students make personal timelines showing the highlights of their lives.

Science—Comets and Asteroids

Explain that although the rate of comet and asteroid impacts is much lower now than it was four billion years ago, there is always a chance of another major impact. Students may research NASA’s Near Earth Asteroid Tracker (NEAT) and NASA's Asteroid and Comet Impact Hazards (ACIH).

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Mission 8
Evolving Planet X

Mission Briefing

Name: ____ Date: ____________

Dr. Nathalie Cabrol, Planetary Scientist on the SETI Academy Team.

Just as Earth passed through many phases in its development to become a planet that can support life, your planet will also go through phases. You will play a game that will allow you to construct a timeline of your planet's development. In this game, dice rolls will determine the kinds of chance encounters that your planet will experience in its evolution. All the possible dice-roll encounters were actually experienced by Earth in the past as it evolved over hundreds of millions of years.

What Do You Think?

1. How do you think early Earth was different from present-day Earth?

2. What caused the changes on Earth?

Mission 8
Evolving Planet X

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Timeline Directions

1. All planets begin as a mass of hot rock. Start by making a picture of this.

2. Roll the dice to find out the events that will happen on your planet. Each roll of the dice represents 100 million years. After you roll, read the card and tape or glue the appropriate drawing onto the timeline.

Figure 8.2—Sample Timeline.

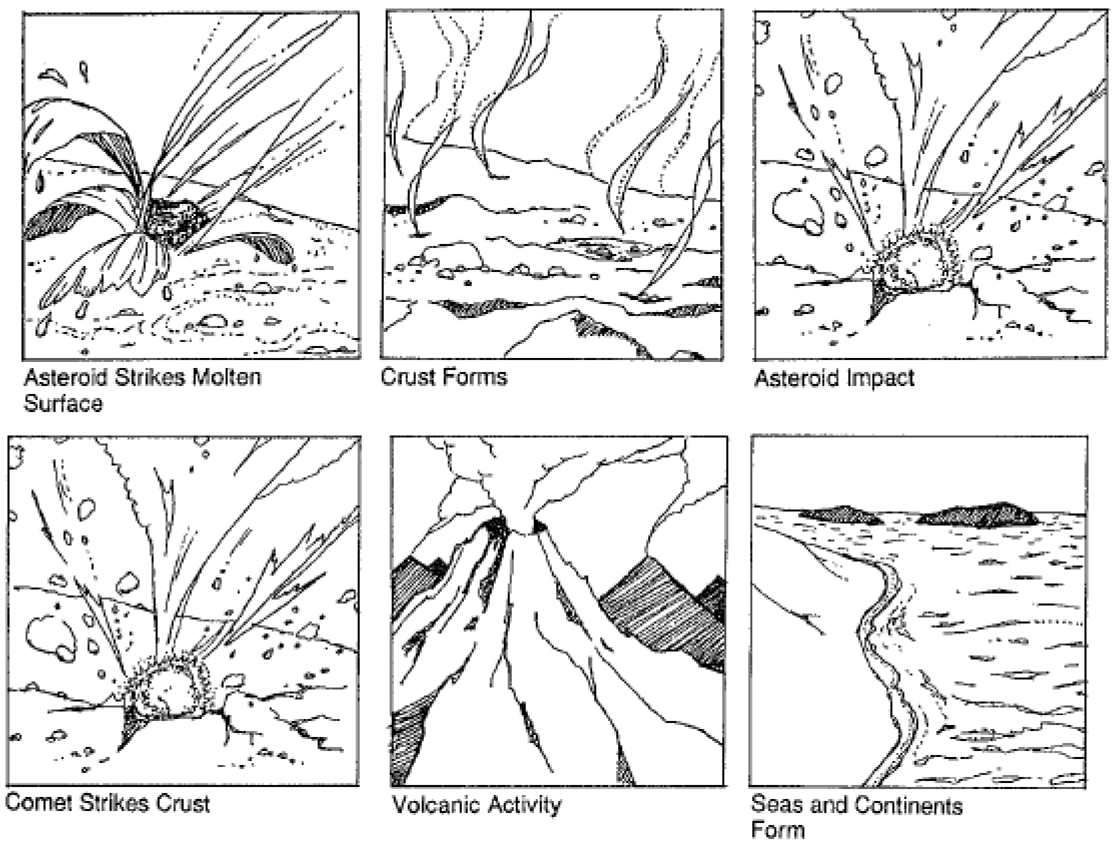

Table 8.1—Directions for Making Planet X's Timeline.

A) If you roll a … **2 through 8**: Read event card for *Asteroid Strikes Molten Surface*, and attach the correct drawing to the timeline. Return to A. **9 through12**: Read event card for *Crust Forms*, and attach the correct drawing to the timeline. Go on to B.
B) If you roll a … **2 through 6:** Read event card for *Asteroid Impact*, and attach the correct drawing to the timeline. Return to B. **7 through 12**: Read event card for *Comet Strikes Crust*, and attach the correct drawing to the timeline. Go on to C.
C) If you roll a … **2 through 6:** Read event card for *Comet Strikes Crust*, and attach the correct drawing to the timeline. Return to C. **7 through 12**: Read event card for *Volcanic Activity*, and attach the correct drawing to the timeline. Go on to D.
D) If you roll a … **2 through 4:** Read event card for *Volcanic Activity*, and attach the correct drawing to the timeline. Return to D. **5 through 12**: Read event card for *Seas and Continents Form*, and attach the correct drawing to the timeline. Congratulations, your planet is ripe for life to begin.

Mission 8
Evolving Planet X

Planet Evolution Event Descriptions

Table 8.2—Planet Evolution Descriptions.

Asteroid Strikes Molten Surface The heat from Asteroids hitting your planet and the radioactivity in the rocks make your planet warm up. Your planet is a glowing ball of molten rock. Because it is so hot and liquid, the heavier elements, like iron, sink to the center and the lighter elements float to the top.	**Crust Forms** There are fewer asteroids no, so they hit your planet less often. The surface of your planet can cool enough to form a solid crust.
Asteroid Impact A huge asteroid hits your planet and creates an enormous crater in the newly formed crust.	**Comet Strikes Crust** A huge comet hits your planet. The heat from the impact melts the comet's icy center, adding to the water on the planet's surface. Organic molecules are also brought by the comet.
Volcanic Activity Volcanoes on your planet give off gases that form a poisonous atmosphere of ammonia and methane. They also release water. The planet is so hot that water immediately evaporates and hangs in the atmosphere as water vapor. Your planet has brown and orange clouds and constant intense lightening.	**Seas and Continents Form** The planet has cooled down enough for the water to stay liquid and form seas. The lightest rock has formed continents on your planet, and the water covers the heavier rocks. There are still huge lava flows and continual lightening. Your planet is ripe for life to begin.

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Mission 8
Evolving Planet X

What Do You Think, Now?

Name: ____ Date: ________________

After you have completed this mission, please answer the following questions:

1. What was your planet like just after it formed?

2. What were some of the major events in the lifetime of your planet?

3. What is your planet like today?

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Mission 9
200 Million Years Ago

What Happened Way Back When?

Notes

In Mission 8, students evolved Planet X make it suitable for life.

Overview

About 20 years ago, a major revolution occurred in the field of geology. At that time, there was considerable argument about whether or not the continents were moving. Many different lines of evidence eventually forced geologists to conclude that the continents on both sides of the Atlantic were indeed drifting apart because of the forces of plate tectonics. In Mission 9.1, students are introduced to this idea in one of the ways that scientists were: by thinking about how the continents might fit together into a huge "supercontinent" that came to be called Pangaea.

Concepts

- Today's continents seem to fit together like puzzle pieces.
- Scientists believe that, 200 million years ago, the current continents formed an unbroken supercontinent called Pangaea.
- Pangaea broke apart and the current continents slowly drifted to their present-day positions.
- The continent shapes no longer fit together perfectly because their edges have been worn down and changed with time.

Skills

- Fitting together complex shapes.
- Using clues to solve a puzzle.

Mission 9.1
Materials

For the Class

- World maps, globes, or atlases
- *(optional)* Overhead projector or data projector
- *(optional)* Pangaea Puzzle Answer Key transparency

For Each Group of Two or Three Students

- Scissors
- Glue sticks
- Blue construction paper, 22 by 48 cm
- Copy of Pangaea Puzzle cutout sheet

For Each Student

- SETI Academy Cadet Logbook
- Pencil

Getting Ready

One or More Days Before Class

1. Students work in groups on the Pangaea Puzzle, or each student can work his or her own puzzle. If short on time, ask students to cut out and label the puzzle pieces as homework, or make this entire lesson into a homework assignment.

2. *(optional)* Make a PowerPoint slide or transparency of the Pangaea Puzzle Answer Key.

Just Before the Lesson

1. Display the world maps and globes around the room. Display atlases if they are available (check social studies texts).

2. *(optional)* Set up the data projector for the PowerPoint slide of the answer key.

Classroom Action

1. **Introduction.** Tell students about the "puzzle" of the supercontinent of Pangaea. Tell students that they will see how the continents on Earth have evolved. This will allow them to make some reasonable guesses about the formation of continents on the planets that they are creating.

2. **Mission Briefing.** Students will now jump to a time "only" 200 million years ago *(not long ago compared to the age of Earth)*, when dinosaurs already roamed Earth. The class refers to the "Mission Briefing" for Mission 9 in their student logbooks as one student reads it aloud.

3. **What Do You Think? S**tudents answer the pre-activity questions on the "Mission Briefing". Invite them to share their answers in a class discussion.

4. **Lecture.** Explain to students that in 1912 a German scientist, Alfred Wegener, hypothesized that the continents were once joined together and are slowly drifting apart. Explain that while it may be difficult to think of a huge continent like North America "drifting," continents can move

because the crust on which they sit floats on a molten layer deeper inside the planet. *(Students will learn more about this in upcoming missions.)*

Ask students to look carefully at the land masses on the “Pangaea Puzzle” sheet in their logbooks. Explain that each of the symbols on the continents represents rock of a certain type and age, fossils of a specific plant or animal, or big gouges in the continent made by a glacier.

5. **Activity.** Instruct students, as a class or individually, to identify and label the continents and Greenland and then cut them out. They also identify and label the subcontinent India.

6. **Lecture.** Discuss the symbols that are used on the map. Repeat to students that their job is to use the shapes of the land masses together with the rock, fossil, and glacier clues to reconstruct the supercontinent Pangaea. Suggest that they move the pieces around as a method of solving the puzzle. Remind students that continents cannot jump up or flip around. They may only slide the land masses toward or away from each other, or rotate them slightly. Tell students that the pieces may not fit together perfectly because in some places the continents extend beyond the coast in large flat regions called *continental shelves* and the edges of continents have eroded or grown since the time they broke away from each other. For example, continents could grow when islands collided with them, or could scoop up material from the ocean bottom. Much of California was formed in this way, in part over the last 200 million years.

7. **Activity.** Referring to an atlas or wall map, students put the continents in their current positions on top of their piece of blue construction paper. Students will rely heavily on rock types and fossil clues to know where to put the pieces. When done, students should glue the pieces down to the blue paper. Students look at the shape of the continents on a world map or in their atlases *(available in most current social studies texts)*. Ask them if they can see any evidence that might support Wegener's theory of continental drift. They might see that some of the continental shapes fit together like pieces of a jigsaw puzzle, especially South America and Africa. *(Explain that continents are actually carried along on pieces of ocean crust, similar to the way a conveyer belt operates. Continents do not plow through the ocean floor.)*

Closure

1. **Discussion.** Invite students to compare their solutions with one another.

2. **Lecture.** Display the “Pangaea Puzzle Answer Key”“ on an overhead projector or PowerPoint slide, or go from group to group showing the answer key. This key shows the way that scientists have solved the puzzle. They believe that the land masses of Earth looked like this 200 million years ago, the time when dinosaurs began to roam Earth. Put a label or picture of “Pangaea” on the “Earth's Timeline,” 200 million years before the “Today” mark (*i.e.*, 20 cm from the “Today” mark). Point out how “recently” this was, and emphasize that most new theories suggest that, in the past few billion years, many such supercontinents have formed and broken up. Pangaea is just the most recent one.

3. **Discussion.** Encourage students to discuss the evidence that supports the theory of Pangaea, and share their ideas in a class discussion. The excellent “fit” of the shapes of the continents and the deposits of rocks, minerals, and fossils provide convincing evidence that Pangaea once existed.

4. **What Do You Think, Now?** Students answer the post-activity questions on the logbook sheet "What Do You Think, Now?" Invite students to share their responses.

5. **Preview.** Students may wonder if the continents are still moving. Tell students that, in the next mission, they will see that the continents *are* still moving, and they will also see *where* the continents are headed.

Going Further

Research: Dinosaurs of Pangaea

Dinosaurs! Let students discuss these marvelous creatures that lived on the super-continent of Pangaea. They may share models, drawings, stories, books, games, or dolls of these extinct reptiles.

Research: Stories in Stone

Research and discover the specific fossils that helped scientists to piece together the real puzzle of Pangaea. Discover the rock types that "match" but today lie across the oceans from each other.

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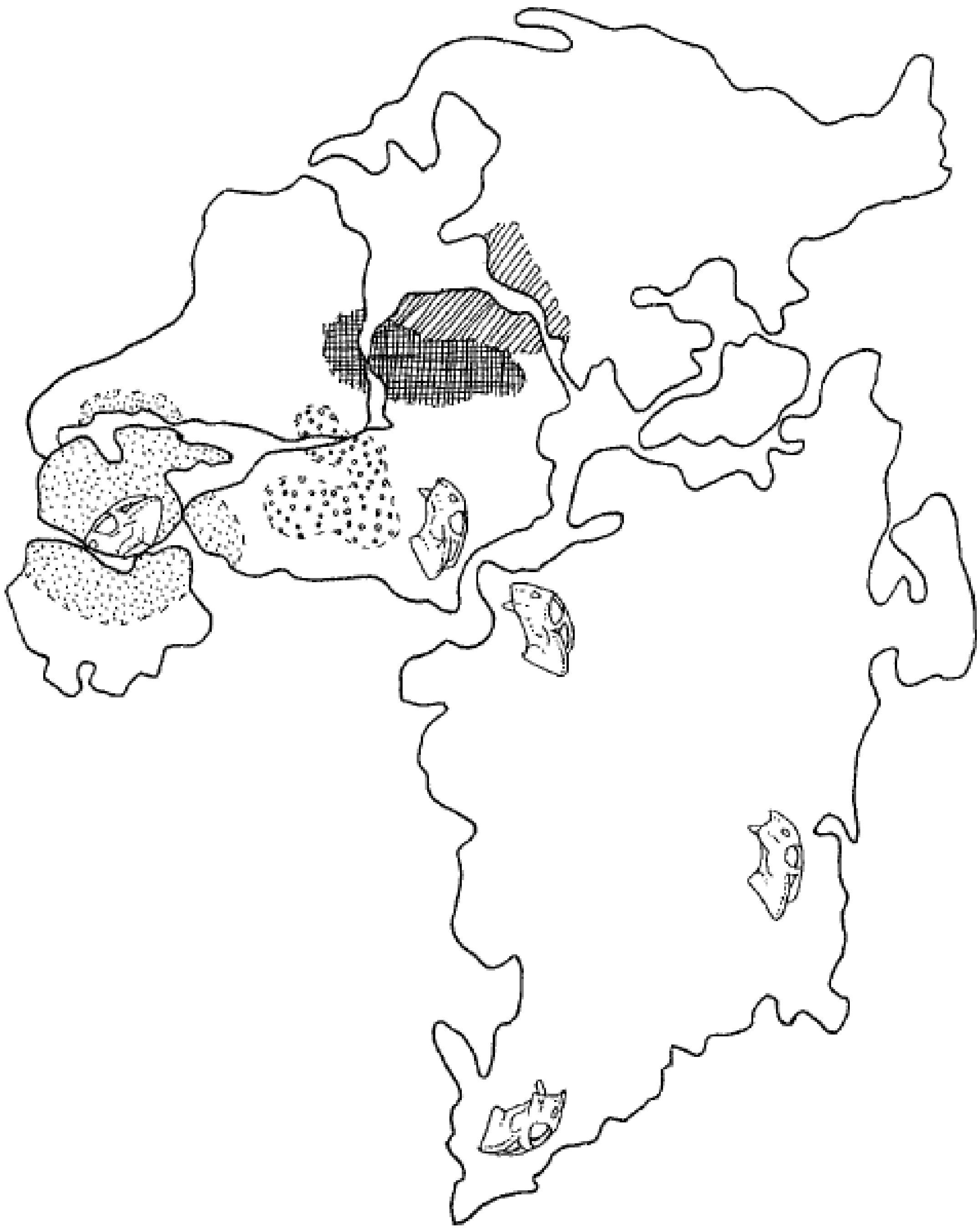
Mission 9
200 Million Years Ago

(optional) Prepare overhead transparency or PowerPoint slide.

Figure 9.1—Pangaea Puzzle Answer Key.



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Mission 9

200 Million Years Ago

SETI INSTITUTE

Mission Briefing

Name: ____ Date: ______________________

Dr. Rufus Catchings, Geologist on the SETI Academy Team.

Only recently has Earth taken on its current appearance. Only *very* recently have humans evolved and created the civilizations that we take for granted. Visitors to Earth in the past would have seen a very different planet. As a way of thinking about what we might see when we go to other planetary systems, please consider what extraterrestrials might have seen if they had come to Earth 200 million years ago. Geologists believe that only one huge continent existed on Earth 200 million years ago. Your next mission is to reconstruct the supercontinent, called *Pangaea*, using the same evidence that was used by geologists.

What Do You Think?

1. Have the continents always been in the place they are in today?

2. How do you know?

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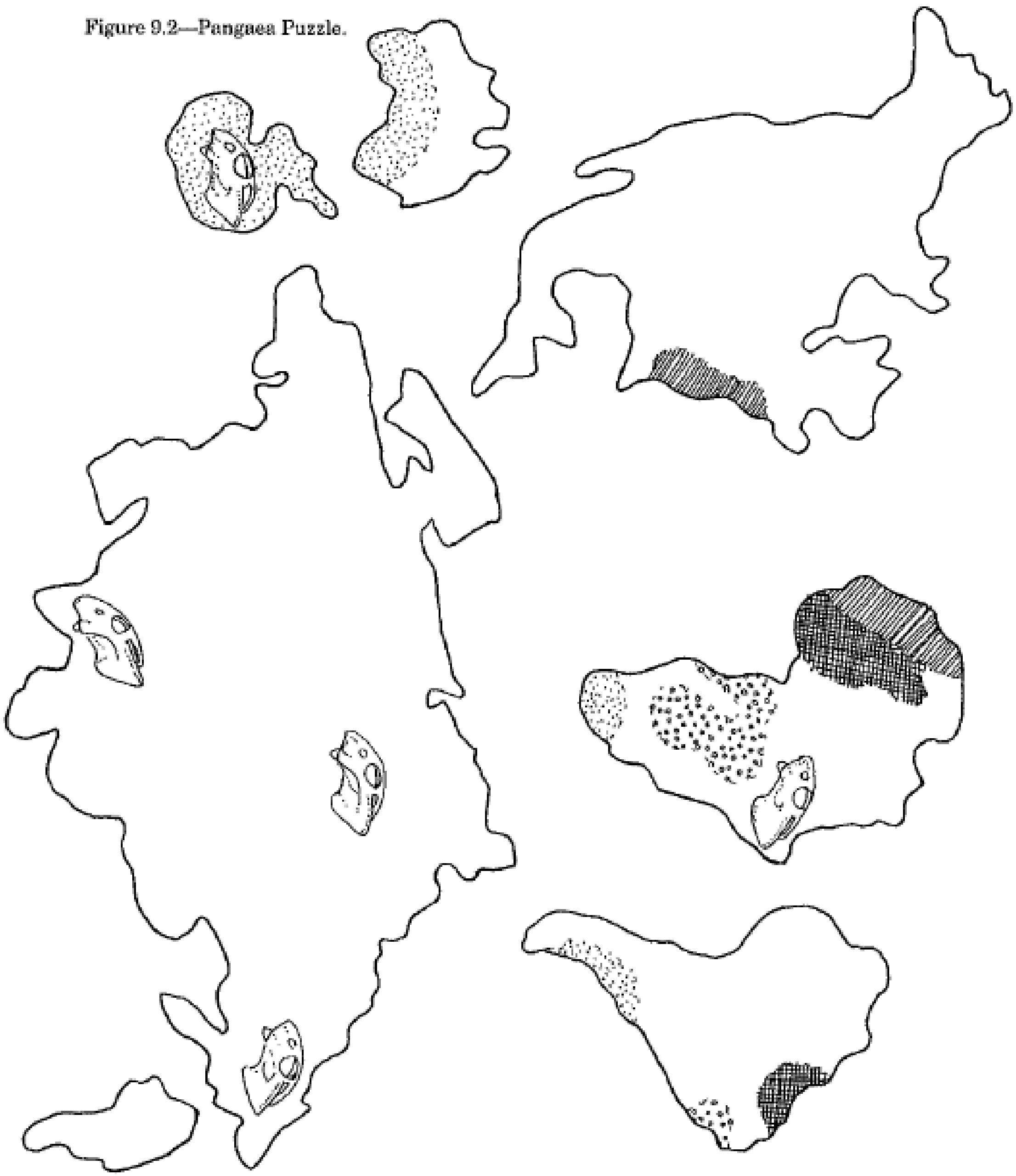
Mission 9
200 Million Years Ago

Figure 9.2—Pangaea Puzzle.



SETI INSTITUTE

Mission 9
200 Million Years Ago

What Do You Think, Now?

Name: ____ Date: ____________________

After you have completed this mission, please answer the following questions:

1. What evidence leads scientists today to believe that Earth's continents were once together in one supercontinent?

2. Was Pangaea the only supercontinent that ever existed? How do you know?

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Mission 10
Drifting Continents

How Did the Continents Move?

Notes

In Mission 9, students learned about the supercontinent Pangaea.

Overview

Since Pangaea broke up, the continents have drifted slowly over the past 200 million years. They are still drifting today, and they will continue to drift in the future. Helping students to grasp this important geologic concept is the primary goal of Mission 10.1, in which they make a flipbook with four images of Earth in chronological order, from 200 million years ago to the present.

Concepts

- The supercontinent Pangaea was not the first huge land mass. It was the first time that all land was "smashed" into one continent.
- Pangaea broke into continents. Over the past 200 million years, the continents have drifted to their present-day locations and worn down to their present-day shapes.
- In the future, the continents will continue to change their positions and shapes.

Skills

- Creating a time sequence.
- Using a series of pictures to infer movement.
- Projecting a time sequence into the future.

Mission 10.1
Materials

For the Class

- PowerPoint slide or transparency of Continental Drift Flipbook Answer Key
- Data projector, computer
- World maps and globes
- Butcher paper
- Tape
- Marking pen
- *(optional)* Blue construction paper and glue

For Each Group of Students

- Scissors
- Markers or crayons
- Transparent tape
- 3x5 index cards
- Binder clips
- *(optional)* 1 meter of adding machine tape
- *(optional)* Butcher paper

For Each Student

- SETI Academy Cadet Logbook
- Pencil

Getting Ready

The Day Before Class

1. If possible, make PowerPoint slide or transparency of the Continental Drift flipbook. If not, cut out the pieces of one puzzle and glue them to blue construction paper to show students after they complete their flipbook.

2. Gather the tape, scissors, and crayons.

Just Before the Lesson

1. Display the world maps and globes around the classroom.

2. If a PowerPoint slide has been made, set up a data projector.

Classroom Action

1. **Mission Briefing.** Class refers to the "Mission Briefing" for Mission 10 in their student logbooks while one student reads it aloud.

2. **What Do You Think?** Students answer the pre-activity questions on the "Mission Briefing." Invite them to share their answers in a class discussion.

3. **Activity.** The Continental Drift Flipbook. Explain to the class that today they will look at some images of continental positions from Pangaea to the present. Go over the directions for the Continental Drift Flipbook Instruction Sheet and answer questions as needed. Students work individually or in groups as desired. Students tape their images together in a sequence or mount them on adding machine tape.

4. **Discussion.** Allow time for students to share their results.

Closure

1. **Discussion.** Invite students to share their solutions. Try to identify differences of opinion. Invite groups of students who disagree to show each other their results and try to come to conclusions that they all agree on. Show an overhead transparency or PowerPoint slide of the answer key. Ask students what they think of the solution proposed by scientists.

2. **What Do You Think, Now?** Have students answer the post-activity questions on the logbook sheet "What Do You Think, Now?" They will be able to answer the first question by linking periods in history with images from their Pangaea flipbook. The second question relates to the future positions of the continents.

3. **Lecture.** Tell students that these changes in position occur very slowly, about an inch per year. This is the speed at which a fingernail grows! They can calculate this rate, since the Atlantic Ocean became about 3,500 miles wide in about 200 million years. Students may wonder *why* the continents are still moving. The underlying reason is plate tectonics, which will be studied in the next mission.

Going Further

Activity: Flipbook

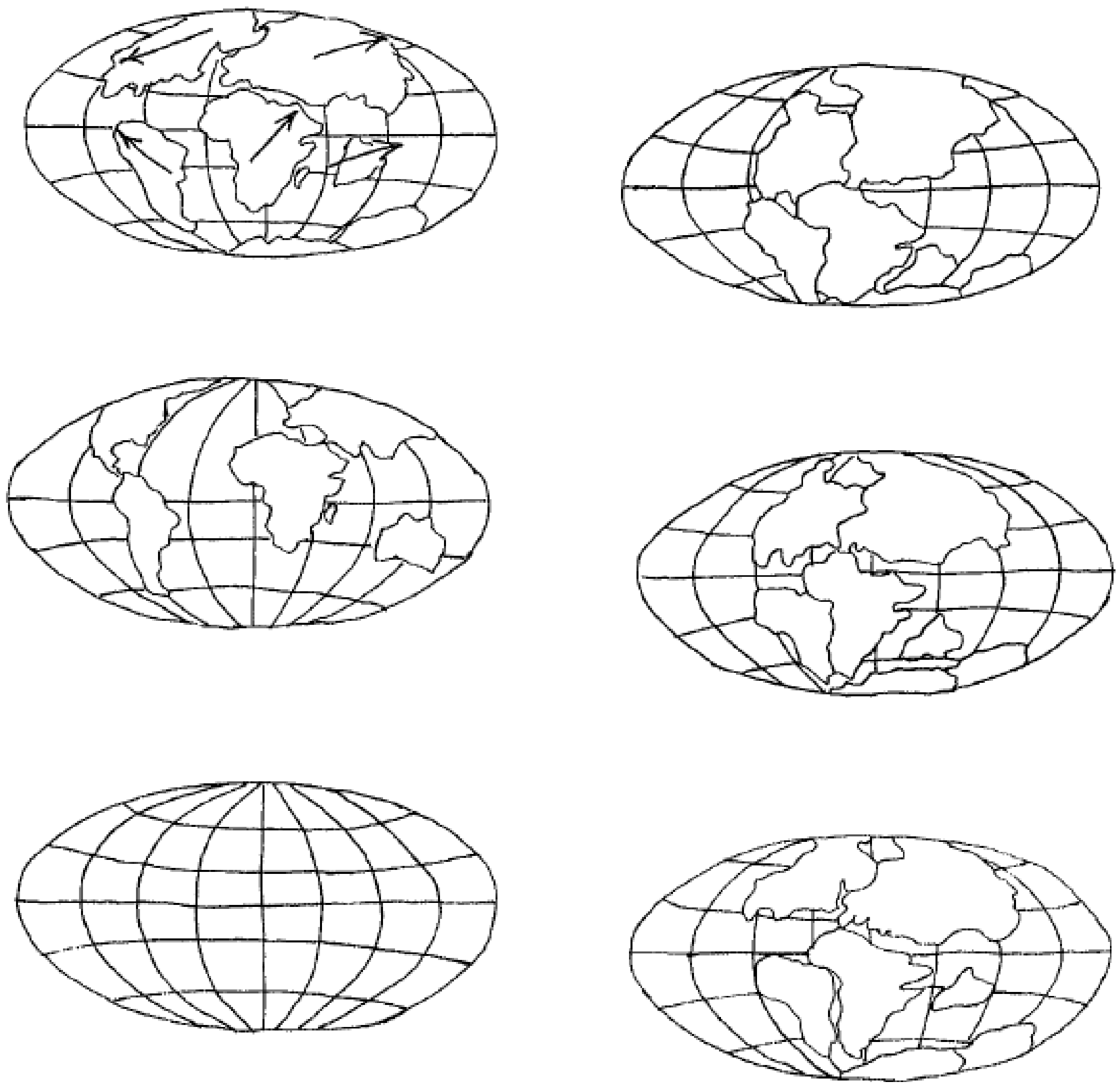
Students may wish to use the instructions in their student logbooks to make a Continental Drift Flipbook.

Activity: Before Pangaea

Students make a new theory for the time *before* Pangaea. Draw it, script it, and play it in the "theater" with narration.

Students write a script that tells the story of Pangaea from Earth's point of view. Add commercials, public service announcements, or news flashes that are appropriate to the eras represented by the pictures. You could have a dinosaur explaining how it became extinct inserted between the fifth and sixth cards.

Figure 10.1—Continental Drift Filmstrip Answer Key.



Mission 10
Drifting Continents

Mission Briefing

Name: ____ Date: ___________________

Dr. Cynthia Dusel-Bacon, Geologist on the SETI Academy Team.

Your next challenge will be to reconstruct the history of Earth's continents, step by step, from the time when all of the land was pushed into one super-continent until today. Then, you will imagine what Earth will probably look like millions of years from now.

What Do You Think?

1. What do you think were the shapes and arrangements of Earth's continents 100 million years ago?

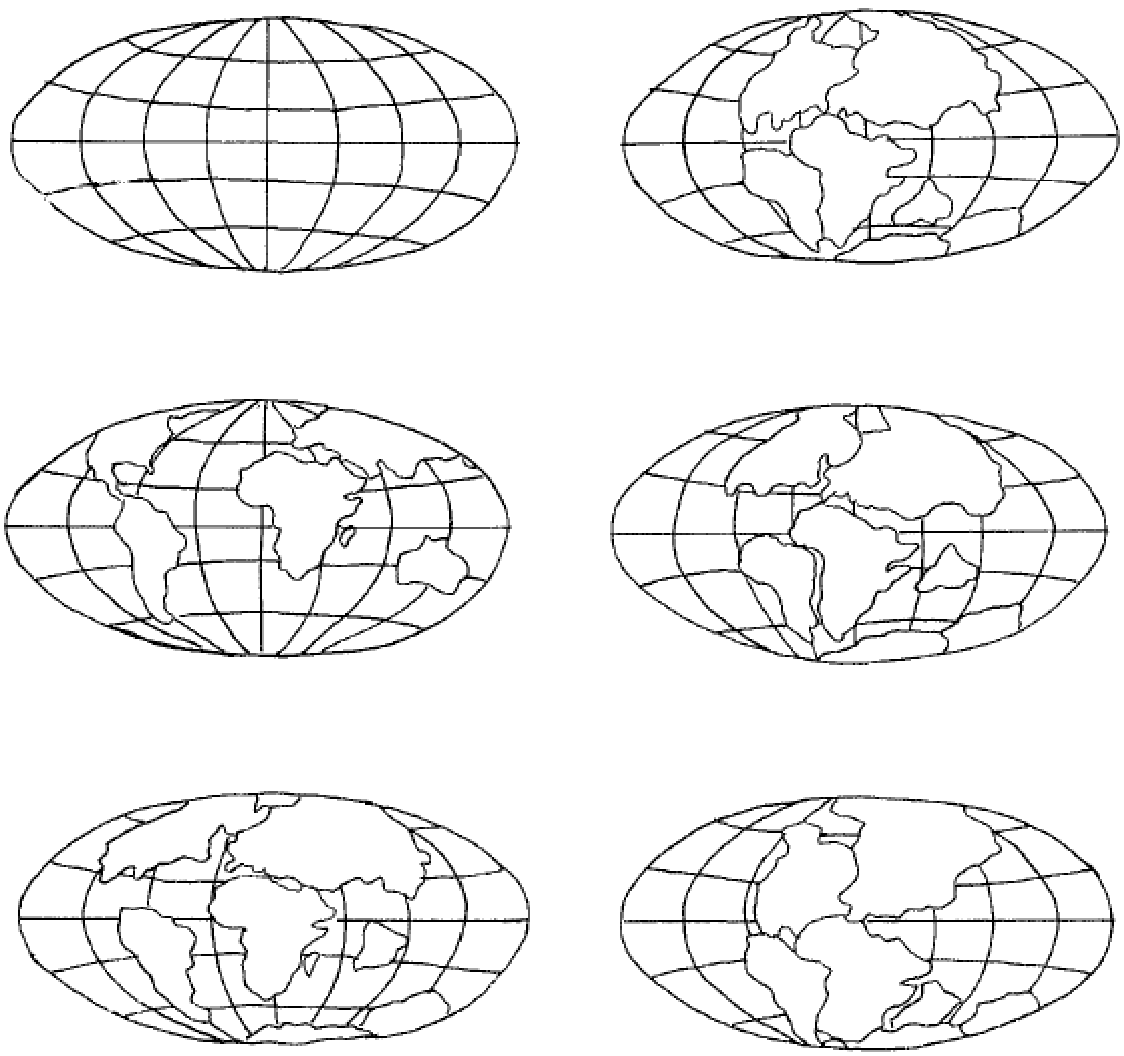
2. What do you think the shapes and arrangements of Earth's continents will be 100 million years from now?

Mission 10

Drifting Continents

Name: ____ Date: ______________________

Figure 10.2-Continental Drift Images.



Mission 10
Drifting Continents

Continental Drift Flipbook Directions

1. Carefully color in the oceans and continents in each frame. Cut the cards apart. Find the one that shows Pangaea. It will be the first card in your flipbook.

2. Put the rest of the cards in the order you believe to be the most accurate. The next to last card is a blank map. The last card is "credits."

3. When you have all your cards in order, check them by holding them in a stacked flipbook and thumbing through. Each continent should travel steadily in the same direction.

4. On each card, draw arrows on the continents showing the direction that it is moving. Use this information to imagine the future position of each continent and draw them on the blank future map.

5. Using the table below, neatly write the period and time in "MYA" (million years ago) on each card.

6. Carefully print the title of your flipbook and your names on the card at the upper left corner of the paper. Do the credits on the card in the lower right corner of the paper.

7. Add any other information about plants, animals, geology, *etc*. that you like. Use your "Pangaea Puzzle" to help you.

8. Hold the pictures together in the correct order with a binder clip.

Table l0.l—Flipbook Years.

Order of Frames	Period	Time in MYA
First Card	(Title)	
Second Card	Triassic	230 to 205
Third Card	Jurassic	205 to 140
Fourth Card	Cretaceous	140 t0 68
Fifth Card	Tertiary	68 to 3
Sixth Card	Quaternary	3 to present
Seventh Card	Future	50 in the future
Eighth Card	(Credits)	

Mission 10
Drifting Continents

What Do You Think, Now?

Name: ____ Date: _________________

After you have completed this mission, please answer the following questions:

1. About when did North America separate from Europe?

2. What do you think may happen to Earth's continents in the future? Draw your idea and explain what you think.

Mission 11
Changes on Planet Earth

So Much for a "Solid Earth"!

Notes

In Missions 9 and 10, students studied the effects of continental drift on Earth.

Overview

In Mission 11, students learn about the theory of plate tectonics. Earth's crust is broken up into several very large plates that float on top of its semi-liquid mantle. Heat from Earth's core creates huge convection currents in the mantle that, in turn, cause continental drift. Major geologic features of our planet are caused by interactions of its tectonic plates. In Mission 11.1, students build a simple clay model of Earth and cut their Earth models in half to observe the interiors. In Mission 11.2, students model four types of plate tectonic movement, observe a convection current in water, and draw the convection cells that drive the continents. In Mission 11.3, students search for signs of plate tectonics.

Concepts

- Earth is composed of three major regions: a metal *core,* solid inside and liquid outside; a semi-liquid *mantle,* composed of magma or molten rock; and a thin, hard *crust* that surrounds Earth.
- The crust of Earth is broken into pieces called *tectonic plates.*
- There are oceanic plates and continental plates.
- The driving forces that carry the tectonic plates are convection currents in the mantle, created by heat rising (radiating) from the core.
- The major types of plate boundaries are *convergent* boundaries, *divergent* boundaries, and *strike-slip* boundaries.
- Subduction, earthquakes, volcanoes, and mountain-building processes occur at plate boundaries.

Teacher's Note: *Review the formation of our solar system and planets, the cooling of Earth, the contributions (especially the water) of asteroid and comet impacts to Earth's evolution, and the necessary presence of water in liquid form for life to begin and survive.*

Skills

- Constructing, interpreting, and predicting with a model.
- Interpreting geologic evidence found on maps.
- Reasoning and questioning.

- Condensing and correlating previously explored materials into a new, exploratory context.

Mission 11.1
Materials

For the Class

- Data projector and computer
- “Inside Earth” PowerPoint presentation
- 3 colors of clay (at a volume ratio of 1 part to 20 parts to 100 parts)
- Dental floss
- *(optional)* Blue and green paint that will adhere to clay
- *(optional)* Paintbrushes
- *(optional)* World maps or globes
- *(optional)* Flour or powder

For Each Group of Two or Three Students

- Metric rulers or meter sticks

For Each Student

- SETI Academy Cadet Logbook
- Pencil

Getting Ready

One or More Days Before Class

1. Make PowerPoint slide or transparency of “Inside Earth” (page 135).

2. *(optional)* Build a clay model of Earth as a demonstration.

Just Before the Lesson

1. Set up the data projector.

2. Divide each color of clay so there is enough for each group to have some of each color. The clay model Earth may be any convenient size, but the *relative* sizes of the inner core, outer core, mantle, and crust are important. The correct ratios are shown in Table 11.1.

Table ll.l—Ratios for a Model of Earth.

	Volume or Weight for Larger Model	Volume or Weight for Smaller Model	Diameter for Any Size Model
Inner Core	1	1/16	1
Outer Core	20	1	3
Mantle	100	6	5
Crust	Almost 0	Almost 0	Almost 0

Classroom Action

1. **Review.** In the missions you just finished you noticed that Africa fits like a huge puzzle piece into North and South America. Evidence shows that they were once part of one large continent, but were pushed apart. What could have been powerful enough to move such huge land masses?

2. **Mission Briefing.** Refer the class to the "Mission Briefing" for Mission 11 in their student logbooks while one student reads it aloud.

3. **What Do You Think?** Students answer the pre-activity questions on the "Mission Briefing". Invite them to share their answers in a class discussion.

4. **Discussion.** Ask students if they have any personal experience with movement in Earth's crust, with earthquakes, or possibly volcanoes. Ask students if they have any opinions (hypotheses) about *why* the continents move. List their ideas on the whiteboard. Explain that today they will model Earth to help them to understand these movements.

5. **Activity.** Review the "Building a Model of Earth" directions with students. Give the teams time to make their Earth models. If clay that accepts quick-drying paint is available, let students paint oceans and continents on their models, perhaps using maps or globes for references. Explain that the paint represents the crust, although even paint is too thick on this scale! Instead of paint, students roll their models in flour or powder to represent Earth's crust. If you are using a slow-drying paint, let students cut their models now, and "reassemble" the pieces for painting during the next part. When finished, they will cut the models in half with dental floss to see what the interior looks like. Tell them to roll the planet as they cut it to keep it from deforming too much. Students label the diagram on their worksheet. If the clay requires drying time, each team should write their names on a piece of paper and put their model on the paper. *(If using baker's clay, the models will need to be turned frequently as they dry to keep them round.)*

6. **Discussion.** Put the PowerPoint slide of "Inside Earth" on the data projector and lead a discussion. Explain that Earth is made of many layers like an onion, and the model only shows the most basic layers, more like a hardboiled egg than an onion. In the center is a very hot, solid core of heavy metals that moved there during the formation of Earth. The outer core, also made of metals, is so hot that it is believed to be liquid. Surrounding the outer core is a mantle made of semi-liquid rock. Floating on top of the mantle are the crustal plates made up of oceanic plates and continental plates that are composed of the types of rocks that

we see every day. Based on this explanation, ask students to hypothesize again about why the continental plates move. Record their ideas on the whiteboard.

Mission 11.2
Materials

For the Class

- Data projector and computer
- “Inside Earth” PowerPoint slide
- Glass cake pan, 9 by 9 inches (Pyrex)
- Small bag of ice
- 2 bricks
- Short candle and matches
- Blue and red food coloring
- *(optional)* Eyedropper
- *(optional)* 4 envelopes
- Copy of each of the four Student Station Directions

For Each Group of Two or Three Students

- Towels
- Books or magazines
- String (or dental floss)

For Each Student

- SETI Academy Cadet Logbook
- Pencil

Getting Ready

One or More Days Before Class

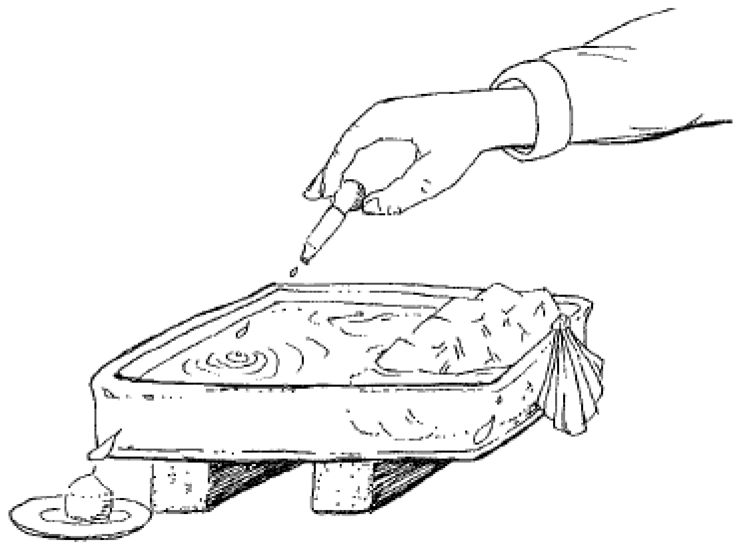
1. Arrange for one to five adults to help out with this part. One adult *must* supervise the convection zone demonstration. Other adults should supervise the four student stations.

Just Before the Lesson

1. Set up the convection zone demonstration station as shown in Figure 11.1. This station requires an adult demonstrator. Fill the 9-by-9-inch cake pan half full with water. Put the bag of ice into one corner of the pan. Remove some ice from the bag if it takes up too much space. Put the cake pan on the bricks. Add water until the cake pan is filled to just below its rim. Place the candle underneath the corner of the cake pan that is diagonally opposite the

corner with the bag of ice. If necessary, trim the candle so that it fits underneath the pan and has room to burn.

Figure 11.1—Convection Demonstration.



2. Set up four student stations, with a copy of the appropriate Student Station Directions at each. *(See the directions for specific setup details.)*

   - Divergence and Sea Floor Spreading: Move two desks close together and provide two towels.
   - Continent-Continent Convergence: Provide several towels on a continuous table surface.
   - Continent-Oceanic Plate Convergence: Fold a hardback book into the continental plate towel, and fold a magazine into the oceanic plate towel. Move two desks close together, with a 10-cm gap between them.
   - Strike-Slip Boundary: Provide several towels and string; use a table or the floor.

3. *(optional)* Cut up the Plate Tectonics Cards. Put each one into an envelope at the appropriate station. Students may open the envelope only if they need more information.

4. Set up the data projector.

Classroom Action

1. **Demonstration.** Quickly demonstrate the use of towels to model the plate-plate interactions.

2. **Activity.** Students visit the convection zone demonstration station and the four student stations (in any order), using the instructions at each student station to explore the events that occur at the tectonic plate boundaries. Ask students to complete their worksheets as they go. Move from station to station to assist students in their models, and in their interpretations. It

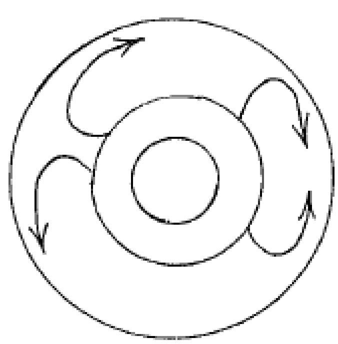
is important for each group to put back the materials the way that they found them. Half (or a third) of the class should watch the adult convection zone demonstration station at a time. This demonstration can be repeated about every 15 minutes. Students who have finished at all the stations may paint their Earth models, or do other activities while everyone finishes.

3. **Demonstration.** Light the candle 5 to 10 minutes before starting each convection demonstration. (See Figure 11.1.) Students hypothesize *(make an educated guess)* about what will happen to drops of blue food color put into the water by the bag of ice. Ask students to hypothesize about what will happen to drops of red food color put into the water above the candle. Place a drop of blue food color carefully into the water by the bag of ice. It will sink and then spread toward the hot spot. Ask students to observe from the side of the glass pan and describe and record what they see. Place a drop of red food color carefully into the water above the candle. It will rise, then spread toward the cold spot. Students observe from the side of the glass pan and describe and record what they see.

4. **Lecture.** Ask students why they think that a hot air balloon floats up. (*The hot air is lighter than the air around it* so *the balloon goes up)* Ask students what would happen if the balloon were *colder* than the air around it. (*The balloon would sink because it would be heavier than the air around it.)* Ask students to hypothesize about how the convection demonstration and the structure of Earth could be related. What does the candle represent? (*The hot core.)* What does the water represent? (*The mantle.)* What does the ice represent? (*Cooling caused by distance from the heat source.)* Use overhead projector markers to illustrate the convection currents on the "Inside Earth" transparency, as shown in Figure 11.2.

   Explain that convection currents occur in the semi-liquid mantle of Earth. Evidence suggests that the semi-liquid rock of the mantle moves in very slow currents like boiling water. It heats up when it is near the hot outer core, and rises. Then it cools and sinks again forming a circular current or convection cell. The hotter material rises because it is lighter while the cooler materials sink because they are heavier. As the rock moves along the top, it drags Earth's crust with it. The reason the cooler crust does not sink is that it is lighter than even the coolest mantle so it will still float on the mantle.

Figure 11.2—Convection Currents in the Earth.



   Review each of the cases where crustal plates interact, and the kinds of geologic formations that occur. If there are any such formations in your area, be sure to discuss them with students.

Possible answers to
"Changes on Planet Earth" recording sheet.

Convection Demonstration
What causes this motion? *Hot water rises, as it moves across the surface it cools and sinks.* Why do you think this motion is important to plate tectonics? *Because convection currents in the mantle move the continents around.*

Sea Floor Spreading
What do you think is happening inside the Earth under the Himalayan mountain range (where Mt. Everest is)? *Two continents are colliding, the rock where the continents meet is being pushed up—forming mountains.*

Continent-Continent Convergence
Why would this kind of process cause volcanoes? *The oceanic plate gets pushed under the continental plate. As it moves deeper into the mantle it heats up. Since hot rock (magma) rises, it pushes its way to the surface, building up a volcano.*

Strike-Slip Boundary
Why do earthquakes often occur near strike-slip boundaries? (*Because two continents are scraping by each other. They tend to move suddenly once in awhile, rather than a little bit at a time.)*

Mission 11.3
Materials

For the Class

- *History of Earth* PowerPoint presentation
- Data projector and computer

Just Before the Lesson

1. Set up the data projector. Start the *History of Earth* at Mission 11. The "Changes on Planet Earth" script is found in the PowerPoint file under "Notes."

Classroom Action

1. **Review.** Review the previous days' missions. Tell students that they are going to examine the transparencies (or PowerPoint slides) for the geologic features they modeled in the previous missions.

2. **PowerPoint Presentation.** Introduce the still images. The script, "Changes on Planet Earth," follows this lesson plan.

3. **Discussion.** Discuss any portions of the images that may have confused students. Use transparencies or PowerPoint slides of the images if desired.

4. **Activity.** Ask students to share their Earth models.

Closure

1. **What Do You Think, Now?** Students answer the post-activity questions on the logbook sheet "What Do You Think, Now?" Invite students to share their responses. Ask students to look back at their answers to the "What Do You Think?" questions on the "Mission Briefing." Ask students how their opinions have been changed by this experiment.

2. **Review.** Review the interactions of crustal plates, and the geologic formations they cause. Explain that active geologic processes have proved to be important to the presence of life on Earth, and volcanism introduced many elements and much energy to the early Earth environment, thus contributing to the origin of life on Earth.

Going Further

Activity: A Brave New World

Cut your own continent pieces by tracing them from a globe. Rearrange them and tape them back onto the globe. Show the possible future positions of these continents.

Activity: Earth in a Jar

If you put top soil in a glass jar with water and shake it up, the dirt will settle into layers. Ask students how this relates to the layers you saw in your model of Earth?

Activity: Mountains of Clay

Use two slabs of different rigidity clays, such as modeling clay and fresh baker's clay. Squish them together, slowly but forcefully, and watch the formation of mountains. The tectonic plates buckle and form mountains in the same way, when two continents collide. This brings the oldest rock back to the surface-part of the vast rock cycle.

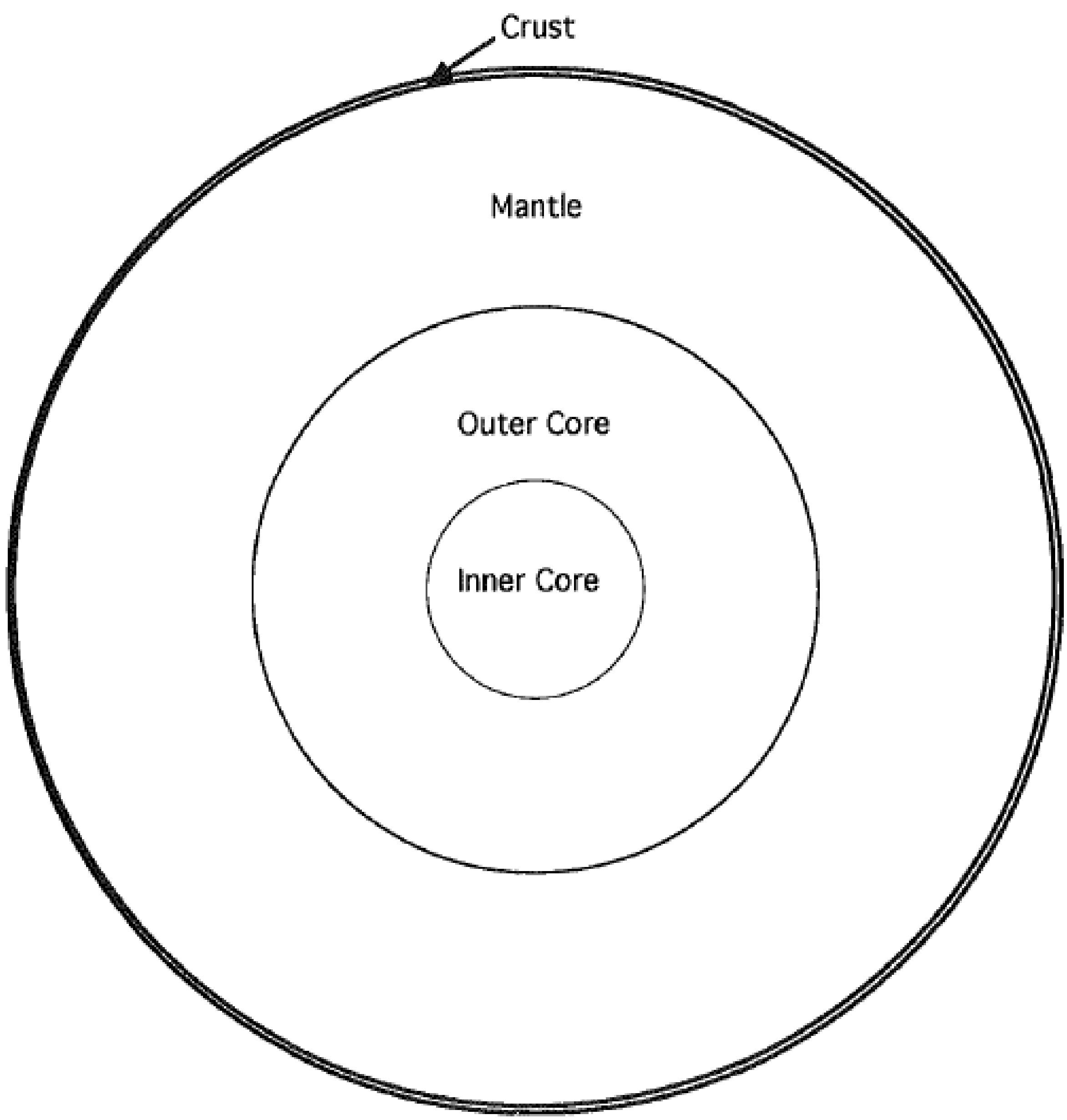
Activity: Miniature Geology

Stream formation and erosion can be shown simply by sloping a pile of dirt in a plastic box and using a sprayer to "rain" on the new landscape. Miniature volcanoes are always popular. Make a model volcano and relate volcanism to plate tectonics.

Research: Earthquake! Volcano!

Ask students to look at earth science texts for the occurrences of earthquakes and volcanoes. Ask how these locations compare to the experiments they conducted in this and in the last mission? What is the "Ring of Fire"?

Figure ll.4—Inside Earth.



Mission 11
Script for Video Images

"Changes on Planet Earth"

Many factors have contributed to the evolution of planet Earth. In this series of images, students will explore the history of Earth through its many stages. The following narrative provides a focus, some information and questions. The importance of this presentation, however, is to carefully observe patterns of change on Earth and to observe, especially in the images on the left, direct and indirect evidence of continental drift.

Figure 11.5--You will recall from previous missions that our solar system was formed from a giant cloud of gas and dust more than four and a half billion years ago

Figure 11.6—The planets, as well as other solar objects, were formed by a clumping together, or *accretion,* of the particles that were left over from the formation of the Sun.

Figure 11.7—Gravity caused these particles to be attracted to each other. It also held Earth and other planets in their orbits around the Sun. Earth became a ball of molten rock and metal with the heavier metals, which we labeled in our model, sinking to the center and forming the *core.* The lighter rocks floated to the top and eventually became Earth's *mantle* and *crust.*

Figure 11.8—The formation of our Moon in a dramatic collision has caused Earth—a relatively small planet—to be accompanied by a very large satellite. he Moon not only contributes to the ocean tides, but it may also help to stabilize Earth's axis of rotation.

Figure 11.9—The surface of early Earth was probably bombarded by asteroids and other leftover space junk. These impacts made the craters, or big holes, in the dark gray basalt rock that you see in the Earth view on the left. Volcanoes threw out hot lava into an atmosphere of thick brown clouds of gas and water vapor and ash. What is a volcano? *An escape vent for a particularly hot spot in magma.*

Figure 11.10—By 300 million years later, some significant changes had occurred. What changes can you see? *Water covers much of Earth. There are fewer volcanoes, but gases coming from them are making the atmosphere a lighter brown. There are lines of explosive volcanoes.* During this period of time, volcanoes continued to erupt. sending gases rich in carbon dioxide and water vapor into the atmosphere. At first, when the water vapor condensed and fell as rain, it turned to steam because Earth's surface was still so hot. Finally, Earth cooled enough that the rain water stayed on the surface and formed shallow seas. Comets also delivered water when striking Earth.

Figure 11.11—As time went by, large islands and the first sea floor started forming. How does a sea floor form? *Where two tectonic plates diverge, molten rock oozes up to the surface, where it hardens into a new seafloor.*

Figure 11.12—By 3.5 billion years ago, just a billion years after its formation, Earth and its atmosphere were undergoing many changes. What changes do you see? *Seas cover more area, some darker and deeper. Thick white clouds indicating carbon dioxide and oxygen atmosphere. Island chains forming from old volcanoes. Continents forming in the upper right and lower left. Volcanoes emitting steam.*

Figure 1l.13—What had happened by the time another billion years had passed? *Large continents collided.* How can two continents collide? *The plates they are on are moving towards each other.* What would be the result of two continents colliding? *Mountains might form.* What other changes do you see? *Size of ice caps increasing. The atmosphere is less thick. Blue-green color along shores is, a sign of life.*

Figure 11.14—What changes occurred in 800 million years? *The continents are splitting and drifting westward. The seas are a deeper blue and there is green along the shores.* What is probably causing these two continents to separate? *Material from the mantle is in Earth's crust and forming an undersea ridge.* Where are the seas darkest? Lightest? Why? *The lightest seas are continental shelves. The darkest seas are deep ocean, over the thin oceanic plates.*

Figure 1l.15—What is happening to the land masses here? *Mountain building and volcanoes where continents collide. More land above sea level, closer to modern times. Volcanic island arc. Increasing number of large continents.* What other changes do you see? *Ice cap at North Pole expanding.* Why do you sometimes get mountains and sometimes volcanoes? *Mountains form when two plates push on each other and the place where they meet pushes up. Volcanoes form when one plate slides under the other plate, called* subduction *and melts into very hot magma.*

Figure 1l.16—By 700 ml1lion years ago North America had split from the large continent called Gondwana, which is hidden from our view by a glacier. What happens when a continental plate splits from its adjoining plate? *A rift occurs that fills to form a ridge, which widens the Atlantic Ocean. Second Ice Age occurs.* What would happen to the seas during an ice age? *Water would become ice and sea levels would be lower.*

Figure 1l.17—(Figures 11.17 to 11.21 are shown slowly as a series.) By 520 million years ago, the larger continent (of 600 million years ago) had broken up. Much of the land that appeared in the last figure is now underwater. Do you know why? *Water is no longer tied up in extensive glaciers.*

Figure 11.18—As you observe the next five figures, can you see any patterns of continental drift? *Continents moving toward Pangaea.*

Figure 11.19

Figure 11.20

Figure 11.21

Figure 1l.22--(Figures 11.22 to 11.25 are shown as a series.)

Figure 11.23—These figures show the artist's interpretation of the evidence of continental drift *since* Pangaea, from 200 million years ago to the present. Trace the path of each continent to see how it is moving in relationship to the other continents. What do you see? Look carefully for other details. The continents should be looking more familiar now.

Figure 11.24

Figure 11.25

Figure 11.26

Figure 11.27—Whenever there are earthquakes in California people say that Southern California will eventually fall into the sea. This will not happen, but Southern California will slide northwards over millions of years. In this glimpse 50 million years into the future Baja California has shifted considerably. Can you find it? What kind of plate movement causes a piece of land to move as Baja is shown? *Two plates sliding alongside each other.*

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SETI INSTITUTE

Mission 11
Changes on Planet Earth

Mission Briefing

Name: ____Date:____________

Dr. Janice Bishop, Chemist and Planetary Scientist on the SETI Academy Team.

We know that some of Earth's continents have slowly drifted apart. What caused them to move apart? Do continents always drift apart, or can they move in other ways? We know that there are earthquakes and volcanoes. What has caused them? We know that there are mountain ranges along the coasts of many continents. What has created these mountains? Your next mission is to find out answers to these questions by investigating what is happening inside Earth. Later, you will use this information to design a realistic planet of your own.

What Do You Think?

1. What do you think causes volcanoes?

2. What do you think causes earthquakes?

3. What causes continents to drift across Earth's surface?

4. What do you think makes mountains form?

Mission 11
Changes on Planet Earth

Building a Model of Earth

Name: ____ Date: ____________________

1. Have a member of your team collect a piece of each color (3 different colors) of clay.

2. Roll the smallest piece of clay into a ball to make the *inner core* of your Earth model.

3. Flatten the middle-sized piece of clay and wrap it around the inner core. Roll the clay until you have a sphere.

4. Flatten the largest piece of clay and wrap it around the outer core. Roll the clay until you have a sphere.

5. Now put on the *crust.* This layer is the outermost layer and should be as thin as you can possibly make it. You may paint the crust in two different colors to represent land and water, or use flour.

6. Use dental floss to cut your planet in half. Pull the floss through the center of the sphere. Roll the planet as you pull to keep it round.

7. Have a member of your team get a ruler. Measure the width of each layer. Which is the biggest? The smallest?

8. Draw the inside of your model Earth. Label each part.

Table 11.2—Draw a line from these labels to the drawing of your model Earth.

Inner Core	**Outer Core**	**Mantle**	**Crust**
Very Hot Solid Metals	Very Hot Liquid Metals	Dense and Hot Molten Rocks Semifluid	This Crust of Solid Rock Broken into Plates

Mission 11
Changes on Planet Earth

Convection Demonstration

Name: ____ Date: ___________________

1. Draw the convection demonstration below:

Blue **Red**

What causes this motion?

Why do you think this motion is important to plate tectonics?

Station one is a model of _______________________________________

Draw two stages of sea floor spreading that you can model with the towels as seen from above. Label the youngest and oldest rocks. Put in arrows to show which way the crust is moving.

What do the towels under the desk represent?

Draw the model *after* the first mountain has formed as seen from above. Push the plates again and draw the model after several mountains have formed. Put in arrows to show which way the crust is moving.

Station two is a model of _______________________________________

What do you think is happening inside Earth under the Himalayan mountain range (where Mt. Everest is)?

Station three is a model of ______________________________________

Draw the stages of the continent-oceanic plate convergence. Record from the side view. In the last box, include the volcanic stage even though the model does not depict it. Put in arrows to show which way the crust is moving.

Why would this kind of process cause volcanoes?

Station four is a model of ____

Draw the model from above before and after including any rivers and hills. There should be a few hills and a continuous river in the before picture. The after picture should show how these features have changed. Put in arrows to show which way the crust is moving.

Why do earthquakes often occur near strike-slip boundaries?

Mission 11
Changes on Planet Earth

Plate Tectonics Cards

Station One. Divergence and Sea Floor Spreading

Sea floor spreading is caused by convection currents. It occurs where two plates separate and molten material from the mantle rises to the surface, forming the sea floor ridge and then pushes outward. On the surface it cools to form new rocks. Scientists discovered sea floor spreading by observing that the ages of the rocks on one side of the sea floor ridge match the ages of the rocks on the other side. Closest to the ridge you can find the youngest rocks. As you move away from the sea floor ridge, in either direction, you find older and older rocks.

Station Two. Continent-Continent Convergence

Continent-continent convergence is also caused by convection currents. It occurs where continental plates collide. The soil and rocks are pushed up higher and higher forming chains of mountains. The Himalayan mountains were formed this way.

Station Three. Continent-Oceanic Plate Convergence

When an oceanic plate hits a continental plate, the thinner, heavier, oceanic plate slides under the thicker, lighter continental plate. This is called ***subduction***. Oceanic plate material is pushed into the mantle, causing it to heat up and move up under the continental plate. This material eventually erupts through the continental plate as a volcano.

Station Four. Strike-Slip Boundary

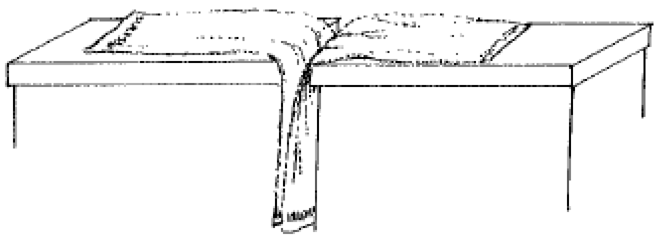
Plates at boundaries can collide and slip sideways. This type of boundary is called a strike-slip boundary. Earthquakes often occur at this type of boundary when the rocks release the tension that has built up from their movement against each other. At a strike-slip boundary, river beds, hills, and sometimes even fences are carried past each other.

Mission 11
Changes on Planet Earth

Station One Directions: Divergence and Sea Floor Spreading

1. Make sure your two desks or tables are about 10 cm apart. Drape a towel over each desk and down into the space between them.

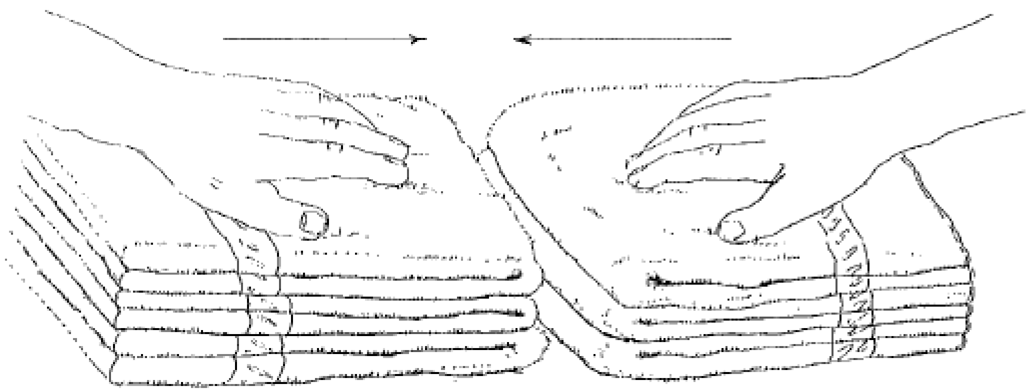
Figure 11.28—Set up for Station One.



2. Draw this stage as seen from above on your recording sheet.
3. Pull the towels farther onto the tops of the desks and record again.
4. Add arrows to your drawings to show the directions the plates are moving under this type of feature.
5. On the drawings on your recording sheet, label the oldest and youngest rocks.
6. Discuss the question for this center with your group. Record your answer.

Mission 11
Changes on Planet Earth
Station Two Directions: Continent-Continent Convergence

Figure 11.29—Station Two Process.



1. Arrange several towels in layers (like a layer cake). Keep the stack smooth and flat.

2. Make a second stack of towels just like the first stack. Each stack represents a continental plate.

3. Now *slowly* push the two stacks into each other. These layered towels model a continent-continent convergence where two plates run into each other.

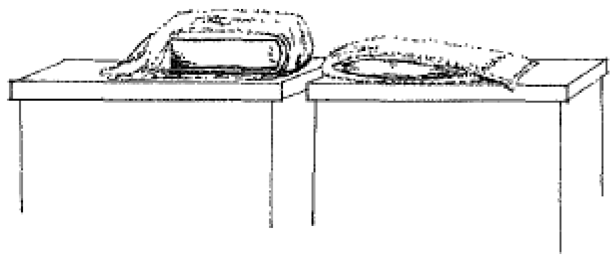
4. Draw two stages of the model as seen from above. First draw the model after the first mountain has formed. Then push the plates again and draw the model after several mountains have formed.

5. Add arrows to your drawings to show the directions the plates are moving under this type of feature.

6. Discuss the question for this center with your group. Record your answer.

Mission 11
Changes on Planet Earth
Station Three Directions: Continent-Oceanic Plate Convergence

Figure 11.30—Station Three Set up.



1. Fold a hardcover book into one towel. This represents the continental plate.

2. Fold a magazine into another towel. This represents the oceanic plate.

3. Push these two "plates" toward each other so they meet at the gap between the desks and watch what happens. Record what happens from the side view.

4. Push a little further, record. Then push a little further, and record again.

5. Discuss the question for this center with your group. This picture may help you. Record your answer.

Figure 11.31—Station Three Process.

Mission 11
Changes on Planet Earth

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Station Four Directions: Strike-Slip Boundary

1. Use towels to create two “plates.”

2. Gently push the plates together, forming small hills.

3. Press the string into the towel to represent a river valley at a strike-slip boundary.

Figure 11.32—Station Four Set Up.

4. Record what your model looks like now from above. There should be a few hills and a continuous river in this picture.

5. Slide the two “plates” sideways against each other. This is a model of a strike-slip boundary.

6. Draw the model again including the rivers and hills. This picture should show how these features changed.

7. Discuss the question for this center with your group. Record your answer.

Mission 11
Changes on Planet Earth

What Do You Think, Now?

Name: ______________________________________ Date: ________________________

After you have completed this mission, please answer the following questions:

1. What causes volcanoes?

2. What causes earthquakes?

3. What causes continents to drift across Earth's surface?

4. What causes mountains to form?

Mission 12
Climate Zones

It's Raining in the Mountains!

Notes

In Mission 11, students studied the theory of plate tectonics.

Overview

Daily weather is almost impossible to predict, but the long-term average of weather, or climate, is very stable for different regions on Earth. Given environmental concerns such as the possibility of global warming, it is important for students to understand fundamental concepts of climate. In Mission 12.1, students learn about two of the fundamental factors that determine climate: location on Earth, and the presence of mountains. Students color maps to reflect these factors.

Concepts

- Earth's *global* climate is determined by its distance from the Sun and by the composition of its atmosphere. Earth’s *regional* climate can be affected by geography.
- The interaction of winds and mountain ranges has a large effect on the climate of a region.
- Clouds will drop much of their water in mountain ranges and in the area upwind of mountains. Consequently, regions upwind from a mountain range often have wet climates.
- After clouds blow past a mountain range, they will have lost much of their water. Consequently, regions downwind from a mountain range often have dry climates.

Skills

- Color coding a map.
- Applying a model concerning the causes of climate zones.

Mission 12.1
Materials

For the Class

- Data projector and computer
- “Wet and Dry Areas” PowerPoint slide

For Each Group or Pair

- Map or globe that shows wet and dry climates

For Each Student

- SETI Academy Cadet Logbook
- Pencil
- Yellow and green markers or crayons

Getting Ready

One or More Days Before Class

1. Collect world maps and globes and spread them around the room (check social studies texts for maps).

Classroom Action

1. **Mission Briefing.** Class refers to the "Mission Briefing" for Mission 12 in their student logbooks while one student reads it aloud.

2. **What Do You Think?** Students answer the pre-activity questions on the "Mission Briefing." Invite them to share their answers in a class discussion.

3. **Lecture.** Explain the difference between *weather* (temperature, rainfall, cloudiness) and *climate* (the long-term average of the weather). For example, we may not be able to predict if it will rain or shine the next day, but we can be sure that the weather will be warmer at the equator than at the North Pole.

   Because the climate there is different, explain that a planet's climate would be simple if the planet surface were perfectly level. However, an Earth-like planet will have geologic features, such as mountains, rivers, and plains.

4. **Discussion.** Show the PowerPoint slide "Wet and Dry Areas." Discuss the ideas concerning how mountains affect the amount of precipitation (rain, snow, sleet) received by a certain region. Ask students if they can point out any local examples of regional weather patterns.

Teacher's Note: *Some students will confuse wind direction arrows with continental drift arrows. Point out this difference.*

5. **Activity.** When students understand these ideas, ask them to color the wet and dry areas on the map of South America (page 155). Invite students to compare notes with their neighbors. Circulate around the room, helping as needed.

6. **Discussion.** Ask students to hold up their maps. Hold a class discussion about any differences in the ways students colored their maps. Ask students how the climate at the North Pole differs from the climate where they live. *(It's much colder.)* Where else on Earth is the climate similar to the North Pole? (*At the South Pole.)* Why is the climate so much different at the North and South poles than where they live? (*They receive less intense sunlight because of their locations on Earth.)* Define the term *ecosystem* as a certain region with characteristic plants, animals, terrain, and climate. For example, a forest ecosystem would have entirely different plants, animals, terrain, and climate from a marine ecosystem or a desert ecosystem or a polar ecosystem.

7. **Activity.** Distribute or refer to the maps and globes available. Ask students to work in groups to answer the questions on "Ecosystems on Earth." Help as needed.

Sample answers to "Ecosystems on Earth" sheet

Write down the names of the two deserts that straddle the Tropic of Cancer. (*Africa has the Sahara, Libyan, and Nubian deserts. Most of Saudi Arabia is desert.)*

Write down the name of the primary ecosystem along the equator. (*Rainforest.)* What do you think is the primary ecosystem along the Tropic of Capricorn? Write down the names of two of these ecosystems that straddle the Tropic of Capricorn. (*Australia has the Great Victoria, Great Sandy, and Simpson deserts. Africa has the Kalahari and Namib deserts.)*

8. **Discussion.** After they have finished the sheet, go over it with the class. Help students notice that winds move away from the tropics, carrying moisture with them. Climates along the equator tend to be wetter because the winds meet there and release moisture in the form of precipitation.

Closure

1. **What Do You Think, Now?** Students answer the post-activity questions on the logbook sheet "What Do You Think, Now?" Invite students to share their responses. These questions relate to the two fundamental concepts presented in this activity: how mountains are related to climate, and how location on Earth is related to climate.

2. **Preview.** Tell students that in the next mission they will return to Planet X!

Going Further

Research: Earth's Axial Tilt

Why are there seasons on Earth? What would Earth's climate be like if it were *not* tilted on its axis?

Activity: The Hawaiian Islands

Obtain climate maps of the Hawaiian Islands. The windward side of these islands is very wet, with rain every day, and lush tropical rain forests. The leeward side is very sunny and dry, almost like a desert. Students trace the outlines of the islands, put in the major mountain ranges, and show the two climates of each island.

Research: Global Warming

Challenge your students to find a modern technology that is changing the climate of Earth. They should discover that increased carbon emissions create greenhouse gases that are already warming our whole Earth. They should discover that destruction of the rainforest will hasten this process, because these trees will no longer remove carbon dioxide from the air, and because the burning of the trees and the increased numbers of termites and cattle that replace the forest put even more carbon dioxide and methane into the atmosphere. How will this affect Earth over the next 10 years? Over the next 100 years? Over the next 1,000 years?

Research: Technology and Terraforming

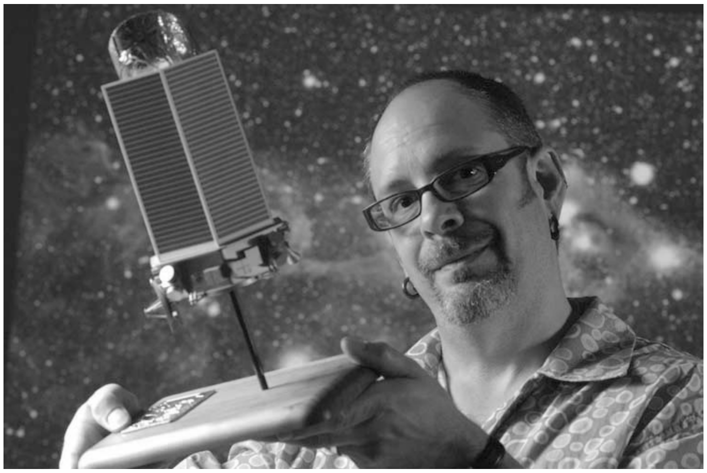
Is *terraforming*, the planet-wide engineering of an Earth-like environment, possible? Could we colonize Mars or Venus after we terraform them? Could we artificially control our own climate on Earth?

Mission 12
Climate Zones

SETI INSTITUTE

Mission Briefing

Name: ____ Date: ________________



Jon Jenkins, Scientist on the SETI Academy Team

The last area that you will need to study before creating a realistic model of a planet is weather and climate. As you will find out, the shape of the land in a particular region determines what kind of weather is experienced by a person who lives in that region. Please study the wind patterns and resulting climates on Planet Earth. You will need this information to create accurate maps of your planet.

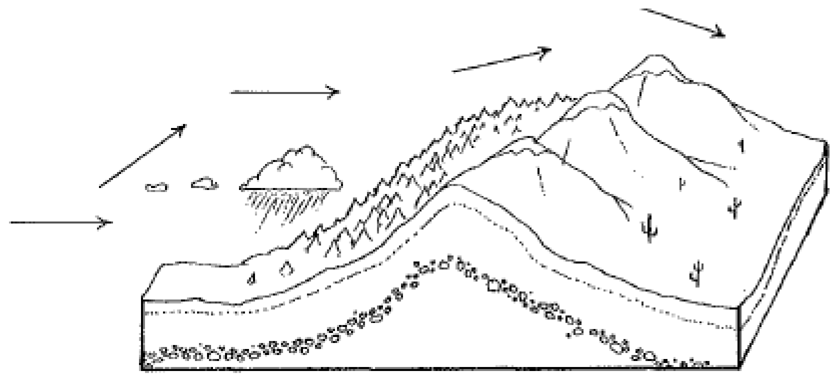
What Do You Think?

1. Why do some areas of Earth have a dry climate and others a wet climate?

2. How do you think mountains affect the climate of a region?

Mission 12
Climate Zones

Figure 12.1—Wet and Dry Areas.



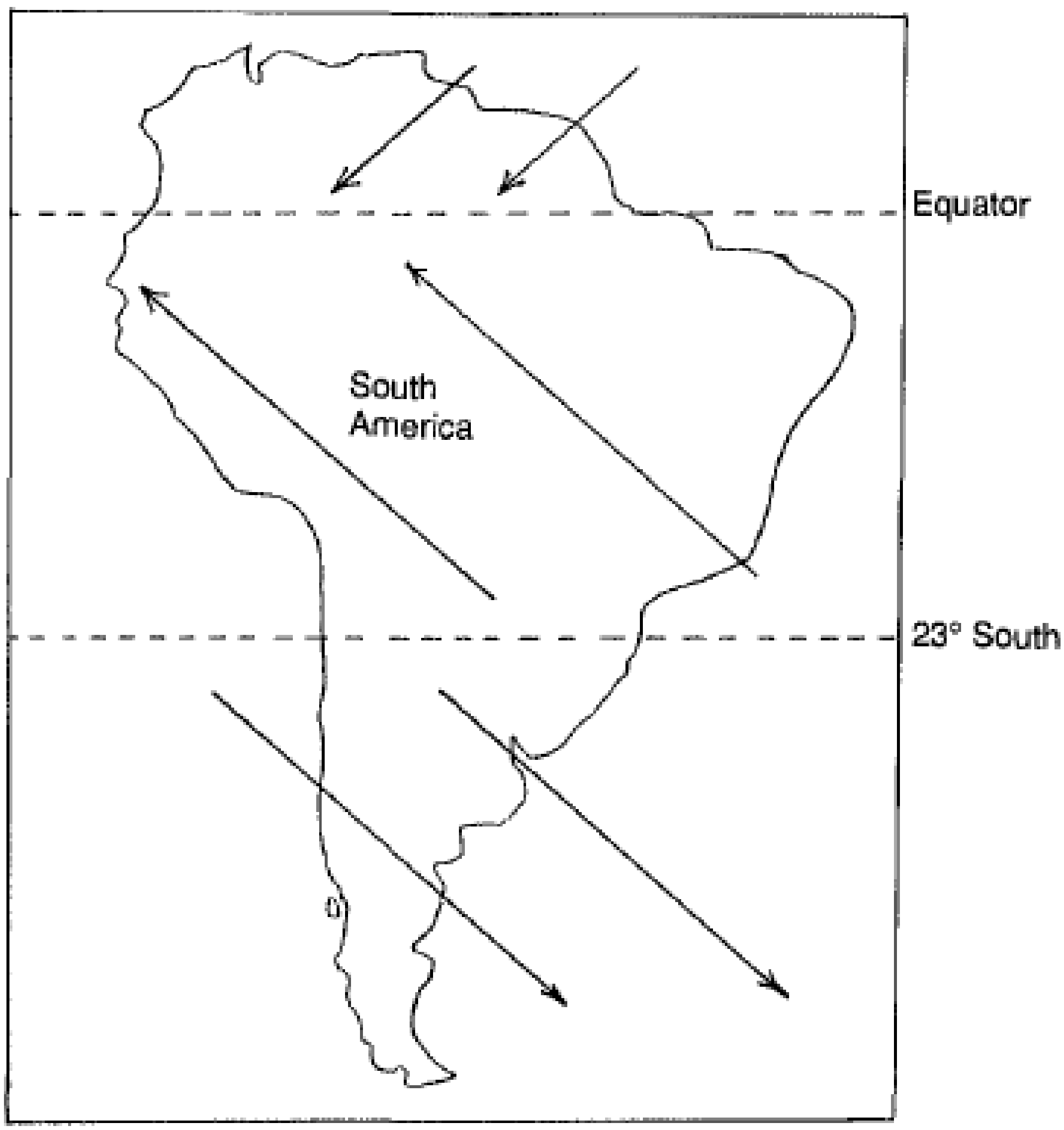
As shown above, clouds precipitate (rain, hail, snow) as they lift to rise over mountains, but there usually isn't enough moisture left to precipitate on the downwind side. This creates forest ecosystems on the upwind sides of mountains and desert or grassland ecosystems on the downwind sides. This is one way geologic features create climates.

Mission 12
Climate Zones

SETI INSTITUTE

Name: ____ Date: ______________________

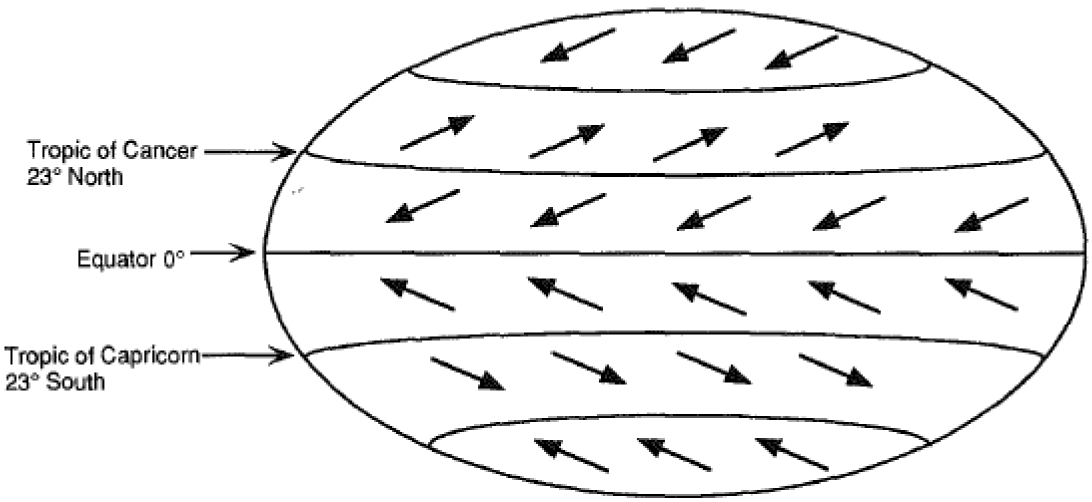
Figure 12.2—Climate Map of South America.



Mission 12
Climate Zones

Name: ____ Date: __________________

Figure 12.3—Ecosystems on Earth.



1. On a map of Earth find the Tropic of Cancer. Notice that desert ecosystems appear along the Tropic of Cancer. Write down the names of two of the deserts that straddle the Tropic of Cancer.

2. If deserts are the primary ecosystem of the Tropic of Cancer, what do you think will be the primary ecosystem along the equator? Check your guess on a map and write down the name of the primary ecosystem along the equator.

3. Based on the pattern of ecosystems you are beginning to see, what do you think is the primary ecosystem along the Tropic of Capricorn? Check your guess on a map and write down the names of two of these ecosystems that straddle the Tropic of Capricorn.

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Mission 12
Climate Zones

What Do You Think, Now?

Name: ____ Date: ______________________

After you have completed this mission, please answer the following questions:

1. If you live in a mountainous region and you want to plant crops that require a lot of water, where would you plant them?

2. Where on Earth would it be easiest to grow food? On one of the tropics or along the equator? Why?

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Mission 13
Creating a Map of Planet X

A Traveler's Guide to Your World!

Notes

In Mission 12, students investigated the influences of mountains and latitudes on weather and climate.

Overview

In the culminating mission of this unit (Mission 14 is a review), students apply what they have learned to design Planet X in its entirety. In Mission 13.1, students create maps showing oceans, continents, and other geologic formations. In Mission 13.2, students refine their maps of Planet X by adding climate zones. Students will very much enjoy the creative aspect of this problem, so they may include some fanciful ideas along with their scientific ideas.

Concepts

- Elements on a world map include continents, oceans, islands, rivers, and major geographic features such as mountain ranges.
- Where tectonic plates meet, various landforms appear.
- Regions downwind from mountain ranges will have dry climates. Regions upwind from mountain ranges will have wet climates.
- Regions at poles are colder than regions near the equator (assuming rotation axis is perpendicular to orbit plane; see the Going Further section in Mission 12 for a related activity).

Skills

- Map making.
- Synthesizing.
- Applying concepts to create an accurate model.

Mission 13.1
Materials

For Each Group

- Large poster board or piece of butcher paper
- Large sheet of scratch paper

- Markers or crayons

For Each Student

- SETI Academy Cadet Logbook
- Pencil

Getting Ready

Just Before the Lesson

1. Make a list on the board of the geologic features that students have been studying: mountain ranges, ridges in the ocean, volcanoes, strike-slip boundaries, super-continent of Pangaea, matching fossils or rock types from different continents.

Classroom Action

1. **Review.** Review geological features on the whiteboard. For each feature, ask how it is caused. Is it caused by plates moving away, moving together, or slipping by each other?

2. **Mission Briefing.** Class refers to the "Mission Briefing" for Mission 13 in their student logbooks while one student reads it aloud.

3. **What Do You Think?** Students answer the pre-activity questions on the "Mission Briefing." Invite them to share their answers in a class discussion.

4. **Activity.** Groups create "rough draft" maps of Planet X, the planet they chose in Mission 7. Tell them to include oceans and continents that might be very different from Earth, but that might exist on an Earth-like planet. Students draw arrows on the continents and ocean floors to show which way they are moving. Students find places in their map where plates are causing continents to collide, and draw them on the map. Students also look for places where plates are causing continents to separate and put in arcs of volcanic islands. Students should include as many of the geologic features as possible on their maps. When the rough drafts are complete, check each one for accuracy, and then students will recreate it on poster paper. Students name their planets, and complete colored drawings showing as many continents, oceans, and geologic features as possible. Tell them *not* to include any forms of life, because at this stage they do not know if any of the planets are inhabited.

Mission 13.2
Materials

For Each Student

- SETI Academy Cadet Logbook
- Pencil
- Crayons

Getting Ready

No preparation is necessary.

Classroom Action

1. **Activity.** Ask students to sketch in the continents of Planet X on the climate zone map on their worksheet, “Climate Zones on Planet X.” You may wish to make extra photocopies of students' continent maps before they begin coloring them, in case anyone makes a mistake while coloring. Ask the groups to write brief descriptions of climate zones on the continental areas of their maps. Which areas are deserts? Where are rainy, fertile areas? Ask the groups to inspect their maps carefully and decide where the most hospitable areas of their planets might be. If they were to explore this planet in search of life-forms, where would they look? Allow time for students to complete their designs and to put them up on the wall.

Closure

1. **What Do You Think, Now?** Students answer the post-activity questions on the logbook sheet “What Do You Think, Now?” Invite students to share their responses. Groups describe their planets to the rest of the class and share their colored maps.

Going Further

Activity: Drifting Planet X

Draw the continents on Planet X on a piece of paper. Cut them out and move them around as they might move on your planet in 200 million years.

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Mission 13
Creating a Map of Planet X

Mission Briefing

Name: ____ Date: ____________________

Dr. Ross Beyer, Planetologist on the SETI Academy Team.

Now you are ready to use what you have learned about Earth to, create an accurate surface map of your planet. Assume that your planet is large enough to have a very hot core and mantle like Earth. Therefore, you can expect to find many of the kinds of features that you find on Earth, such as mountains, volcanoes, and continents. However, it is extremely unlikely that the shapes of the continents will be just like those on Earth.

What Do You Think?

1. In what ways would an extraterrestrial planet be different from Earth?

2. What things would it have to have in common with Earth to support life-forms?

Mission 13

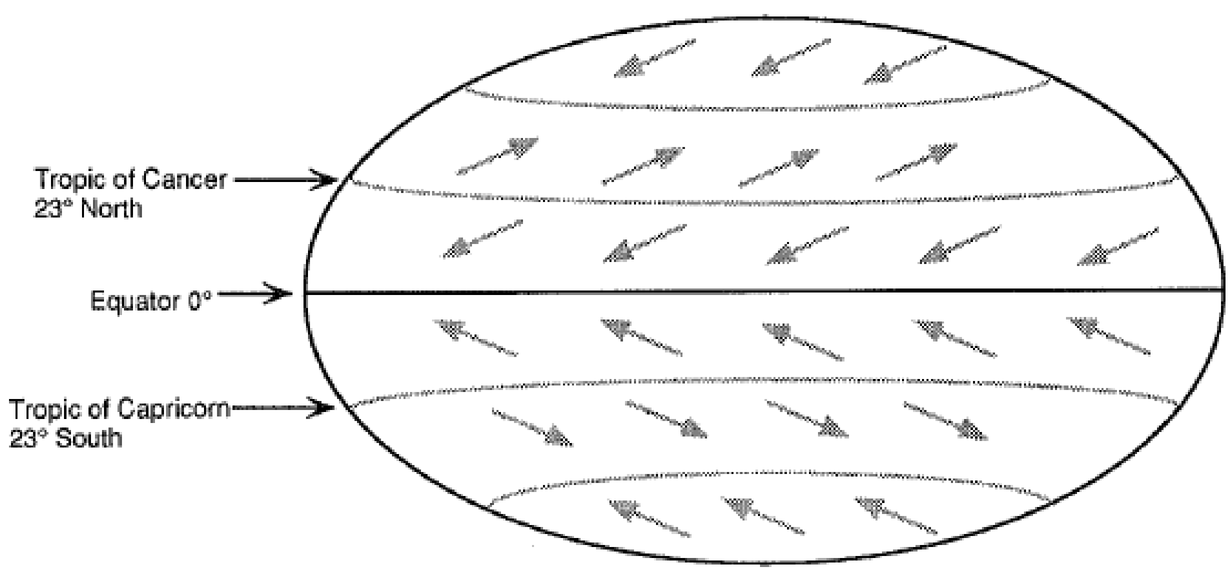
Creating a Map of Planet X

Name: ____ Date: _________________

1. Sketch in your invented planet's continents on the diagram below. Include any large mountain ranges. Color the regions on the upwind side of the mountain ranges green (wet climate) and those on the downwind side of the mountain ranges yellow (dry climate).

2. Add climate bands to the regions without large mountain ranges, using your map of Earth's climate zones to assist you. Color them yellow for dry climates and green for wet climates.

Figure 13.1—Climate Zones on Planet X.



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Mission 13
Creating a Map of Planet X

What Do You Think, Now?

Name: ____ Date:__________________

After you have completed this mission, please answer the following questions:

1. If some form of life exists on this planet, where is it most likely to be? Why?

2. Select two areas of the planet and describe what conditions are like there:

    Region A.

    Region B.

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Mission 14
Mission Completed!

What Have You Done?

Notes

In Mission 13, students applied the knowledge they have gained during this unit to create a realistic map of the fictional Planet X.

Overview

In Mission 14.1, students write and draw what they have learned about the formation of our solar system and the continuing evolution of Earth. To assess how much students have learned, compare their writings and drawings to those on the initial questionnaire in mission 1.

Concepts

- In order to understand the possibilities for extraterrestrial life, we need to study: our solar system, the formation of planetary systems, characteristics of different types of stars and planets, the evolution of habitable planets, plate tectonics, the formation of geologic features, and global and regional climate on the planet.

Skills

- Summarizing and applying knowledge.

Mission 14.1
Materials

For Each Student

- SETI Academy Cadet Logbook
- Pen

Getting Ready

No preparation is necessary

Classroom Action

1. **Mission Briefing.** Class refers to the “Mission Briefing” for Mission 14 in their student logbooks while one student reads it aloud.

2. **Activity.** Allow time for students to answer the questions in writing. Depending on the type of feedback you want, students may work individually or in groups. Ask students to answer the questions in complete sentences, in as much detail as possible (using extra paper if necessary).

Closure

1. **Discussion.** Students bring their logbooks to the discussion area. Invite all students who wish to share their drawings, ideas, and answers. Ask students how they felt about this unit in which they learned about Earth and applied their understanding to imagine what other planets might actually exist in our galaxy. Remind students that the members of the “SETI Academy Team” they met during the unit are actual people, real scientists who are working on problems like these in real life. How would students feel about a career in which their main job is to search for life in the galaxy? How would they feel about a career as an astronomer, a biologist, or a geologist? Explain to students that Dr. Jill Tarter is an actual research scientist and Director of SETI Research at the SETI Institute, and that the people in the photos in each mission are real scientists and science educators, though most of them have never met one another.

2. **Achievement Award.** *(optional)* Hand out Achievement Awards to those students who have successfully completed this mission. Hold an “Awards Ceremony” or a “Graduation” from the “Freshman class at SETI Academy.”

3. **Preview.** If the *SETI Academy Planet Project: How Might Life Evolve on Other Worlds?* will be taught, give students a brief description of what it will be about, as well as a challenging question to think about: Ask students to think about how they would *know* if they had discovered a strange alien life-form on another planet. How can you tell living things from nonliving things?

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THE SETI ACADEMY

CERTIFIES THAT

____

HAS SUCCESSFULLY COMPLETED THE COURSE

THE EVOLUTION OF A PLANETARY SYSTEM

ON ________________ 20____

Dr. Jill Tarter, Chief Scientist

Mr. Thomas Pierson, Executive Director

Mission 14
Mission Completed!

SETI INSTITUTE

Mission Briefing

Name: ______________________________________ Date: ________________

Darlene Lim, Geologists on the SETI Academy Team.

Congratulations on your successful missions! You have completed your investigations of how our Earth and solar system have evolved, and used that information to create realistic models of other planetary systems that might contain habitable planets. Please answer the following questions to show what you have learned so far at SETI Academy.

1. List below as many objects as you can that are in our solar system. On the back of this sheet, draw a rough diagram of our solar system.

2. Based on information you have heard, read, or seen, how do you think our solar system formed?

3. How do scientists think our planet Earth formed?

4. How has Earth changed since its formation?

5. What causes climates on some parts of Earth to be rainy, while it is dry in other areas?

6. If we could get a close look at other planetary systems in the years ahead, what should we study about these new planets to decide whether or not they may contain life?

Glossary

Binary star. Two stars orbiting each other. Also called a *double star*.

BYA. Billon years ago.

Continental drift. The very slow movement of the continents due to currents inside Earth.

Convection current. Movement of heat by way of a moving current of fluid; caused by uneven heating from below.

Double star. Two stars orbiting each other. Also called a *binary star*.

Earth's core. The central part of Earth, called the *inner* core, consists of a mostly solid inner region of iron and nickel. It is surrounded by a layer of molten metal, called the *outer* core.

Earth's crust. The thin, outermost layer of Earth, which ranges in thickness from 37 miles beneath the mountains to 6 miles beneath the ocean floors.

Earth's mantle. The region of Earth between the core and crust.

Ecosystem. A community of plants and animals that is interrelated with their environment.

Extraterrestrial. Anything not of or from our Earth.

Galaxy. A very large group of stars and other forms of matter that are gathered together by gravitation. Our Milky Way is a galaxy containing about 500 billion stars.

Gas giant. A very large planet composed mostly of gas and, perhaps, a small, solid core. In our solar system, these planets are located farther from the Sun than most of the rocky planets.

Gravitational pull. The force by which every mass attracts and is attracted by every other mass.

Habitable zone. The region in a planetary system where planets can have liquid water.

Invertebrate. An animal without a spinal column.

Island arcs. A group of volcanic islands that have been formed by volcanic eruptions in a curved line along the side of a deep sea trench.

Magma. Molten rock.

Meteor. A stone or metal mass that is falling through Earth's atmosphere. Heated by friction with the air, a meteor glows brightly and is sometimes called “a shooting star.” Fragments of a meteor that reach Earth's surface intact are called *meteorites.*

Meteorite. A stone or metal mass that has fallen to Earth. In space, it is called a *meteoroid.* While falling through the atmosphere, it is called a *meteor*.

Meteoroid. A solid mass of rock or metal that travels through outer space, ranging in size from a grain of sand to a large boulder.

MYA. Million years ago.

Nebula. Cloud of gaseous matter and dust in space.

Orbit. The path of a heavenly body around another body.

Ozone layer. The layer in Earth's stratosphere that contains oxygen in the form of ozone. Ozone contains three atoms of oxygen in each molecule, rather than two. This protective layer keeps harmful rays of sunlight from penetrating to Earth's surface.

Pangaea. The supercontinent that existed 200 million years ago on Earth, when the present continents were united as one.

Plate tectonics. The movements of large pieces of Earth's crust, which result in mountain building, volcanoes, earthquakes, and changes in the positions of the continents.

SETI. Search for Extraterrestrial Intelligence.

Universe. Everything that we know to exist, including all stars, planets, galaxies, and even space itself.

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Appendixes

Required Materials List

Table A.1-Office, Art, and General Supplies.

Material	Substitutions or Alternatives. Optional Items are Indicated.	Quantity per Pair, Team, or Center	Quantity for Each class of 32	Reusable in Each Class	Used in Activity
Butcher Paper	Chalkboard				1, 2, 4, 7, 10, 13
Tape or Glue	Transparent tape, or bottle or stick glue	1		No	1, 2, 6, 7, 8, 9, 10
Marking Pens	Crayons	Many			Most
UFO Articles	Optional	Variable		Yes	1
Ink Pads	Optional	1	1	Yes	1
Pen or Pencil					All
10-M Measuring Tape	Meter Sticks		1	Yes	2
Meter Sticks		1		Yes	2, 4, 5, 6, 11
Yellow Ball, 2.5 cm	Ball of Clay, Bread		1	Yes	2
Index Cards	Cut Up Cardboard, Tag board or Paper	9 in No. 2, 20 in No. 8			2, 8
Sticks	Tongue Depressors	9		Yes	2
Sheet of Black Paper		1			2, 6, 11
Film Canister	Tiny Bag, Container	1			2
Salt		Pinch			2
Cake Decorations	Balls of Clay, Beads	4 Tiny			2
Magnifying Glass	Optional	1			2
Adding Machine Tape	Cut Up paper, Taped				3, 8, 10
Ruler			1	Yes	3
3”x5” Index Cards		6	36	No	10
Strainer or Colander	Optional		1	Yes	3
Masking Tape			1 Roll	No	3, 6
Flat Bottomed Clear Bowl	Glass Pie Pan	1		Yes	3
Dried Rolled Oats		1 Tablespoon		No	3
Puffed Rice Cereal		2 Tablespoons		No	3
Black Tea		Pinch		No	3
Wooden Spoon	Wooden Stick	1		Yes	3
Blank Paper		1			3
Clear, White Lightbulb, 200 Watts		1		Yes	4

Material	Substitutions or Alternatives	Quantity per Pair, Team or Center	Quantity for Each Class of 32	Reusable in Each Class	Used in Activity
Poster Board	Butcher Paper	1		No	13
Lightbulb Socket		1		Yes	4
Dimmer Switch, Rotary Dialed		1		Yes	4
Lamp Wire		1 to 3 meters		Yes	4
Electrical Plug		1		Yes	4
Wire Cutters		1		Yes	4
Wire Strippers		1		Yes	4
Blade Screwdriver		1		Yes	4
Phillips Screwdriver		1		Yes	4
Electrical Tape		1 Roll		Yes	4
Permanent Marker		1		Yes	4
Radiometer		1		Yes	4
Stopwatch	Click with Second Hand	1		Yes	4
Clear Plastic Box	Optional	1		Yes	4
Calculator		1		Yes	4, 5
Red and yellow Paper	Red and yellow Markers		1	Yes	6
Small Box	Paper Bag		1	Yes	6
Scissors	Paper Cutter		32	`Yes	6, 8, 9
Tag board Strip			32	No	6
Push Pins			64	Yes	6
Dice		2		Yes	8
World Maps	Globes, Atlases		Many	Yes	8, 10, 11, 12
Sheet of Blue Paper	9-by-12 inch Paper, Option in No. 10	1		Yes	9, 10
Glass Cake pan, 9 by 9 inches		1		Yes	11
Ice			1 small bag	No	11
Bricks		2		Yes	11
Candle and Matches			1 short	No	11
Food Colors: red, Blue	Other Colors, Dyes		1 bottle	No	11
Clay, Three Colors		See Text		Yes	11
Dental Floss	Knife or Wire			Yes	11
Book and Magazine		1,1		Yes	11
Towels	Cloth	See Text		Yes	11
String	Dental Floss			Yes	11
Blue and Green Paint	Optional	1		No	11
Paint Brushes	Optional	1		Yes	11
Flour	Optional		Cup	No	11
Eyedroppers	Optional		1 or 2	Yes	11
Envelopes	Optional		4	Yes	11

Table A.2—Audiovisual Materials.

Material	Substitutions or Alternatives. Optional Items are Indicated.	Quantity per Pair, Team or Center	Quantity for Each Class of 32	Reusable in Each Class	Used in Activity
Data Projector and Computer			1	Yes	1, 3, 11
Overhead Projector	Optional		1	Yes	Most

Teacher Background Information

You do not need to have all the answers to begin teaching your students about SETI! However, many teachers have asked for more information about the various topics presented in this unit. Therefore, the following notes about each of the missions are included. Please keep in mind that this book is written at an adult level, and it is not intended to be read by students. Enjoy!

Mission 1: Welcome Aboard!

The *SETI Institute* is the home for projects related to the search for intelligent life beyond Earth. The Institute's goal is to foster high-quality research into all the various factors influencing the existence, nature, and activities of life in the universe, including the fields of astronomy and the planetary sciences, chemical evolution of life, biological evolution, and cultural evolution. The Institute also has a primary goal to promote public information and education related to the Search for Extraterrestrial Intelligence (SETI). To date (2010), over 30 Institute projects have been conducted, with sponsorship from NASA Ames Research Center, NASA Headquarters, the National Science Foundation, the Department of Energy, the U.S. Geological Survey, the International Astronomical Union, and other funding institutions. At this writing, Jill Tarter is Director for SETI Research, and Tom Pierson is Chief Executive Officer of the SETI Institute. Though the "SETI Academy" discussed in this book is fictional, the SETI Institute is real.

Mission 2: Our Solar System

The huge yellow star that our Earth orbits is named the *Sun*, or *Sol*, from which the name *"solar* system" is derived. A planet is any large rocky or gaseous body orbiting the Sun. Our solar system consists of the Sun and its orbiting bodies: planets, natural satellites (moons), rings that circle the planets, comets, asteroids, and artificial satellites. A comet is a ball of ice mixed with chunks of rock. Comets do not have tails when they are far from the Sun, but when they come into the inner solar system, the Sun evaporates the ice, and the solar "wind" (charged particles that are boiled off the Sun's outer layers) makes the tail glow and stream away from the Sun. Most comets are in the "Oort cloud," which is far beyond the orbit of the dwarf planet Pluto. An asteroid is a large mass of rock and metallic ores. Most asteroids are observed to orbit the Sun in a region between Mars and Jupiter called the *asteroid belt.* The largest asteroids are sometimes called *planetoids.* Very small asteroids are called *meteoroids.*

Mission 3: Formation of Planetary Systems

About five billion years ago, one section of a huge cloud of gas and dust, which is called a *nebula,* began to collapse due to the gravitational attraction of all the matter in the cloud. As the cloud collapsed, it began to rotate, at first slowly, then faster and faster, like a spinning ice skater pulling her arms into her body. As the gas and dust fell inward, a dense clump formed in the center. As the gravity of this clump of gas and dust pulled its constituent material in tighter, enough heat was generated to ignite *nuclear fusion* that transformed hydrogen atoms into helium atoms, generating great amounts of heat and light. Thus, our Sun was born (it continues to generate heat and light today because of this continuous fusion of hydrogen). At the same time, smaller clumps were forming inside the disk of matter that was swirling into rings around the central clump. These clumps were drawn by their gravity into tighter masses, but they did not have enough mass to ignite nuclear reactions. (Jupiter was almost massive enough to start the fusion process. If that had happened, our Sun would have been part of a double star system, and life might never have evolved on Earth.) As time went on, a "wind" of elementary particles from the new Sun blew away the extra gases and dust in our solar system, leaving the rocky inner planets and the gas giant outer planets. Although the formation of our solar system took place a very long time ago, our understanding of this important sequence of events is based on evidence revealed today, through techniques such as radioactive dating and chemical analysis of meteors, and through studies of the surface of the Moon, which has remained much as it was when it was formed by a catastrophic collision of an asteroid with Earth more than four billion years ago.

Mission 4: Types of Stars

Stars come in many different colors and sizes. Just like the flames of a fire, the hottest stars burn blue or violet, and the coolest ones burn red. A star in the prime of its life is labeled with one of the letters *O*, *B, A, F, G, K,* and *M* to indicate its color and mass. O-type stars have the most mass, burn the hottest and brightest, and are blue-white. M-type stars have low-mass, burn much cooler and much more slowly, and are red. Star types have been identified not only by their overall colors, but by detailed analysis of their color spectrum using telescopes equipped with prisms or diffraction gratings. Information on the masses of stars comes from the study of stars in systems of two or more. By analyzing the motions of the stars, it is possible to infer the strength of their gravitational fields and, consequently, their masses. Many people are interested in how the radiometer works. Notice that the blades are black on one side and white on the other side. Because the black sides absorb more heat, the air atoms near those sides move more energetically than the air atoms near the white sides. Consequently, air atoms bounce off the black sides with more force, giving the blades more "kick" in one direction than in the other. This imbalance turns the blades.

Mission 5: Habitable Zones of Stars

Liquid water is required for life as we know it to exist. This is because organic chemical reactions cannot take place without water in liquid form. If a planet is too close to its star, such as Mercury is to the Sun, all water will evaporate. If the planet is too far away from its star, such as Neptune is from the Sun, all water will be frozen. In between the too-hot and the too-cold limits lies the region where liquid water *can* exist on a planet. This region is called the *habitable* *zone.* The size and distance of the habitable zone will depend on the type of star. However, even within the habitable zone, not all planets have liquid water. Venus, for example, is within the habitable zone for our Sun, but is made too hot for liquid water by its thick atmosphere of carbon dioxide gas. Mars once had huge rivers of flowing water, but there are none to be seen today. This is because Mars is much less massive than Earth. With its low gravity, it has lost most of its atmosphere to space. The little atmosphere it has left, which is about 1/1,000th the pressure of Earth's atmosphere, cannot keep the planet warm enough for liquid water.

Mission 6: Building a Model Planetary System

Many simulations have been conducted on computers to see what other kinds of planetary systems might exist. They all support the hypothesis that rocky planets should form closer to the central star and gas giants should form farther out. Star systems with two or more stars might form planets, but the orbits of those planets would take them into drastically different temperature regions, so they would alternately bake and freeze, or their orbits would become unstable and they would either fly out of their system and into open space or spiral into one of their stars. Thus, it seems that life would be most likely to form on a planet orbiting a single star somewhat like the Sun. In recent years, astronomers have found several stars that are likely to have planets currently being formed. These appear in infrared telescopic observations as disks of material, warmed by the central star. Astronomers are also searching for stars that wobble very slightly as they move through the galaxy, which would strongly suggest that they are circled by one or more planets as massive as Jupiter.

Mission 7: Searching for Habitable Planets

Hundreds of extra-solar planets have been detected. NASA’s Kepler Mission is poised to detect Earth-size planets in the habitable zone of other stars. However, we can think about the conditions that would be necessary for life, so that we can search for habitable planets when our telescopic “eyes” can see farther. We know, for example, that it is very unlikely that a planetary system orbiting a hot star will have a planet on which there is intelligent life, because the star would burn out before life could evolve. Thus, we would not look for habitable planets around an O-type star. Planets around small, dim stars would need to be very close to their stellar hosts to be warm enough for life. But these planets would likely be locked into climate-destroying synchronous orbits. Consequently, the most likely type of star to have a family of habitable planets would be a G-type star.

Mission 8: Evolving Planet X

Earth formed from pieces of rock and dust that condensed out of the original solar nebula. However, all the material was not collected into planets immediately. A great deal of it continued to orbit the Sun, occasionally wandering near enough to a planet to fall and make a very big splash! Mass extinctions have resulted from collisions with very large chunks of this space debris. Several tons of this material still falls to Earth every day, although most pieces are so small they burn up unnoticed in the atmosphere. In the early days of Earth, the rate of bombardment by meteors and asteroids was at least 1,000 times greater than today! Also important in the formation of the early Earth was volcanism. When Earth's mass became large enough, the interior became molten. Much heat continues to be generated from the decay of nuclear materials inside Earth. The heat not only melts rocks, but causes water and other liquids to turn to gas and greatly expand, erupting on the surface in great explosions. Volcanoes continue to be important forces in the evolution of our planet today. But evidence of ancient eruptions shows that volcanoes were even more violent and frequent early in our planet's history.

Mission 9: 200 Million Years Ago

Our understanding of how Earth's geologic forms have come to be has increased greatly since the 1960s. The theory of continental drift has become as important in the fields of geology and climatology as Newton's Laws have become in physics. Fortunately for students, some very important evidence for continental drift theory is clearly visible, such as the match between the outlines of continents, and the distribution of rocks, minerals, and fossils. The Pangaea Puzzle is not simply a game; it is a simplified view of what geologists actually do.

Mission 10: Drifting Continents

It is challenging for students to think about the long time scales and vast changes involved in planetary evolution. The Continental Drift Flipbook the students create is one way of conveying to students how the continents continue to change, and how the apparently “stable” Earth is always shifting under our feet. Fortunately, we can only feel these shifts occasionally during earthquakes or volcanic eruptions. Unfortunately, earthquakes caused by the rubbing together of tectonic plates can sometimes be very powerful and destructive.

Mission 11: Changes on Planet Earth

In order to understand the forces that create continental drift, volcanoes, and earthquakes, students need to understand the structure of Earth's interior. This will also help them to imagine how things might work differently on planets that are much larger or smaller than Earth. The structure of Earth is somewhat more complicated than the model presented to students. The convection currents that are thought to occur within the mantle are probably confined to the upper regions. However, recent research suggests that large masses of material may break off from the outer core, and slowly move through the mantle and up to the surface with eruptive effects!

Mission 12: Climate Zones

Broad climate zones related to latitude can be quickly understood by students since they are used to thinking about the equator as a “hot” place, and the North and South poles as “cold” places. Students may find it more challenging to figure out the moist and dry climates that are created by large-scale geologic features, such as mountain ranges. Help students as much as possible with the use of maps and videos that show what it is like to live in these different climate zones.

Mission 13: Creating a Map of Planet X

This is a wonderfully creative experience that gives your students an opportunity to synthesize what they have learned during the entire unit. You may want to obtain maps of other planets and moons within our solar system from your library or from the U.S. Geological Survey.

Mission 14: Mission Completed!

This open-ended post-test gives you an opportunity to find out what your students learned from the unit. Based on the results, you might want to emphasize certain sections when you present the unit again, or leave out certain sections, or find new ways to teach some of the most challenging concepts.

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PowerPoint Images

See PowerPoint File Notes for Script, or Missions 1, 3, and 11Teacher's Guide

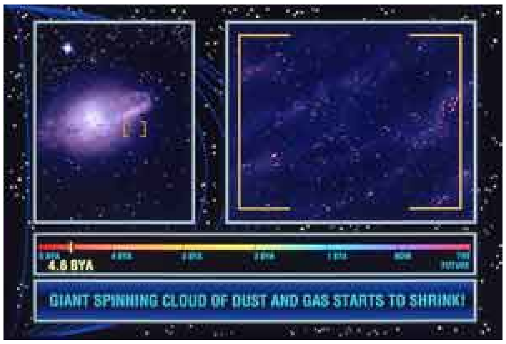


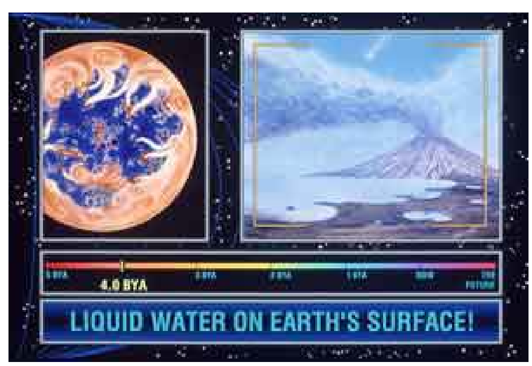
Image 1.1, 3.1 and 11.5

Image 1.4, 3.4 and 11.8

Image 1.2, 3.2 and 11.6

Image 1.5, 3.5 and 11.9

Image 1.3, 3.3, and 11.7



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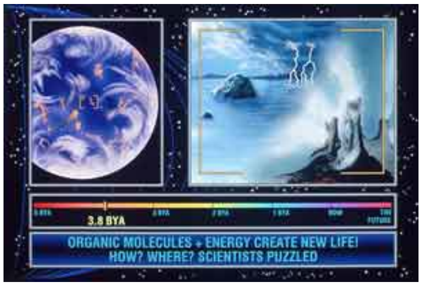


Image 1.7 and 11.11

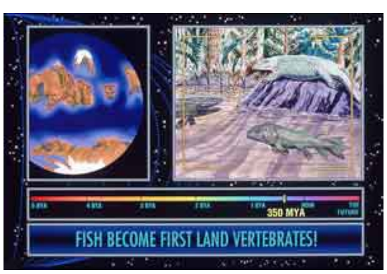
Image 1.11 and 11.15

Image 1.8 and 11.12

Image 1.12 and 11.16

Image 1.9 and 11.13

Image 1.13 and 11.17



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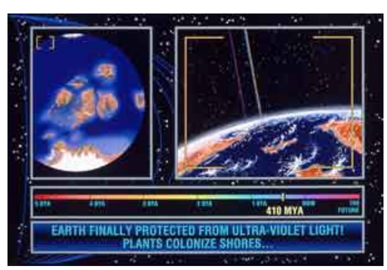

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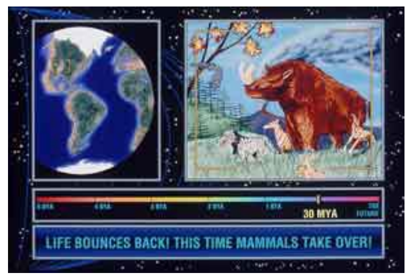
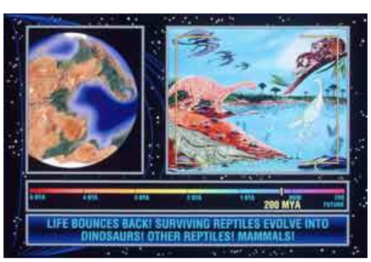
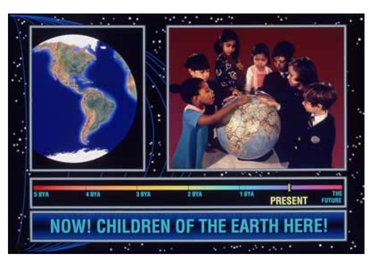
 Image 1.16 and 11.20	 Image 1.20 and 11.24
 Image 1.17 and 11.21	 Image 1.21.and 11.25
 Image 1.18 and 11.22	 Image 1.22 and 11.26

	 Image 1.23 and 11.27