Life: Here? There? Elsewhere?

The Search for Life on Venus and Mars

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Contents

Scope and Sequence
Life in the Universe Curriculum

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

$$(N) = R_{*} \bullet f_{p} \bullet n_{e} \bullet F_{l} \bullet F_{i} \bullet F_{c} \bullet L \bullet$$

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

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

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

Foreword

Carl Sagan, Cornell University
1934-1996

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

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

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

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

PREFACE

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

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

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

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

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

Learning Objectives

Concepts

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

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

Skills

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

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

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

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

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

About Inquiry

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

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

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

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

Timeline and Planning Guide

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

Mission 1: Comparative Planetology

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

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

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

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

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

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

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

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

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

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

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

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

Mission 5: Initial Spacecraft and Lander Design

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

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

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

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

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

Mission 7: Water!

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

Mission 8: What Is Life?

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

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

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

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

Mission 10: Chemical Tests for Life

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

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

Mission 11: Mission to Planet Earth-Life Trap!

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

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

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

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

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

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

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

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

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

Mission 14: Final Spacecraft and Lander Design

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

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

Preparation

Worksheets

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

Keeping a Journal: Portfolio-Based Assessment

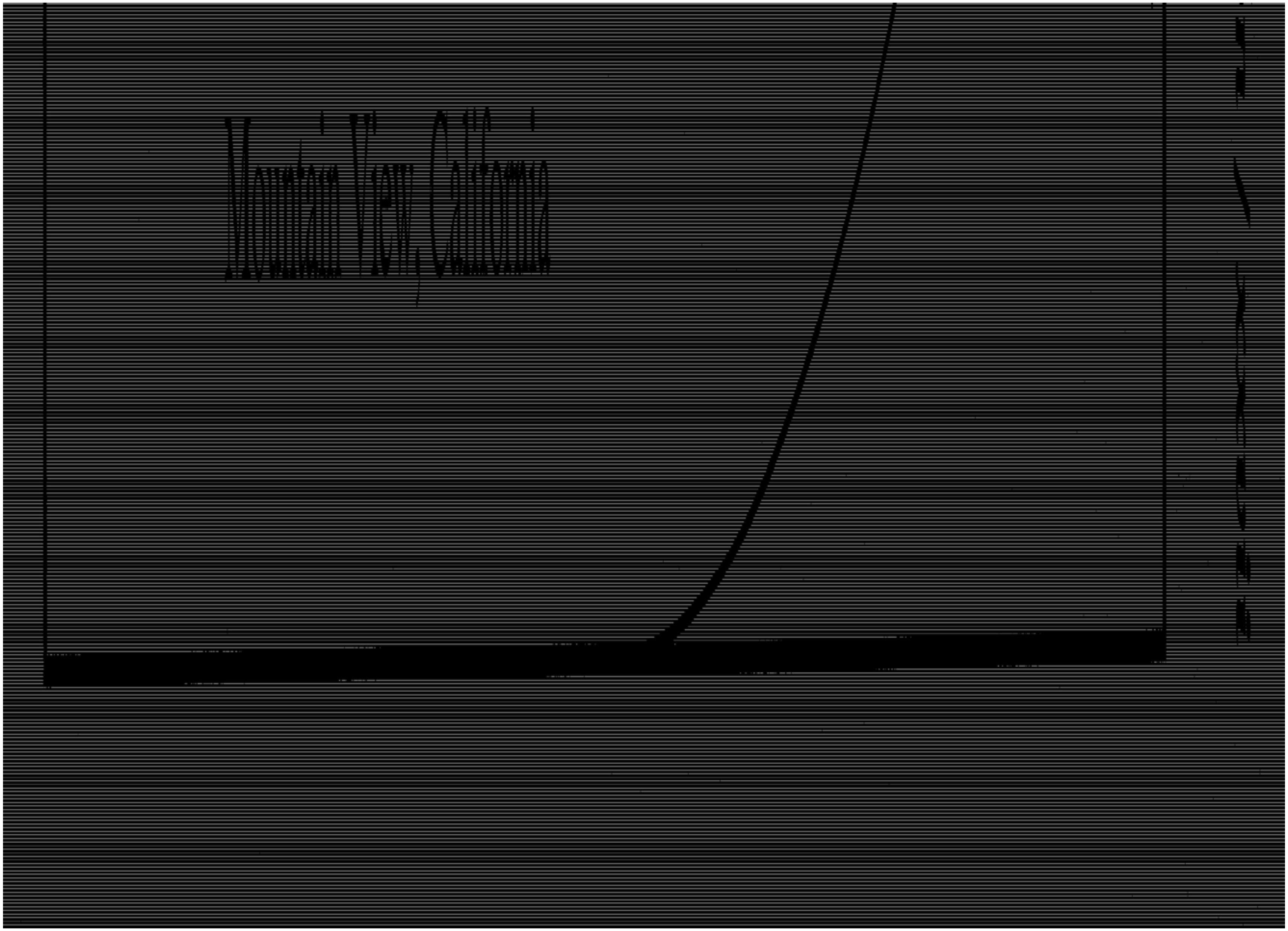
Life: Here? There? Elsewhere? worksheets may be incorporated into a journal, perhaps a "Scientific Laboratory Notebook." This will allow students to keep a personal record of their entire search for life on Venus and Mars. Journals will help students acquire a sense of enthusiasm, a wealth of new knowledge,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

Preparation of Special Materials

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

ZOOM! Cards

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