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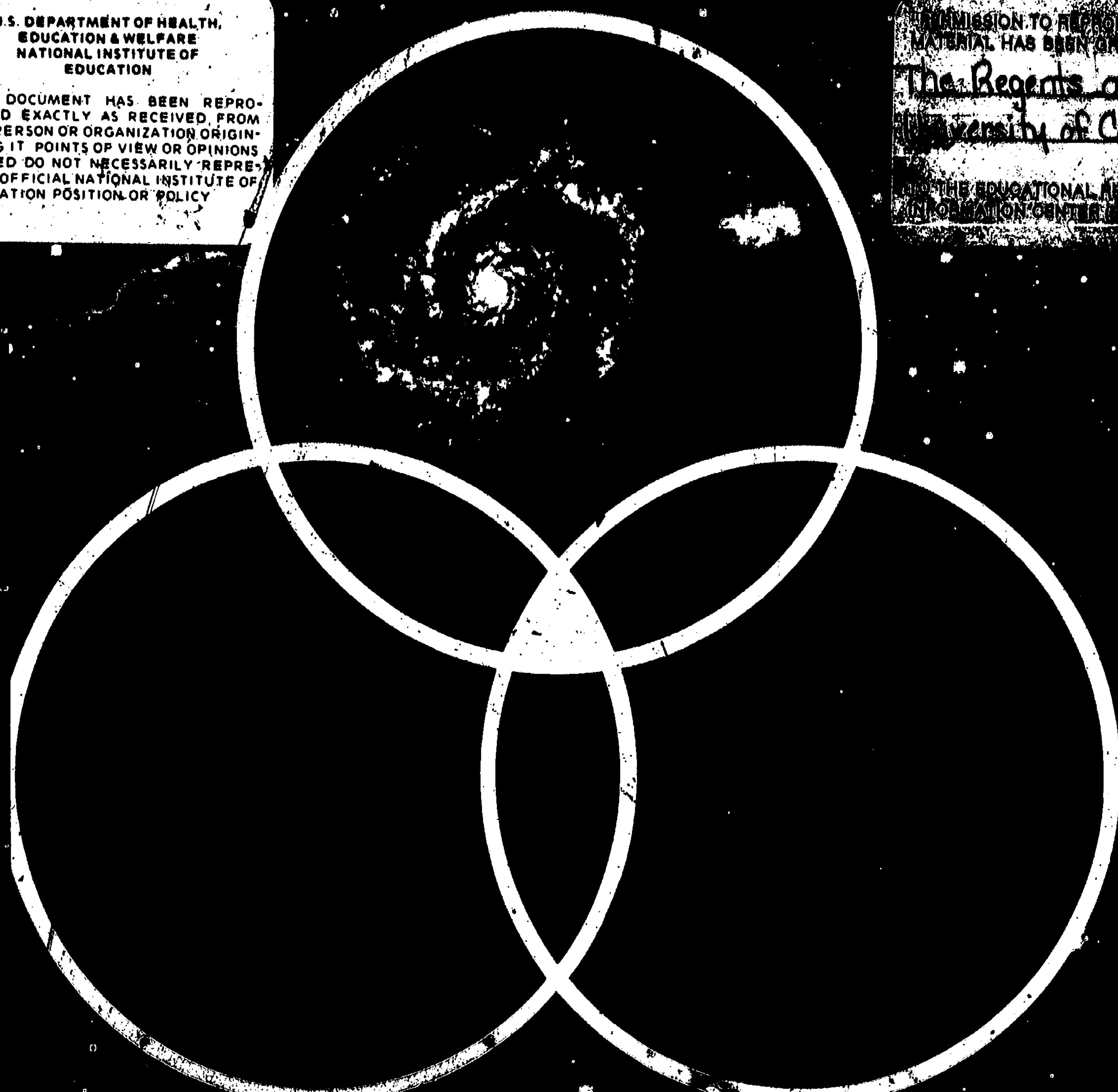
ABSTRACT

Presented is a workshop guide for planetarium educators. Seven modules and four appendices focus on organizational patterns, learning theories, questioning strategies, activities for the planetarium, and incorporating all of the above into teaching. The four appendices include a list of the 1978 workshop participants, an annotated bibliography for planetarium educators, program descriptions from the Holt Planetarium at the Lawrence Hall of Science, astronomy quizzes, and classroom activities. (SA)

International Planetarium Society — Special Report No. 10

PLANETARIUM EDUCATOR'S WORKSHOP GUIDE



by

Alan J. Friedman, Lawrence T. Lowery, Steven Pulos, Dennis Schatz, and Cary I. Sneider

Illustrated by Budd Wentz

International Planetarium Society
Special Report No. 10
1980

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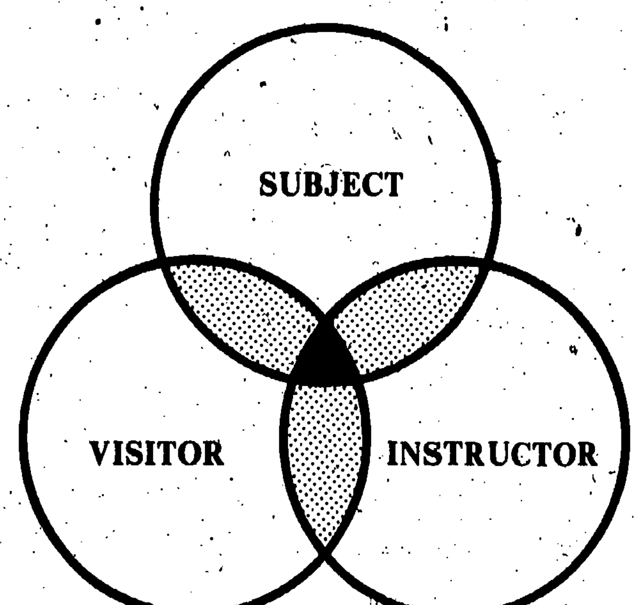
Astronomy Education Program, Lawrence Hall of Science
University of California at Berkeley



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Authors listed in aphabetical order.

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Additional copies of the *Planetarium Educator's Workshop Guide* may be purchased from: The Spaceshop, Strasenburgh Planetarium, P.O. Box 1480, Rochester, New York 14603 (Phone: 716 244-6060).

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INTERNATIONAL PLANETARIUM SOCIETY INC

FROM THE PRESIDENT:

This special publication of the International Planetarium Society is to be used and hopefully you will find that it will become an excellent reference for your planetarium library.

The work of Alan Friedman, Lawrence Lowery, Steven Pulos, Dennis Schatz, Cary Sneider and Budd Wentz is culminated in this professional publication. They are to be commended for their efforts and hard work.

The future continues to come forth. It is in the future that you and I may discover that the universe is teeming with life, and in some way we, in the planetarium profession, will have helped our society to accept it.

If this publication helps spark the imagination to develop more creative thoughts—then, their efforts will not have been in vain, and the future will look even brighter.

Sincerely,

James A. Hooks

James A. Hooks
President
International Planetarium Society

JAH:dp

Foreword

Planetarium educators have one of the happiest of professions. Almost all of us really enjoy what we do and believe that our work in communicating the excitement of astronomy and other sciences is important. Planetarium people are chronically underbudgeted and overworked, but we have the opportunity to be scientist, teacher, actor, magician, and general ham to hundreds if not thousands of people a year.

One of the few fundamental dilemmas we seem to have is trying to balance *education* with *entertainment*. Debate about where the balance point should occur has been going on since the first planetarium program. Some school shows have been criticized as being too dull (all education) while some big planetariums have been accused of presenting flashy programs with no substance (light shows that are all entertainment).

This workshop has been developed by the authors and their many collaborators as a tool for enhancing planetarium education *and* entertainment for any audience and any occasion. Over the past several years we have found strategies for making science content more entertaining and simultaneously more meaningful to general audiences. These strategies include techniques for selecting and arranging content and for actively involving the visitors in the planetarium program. We welcome your comments on these strategies, and your suggestions for improvements.

Introduction

If you have access to a planetarium and are interested in learning more about how to use it to promote science learning, this workshop is addressed to you.

The *Planetarium Educator's Workshop Guide* is intended to be used by any group of planetarium educators who want to get together to experiment with new techniques. This group of educators may be the staff of a single planetarium, attendees at a planetarium association meeting, a few elementary school teachers who have access to a school planetarium, or college instructors who have decided to clean the cobwebs off the campus planetarium projector. While an individual planetarium instructor may find the *Guide* useful, it is designed to be most effective (and most enjoyable) for a group of people who are willing to spend a few hours sharing ideas and challenging each other's assumptions.

The first appendix of this guide gives a few tips on organizing and conducting a workshop in your area.

The goals of the workshop program are to enable you to:

[1] Select realistic goals and effective teaching techniques for particular groups of planetarium visitors.

[2] Involve your visitors in active investigations during planetarium programs, including public shows.

[3] Assess programs to find out which elements are working best in helping visitors learn from their planetarium visit.

While the authors of this workshop guide are enthusiastic about active ("participatory") learning in the planetarium, our purpose is not to prescribe any one technique for developing planetarium programs, nor to criticize poor techniques. Rather, the workshop modules present a variety of perspectives for viewing what occurs in a planetarium, and a number of specific, useful strategies for creating programs.

In 1977, we obtained support from the National Science Foundation to develop and implement workshops to share these techniques with the planetarium community. We prepared a first draft of this workshop guide and presented five workshops during the summer of 1978, at Berkeley, California; Staten Island, New York; Cleveland, Ohio; Herndon, Virginia; and Dallas, Texas. Over 100 workshop participants suggested improvements that were included in subsequent drafts of this guide. The workshop participants are now prepared to present this program to their colleagues.

We hope you will find these strategies for developing planetarium programs useful tools as you create your own sky theater presentations.

Acknowledgements

Many of the modules in this workbook are based on materials initially developed by Lawrence Lowery for the University of California Teacher Preparation Project. Alan Friedman, Cary Sneider, and Steven Pulos of the Lawrence Hall of Science, and Dennis Schatz of the Pacific Science Center, Seattle, adapted those materials and developed new modules expressly for planetarium educators.

The following staff members of the Lawrence Hall of Science Astronomy and Physics Education Project helped develop the planetarium programs included in this book and tested the first version of this workshop: Michael Askins, Bryan Bashin, Cynthia Carilli, Cathy Dawson, Gaylord Fischer, Stephen Gee, Mark Gingrich, Alan Gould, Cheryl Jaworowski, Tom Mathis, Bob Sanders, and Budd Wentz. Diane Blum typed and typeset all of the printed materials, and with Larry Throgmorton, edited the final version. Illustrations and graphics are by Budd Wentz, with the assistance of Michael Askins. The NSF grant supporting this work was administered by Lawrence Hall of Science Associate Director Robert Karplus, Principal Investigator for this project. Alan Friedman was Project Director. Special thanks are extended to Alexander Barton and Linda Kahan of the National Science Foundation for their continuing encouragement and support.

The authors would also like to thank the following planetarium educators who helped develop and evaluate the planetarium programs included in this workshop guide: Jeanne Bishop, Westlake Schools Planetarium, Westlake, Ohio; Jane Geoghegan, Thomas Jefferson Planetarium, Richmond, Virginia; Gerald Mallon, Methacton School District Planetarium, Norristown, Pennsylvania; George Reed, West Chester State College Planetarium, West Chester, Pennsylvania; and Sheldon Schafer, Lakeview Center for Art and Science Planetarium, Peoria, Illinois.

Hosts for the trial workshops, held in the summer of 1978, were: Tom Hamilton, Wagner College Planetarium, Staten Island, New York; Robert Andress, Warrensville Heights High School Planetarium, Warrensville Heights, Ohio; Rolfe Chandler, Herndon High School Area III Planetarium, Herndon, Virginia; Eloise Koonce, Richardson Independent School District Planetarium, Richardson, Texas; and James Rusk, Mesquite Independent School District Planetarium, Mesquite, Texas. Thanks are also extended to Bob Risch and Jim Vickery, Jefferson County School District (Jeffco) Planetarium, Lakewood, Colorado, for hosting a pilot workshop program at the 1976 meeting of the International Planetarium Society.

Many planetarium educators from all over North America attended the trials of these workshop materials. These educators, and the host planetarium staffs, have given us invaluable suggestions and comments, and have designed activities which are included in this book. We hope that planetarium educators everywhere will consult those who participated in these first workshops so that the benefits of this program can be widely shared. Names and addresses of the workshop participants are listed in Appendix B.

Module 1

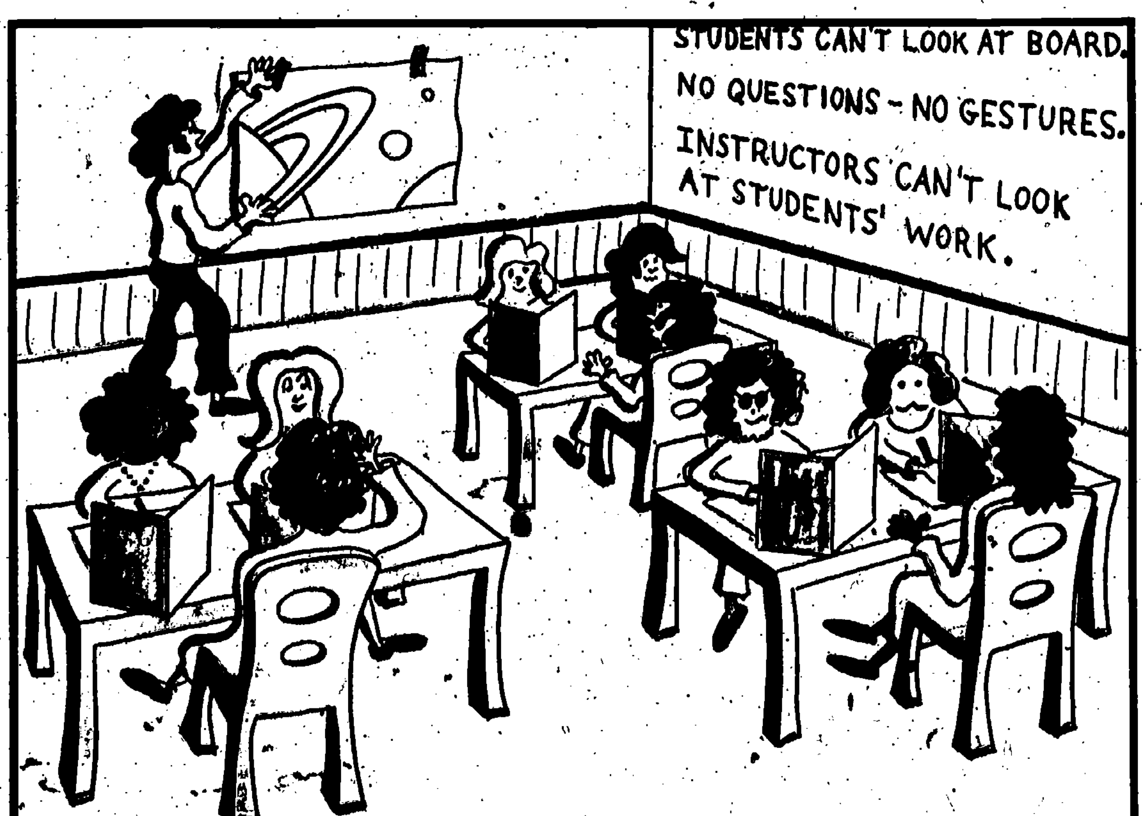
COMMUNICATION

The objective of this activity is to provide an opportunity for you to switch roles with a visitor and experience three different teaching techniques, involving three different levels of interaction with an instructor.

Here is a simple exercise that quickly leads to fundamental issues in planetarium education. Begin by separating workshop participants into groups of three. Each group selects one member to be an "instructor." The other two are "visitors," who sit facing the instructor. The workshop leader places a drawing so that only the instructors can see it. Each instructor's task is to describe the drawing so that the visitors, using paper and ink markers or crayons, can reproduce it as accurately as possible in three minutes. The instructors are asked to limit themselves to certain teaching techniques for each round of the game as described on the following page.

At the end of three minutes, instruction ends and the visitors can compare their work with the original drawing. Instructors and visitors discuss the difficulties they encountered in this task, and identify the teaching strategies that seemed to work best. For each round of the game a new drawing is placed on the wall, and the rules are changed slightly to permit different levels of interaction between the visitors and the instructor. You can also switch roles each round so that each person has the opportunity to play "instructor" and "visitor."

After each round of the activity, stop to discuss with the rest of the group the effect of changing the rules to permit more interaction between the visitors and the instructor. How does your ability to understand what is being communicated change? What instructional strategies become possible as more interaction is permitted? Jot down the insights which you feel are most important.



Rules for round #1: a) Use no gestures. b) The visitors may not ask questions. c) The instructor cannot see what the visitors are doing (a barrier is placed between their papers and the instructor).

Insights: ____

Rules for round #2: a) Use no gestures. b) The visitors may not ask questions. c) The barriers are taken away so the instructor can see what the visitors are doing.

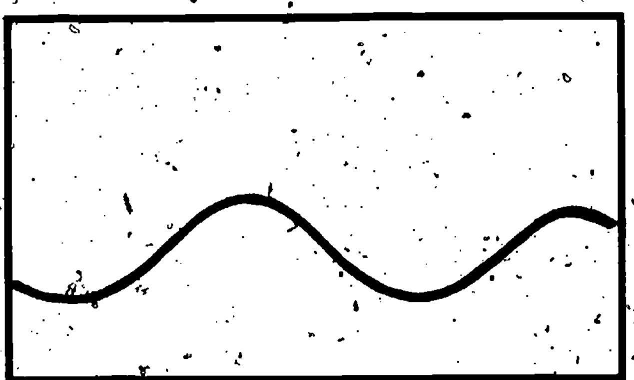
Insights: ____

Rules for round #3: a) Use no gestures. b) The visitors are permitted to ask questions during the activity. c) The instructor can see what the visitors are doing.

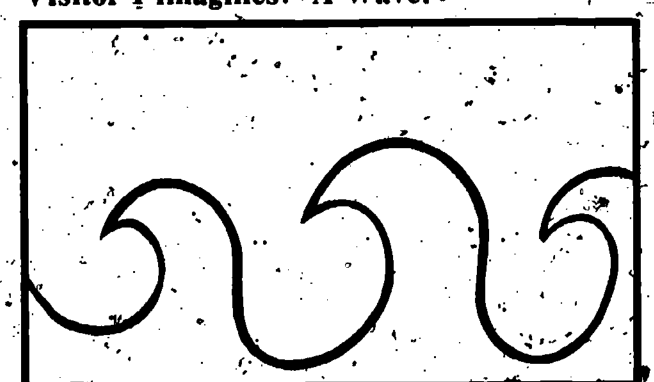
Insights: ____

This activity has proven to be a remarkably efficient (and fun) way to bring out most of the strategies good communicators use to get information across. For example, you'll probably notice that *analogies* are a frequent tool. Rather than trying to describe every detail of the drawing below, an instructor will often say "It's shaped like a wave." This strategy works well as long as the analogy is sufficiently close, *and* the learner has the same picture of "a wave" that the instructor has. As illustrated below, it may not always be appropriate to assume that the visitors' image of a word or concept is what the instructor had in mind.

Instructor says: "A Wave."



Visitor 1 imagines: "A Wave."



Visitor 2 imagines: "A Wave."

Interaction between the visitor and instructor like that allowed in Rounds #2 and #3 is essential to check such assumptions and may suggest the use of other analogies, or an entirely different strategy for communicating ideas.

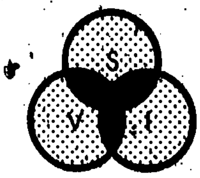
This exercise itself is an analogy to the problem of communicating an idea in your mind to your visitor's mind. Our exercise limits the idea to a simple line drawing which could be communicated in a planetarium by just showing a slide. But even pictures can be interpreted differently by instructors and visitors (see Module 4). Communicating more subtle scientific concepts, such as moon phases, the reason for day and night, gravity, or the nature of a black hole, requires the instructor to continuously check his or her assumptions about how the visitors are receiving the message.

The insights you can gain from doing this activity introduce the remainder of this workbook. In the modules that follow, we examine specific techniques planetarium educators can use to create accurate, enjoyable communication with visitors.

Incorporating more interaction with visitors will be a constant theme. Every technique we discuss will have advantages and disadvantages, and we have no "surefire" guarantees to offer. Techniques that incorporate more visitor-instructor interaction are more effective communication tools than techniques that do not, but interaction does take time. The *quality* and *quantity* of communication must be balanced. We hope you will weigh the advantages and disadvantages of each technique presented in this workbook.

The following modules present a framework for critically examining planetarium programs (Module 2), a set of organization schemes for different modes of instructor-visitor interaction (Module 3), a guide to visitor perspectives (Module 4), useful question and activity strategies (Modules 5 & 6), and a final summary section (Module 7).

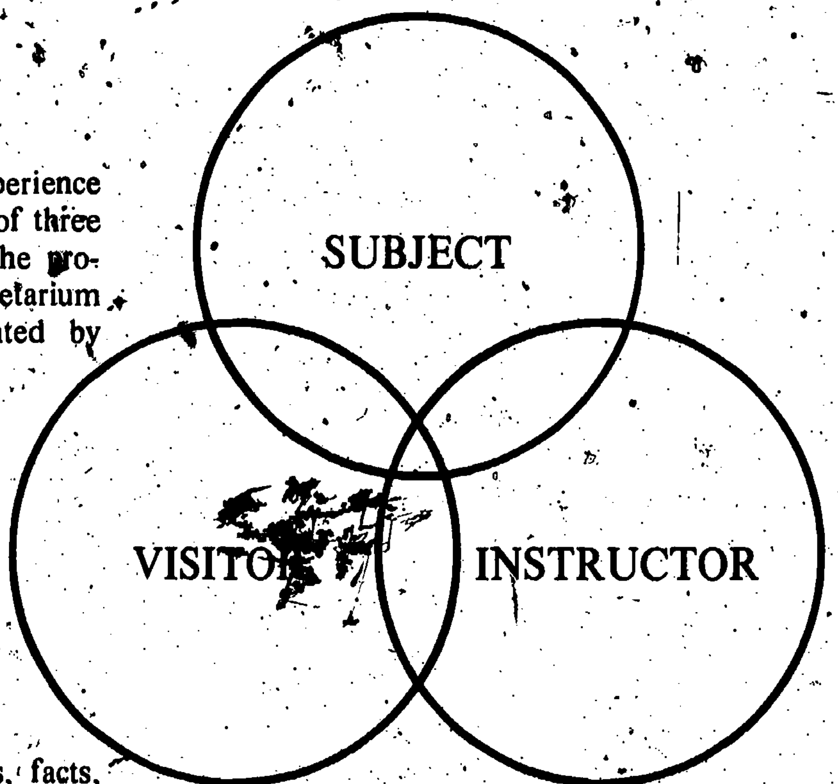
Module 2



A FRAMEWORK FOR EXAMINING PLANETARIUM PROGRAMS

The objective of this module is for you to become familiar with one framework for examining planetarium programs. You'll try out this framework while discussing with other planetarium educators the kind of programs you'd like to present.

Every planetarium program experience can be thought of as a combination of three interrelated factors: The *subject* of the program, the *visitor*, and the planetarium *instructor*. These can be represented by three interwoven circles.



1) *The Subject*--The images, sounds, facts, concepts, skills, and attitudes that you wish to communicate to the visitor.

2) *The Visitor*--His or her background experiences, perspectives, interests and learning abilities.

3) *The Instructor*--All the strategies you use to communicate the subject of the program to the visitor. (The actual instructor can be a person or a machine.)

The framework of three interwoven circles suggests that effective education occurs at the intersection of all three circles. Considering all three aspects can help you create the most meaningful and enjoyable learning experience.

S The Subject

If you had to select only three topics to present in this year's schedule of single-visit planetarium programs for the general public, what would they be and why do you believe they are important?

TOPICS	IMPORTANCE

V The Visitors

What are the most important things you should know about your visitors when a group comes to the planetarium for the primary purpose of learning? Why is this information important?

INFO ABOUT VISITORS	IMPORTANCE

I. *The Instructor*

What are three of the most effective instructional techniques you have used in the planetarium? Why do you believe these are important in helping visitors learn from the experience?

TECHNIQUES	IMPORTANCE

In our trial workshops, we found great variety in the responses various planetarium educators gave to each of these questions, because the particular subjects, visitors, and instruction techniques are different for each of us. Even with these differences, the following modules will help you match your own choices of subjects and instruction techniques with the visitors to your planetarium for the best result.

Intersecting circle symbols next to the title of each module provide a helpful guide to the module's focus. Module 1, for example, stressed the interaction between the instructor and the visitors, so intersecting visitor's and instructor's circles are shaded to show that the interaction between these two factors is the focal point.

Module 3

ORGANIZATION PATTERNS

The objective of this module is for you to become aware of six different ways in which you can organize the planetarium experience for the visitors.

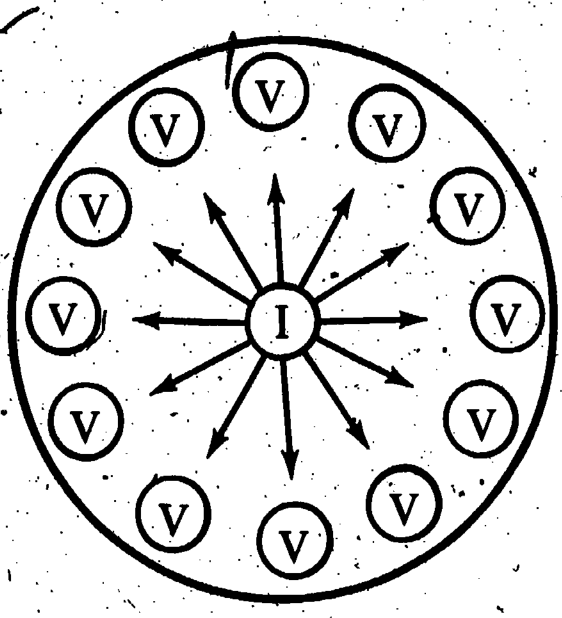
This section outlines a number of ways you can interact with your visitors in the planetarium. As you read about each pattern of organization, turn back to this page and list the advantages and disadvantages you see in each.

Each organization scheme will be illustrated by using a section of an actual single-visit planetarium program. In a workshop, you'll want to try out each section live. If you are reading this module by yourself, you might like to look at "Observing a Variable Star" (pp. 66-67), and the full program "Constellations Tonight" in Appendix D, since examples are from those sources.

Organization	*Advantages*	*Disadvantages*
Didactic		
Small Group Task		
Individual Task		
Informal Discussion		
Group Meeting		
Socratic		

Didactic Organization

In this type of arrangement, you present material verbally and/or visually to the learners, without expecting any response from them. As the diagram illustrates, information flow in the didactic mode is entirely in one direction -- from the instructor to the visitors.



Most completely taped shows are examples of didactic organization, as are live lecture-style shows in big planetariums.

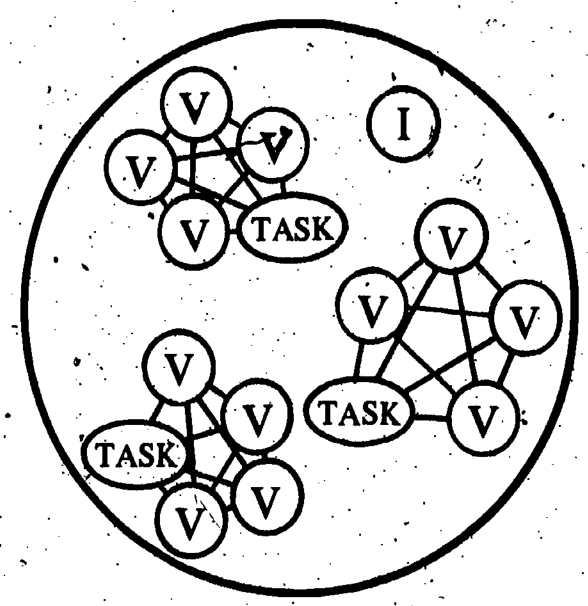
A typical didactic presentation on constellations would feature the instructor telling constellation mythology, or describing to visitors how to find the big dipper.

Didactic organization is almost always a part of any planetarium program, even one which will feature audience participation, and visitor interaction with the instructor. For example, the program "Constellations Tonight" (in Appendix D) has an essential section on top of page 121, in which the instructor tells the visitors how to use a simple, one-page star chart for the constellations of the season. A few questions to the audience appear, but the basic organization of this part of the program is didactic. What advantages and disadvantages do you see with this pattern? Record your views on page 10.

Small Group Task Organization

The whole audience is divided into small groups by row or seating section to initiate this organization. Each group is given a task to accomplish.

The small group task organization allows each visitor to interact with other visitors while working on a common task. Each individual has sufficient time to make his or her own contribution to the task solution.



An example of the small group task organization may be found in the Sky Map Activity in "Constellations Tonight" (pages 121 to 122). After the visitors learn how to use a star-map through a didactic approach, the audience is divided into groups of four or five to cooperate in finding an assigned constellation in the planetarium sky.

This organization has the advantage that visitors can easily help each other, providing mutual encouragement.

The following suggestions may contribute to the success of small group organization patterns.

1) Be sure the task is clearly defined and understood.

2) Provide the necessary materials in advance.

3) Check on the progress of each group.

4) Hold to a realistic time schedule.

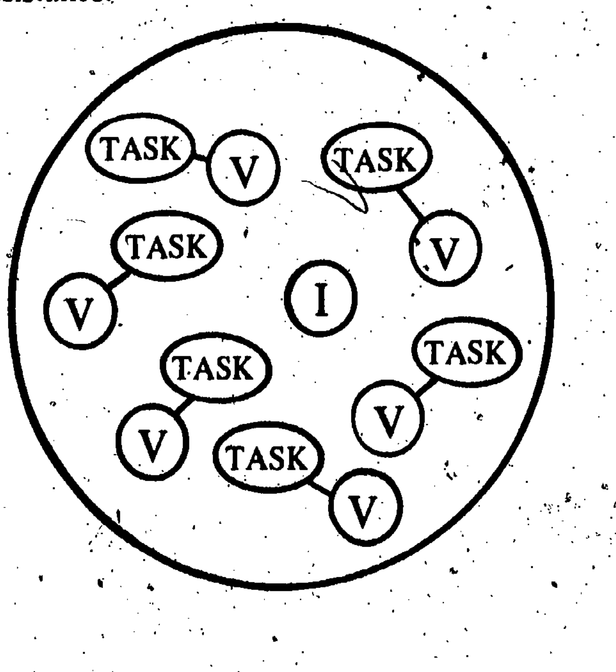
5) If possible, keep each group small, not more than six members.

6) Provide for reports to the larger group when tasks are completed.

Turn back to page 10 and list the advantages and disadvantages of the small group organization.

Individual Task Organization

This pattern of organization enables each visitor to make his or her own observation, perform a unique role, or solve a problem. Thus, each visitor becomes physically and intellectually involved in the subject you are presenting. Each individual can be engaged in a different task or each can be assigned the same task. With a small audience, this pattern allows you to move from person to person to provide information and assistance.



For example, the topic of variable stars can be presented as an observing and recording task for the visitors to perform individually during the planetarium program. This activity is described in detail in Module 6 (pp. 66-67) and is described briefly here to illustrate this pattern of organization.

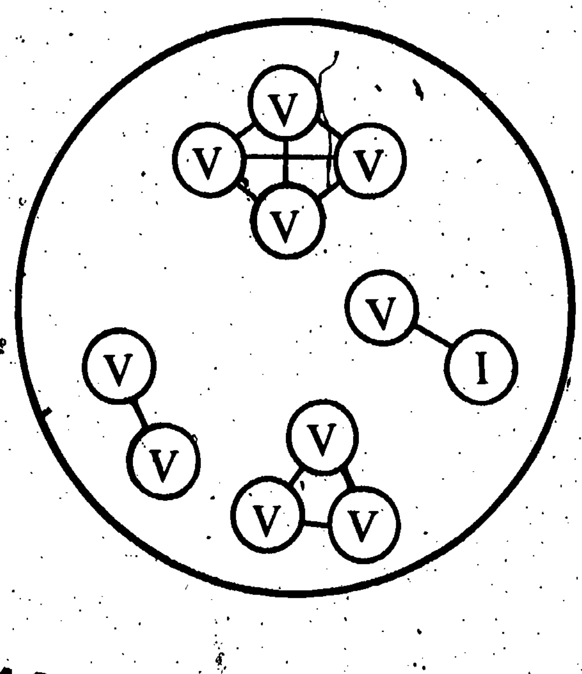
After a short didactic presentation of what variable stars are, and how amateurs provide useful scientific data on them, each visitor receives a clipboard, pencil, and sheet of graph paper. A "variable star" is projected onto the dome. Surrounding stars of constant brightness are labeled with numbers (via another slide projector) to show their magnitudes.

Each visitor estimates the brightness of the variable star and marks a dot on his or her graph to show that estimate. Each "night" a new point is plotted until the visitors have recorded the entire light curve of the variable star. Discussions follow this activity to interpret what the light curve might mean.

Record your thoughts about the advantages and disadvantages of this organization scheme on page 10.

Informal Discussion Organization

This pattern of organization allows free, uninhibited discussion by the visitors among themselves.



Recording the light curve of a variable star: an individual task activity.

As instructor, your role is to set aside your own objectives, listen to the visitors' opinions, and be ready to answer questions if asked. Since the visitors quite naturally break into informal discussions among themselves at the end of any planetarium program, this behavior is often not considered an "organization" at all. However, visitor discussion can be consciously planned *during* the program and can make a very valid contribution to learning.

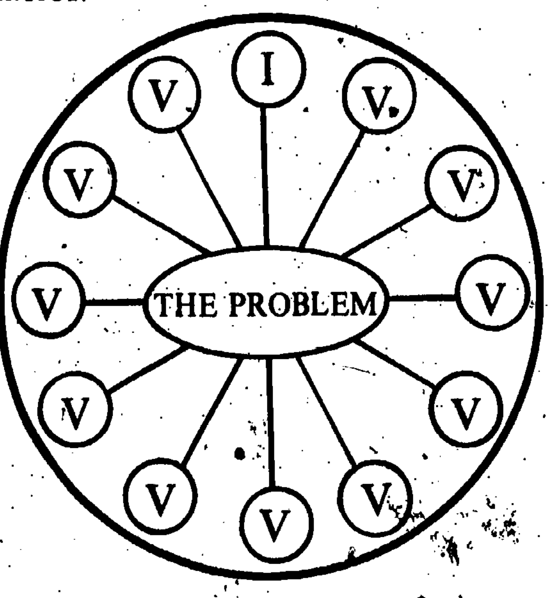
For example, this pattern is especially useful after an activity like the variable star task described above. Visitors are naturally curious to see if they made the same estimates as their neighbors, and the instructor can make this easier by explicitly suggesting that they take a few minutes out to compare observations.

Informal discussion is particularly important if you are going to call on visitors to describe an observation to a large audience. Visitors are often shy, and uncertain that they have observed correctly. Informal discussion permits them to confirm their observations with peers.

What are the advantages and disadvantages of this approach?

Group Meeting Organization

In contrast to the didactic organization which is instructor-centered, or the informal discussion organization which is visitor-centered, the group meeting is problem-centered.



The problem may be initiated by you or the visitors. Your role is to facilitate the discussion and not to direct it. You may listen, call on individuals to speak, make suggestions, or appoint a member of the audience to lead the discussion. In any case, you must be prepared to go along with the group's decision.

After the variable star activity with a group of high school or college students, this kind of discussion is a very good way of drawing together the visitors' observations of the variable star.

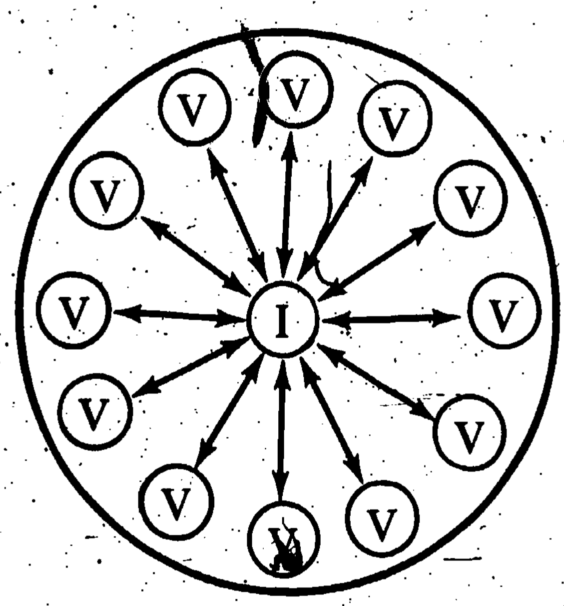
The instructor might ask one of the visitors to lead the discussion for a while to try to decide: 1) How many dips in the brightness occurred? 2) When? 3) What was the minimum brightness? Individuals will have different answers, so the group task will be to reach a consensus about the best description of the variable star light curve. The group might decide to average different observations, to discard extreme data, or to give a range of answers to each question. The instructor must work with each group's decisions.

What are the advantages and disadvantages of this approach?

Socratic Organization

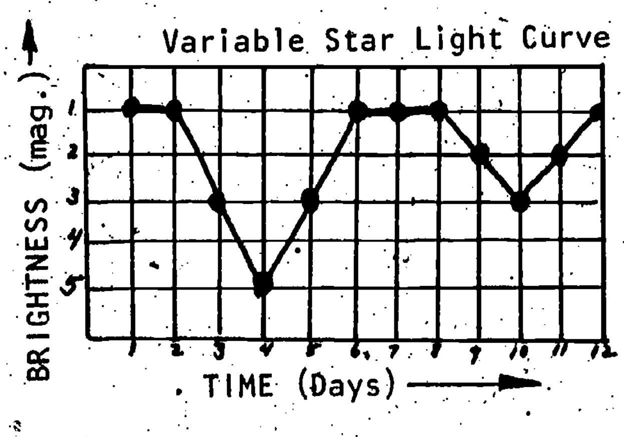
In this pattern of organization, you frequently ask questions of individual visitors, respond to their answers, and lead them step-by-step to the particular ideas you have in mind.

After posing the first question, and listening to the responses, you might probe further by asking the visitors to justify or clarify their answers. You might also refocus the discussion by adding new data, or asking for further ideas and feelings. A good socratic interaction in the planetarium requires you to be conscious of how your questions affect the visitors.



As an example of the socratic approach, consider the following way of concluding the variable star activity. Suppose you would like visitors to consider several explanations for the light curve, and conclude that an eclipsing binary star is the best model. You would like them to infer this from the light curves, but know that they probably cannot do this on their own. You might lead them to the answer, however, with a series of questions as follows [intermediate questions and responses omitted]:

Visitors' Data Sheet



"What might have caused these dips in brightness?"

....

"Let's take those possibilities one at a time. If haze is blocking light from the star, what would happen to the comparison stars?"

....

"Now suppose I tell you both dips repeat every twelve days. Which model works best now?"

....

A similar approach can be used to induce the visitors to consider the relative sizes of the two stars from the data they have recorded.

Record the advantages and disadvantages you see in this pattern of organization on page 10.

A Review of Organizational Patterns

As you look back over these six organizational patterns, notice how your role as planetarium instructor differs. In the *didactic* and *socratic* patterns you decide which ideas are discussed. In the *group meeting* structure, you still control the flow of ideas, but the visitors have greater freedom to select the content. When the visitors are organized in *small groups* to discuss ideas or work on a task, you are free to wander from group to group and offer suggestions and assistance where needed. When each *individual* is working on a *task*, you can assist individuals as a personal tutor.

Examples of each of these strategies in the context of an actual program may be found in the two complete scripts at the end of this workbook. You might enjoy identifying each of the strategies used in the scripts, or speculating on alternative strategies for each segment.

The following segments from a variety of planetarium programs illustrate the various organizational patterns. Please fill in the pattern that you think the instructor is attempting to initiate in each example.

1. "Overhead, you see a photo of the moon taken by the Apollo astronauts. What do you notice about these circular features? What shapes like these have you seen on earth?"

_____________________ Organization

2. "Now I will show you some spectacular photographs of the moon, and explain what they tell us about how old the moon is, and how it was probably formed."

_____________________ Organization

3. "This lamp will represent the sun. I want each of you to stand up and turn around, so the sun appears to ~~rise and set~~ for you."

_____________________ Organization

4. "Work together in groups of three. Pick out a group of stars, and make up a story about some animal or person represented by those stars."

_____________________ Organization

5. "Since many of you seem concerned with the tremendous cost of the Viking mission, let's take five minutes to discuss whether or not the mission was worth the cost. Who would like to express an opinion first?"

_____________________ Organization

6. "Please feel free to come up to the console at the end of the program and ask whatever questions you would like."

_____________________ Organization

Module 4

HOW THE VISITORS SEE IT

This module presents an approach, based on the psychological research of Jean Piaget, for appreciating how visitors understand a planetarium program. You will be able to use this approach to: 1) select appropriate concepts for presentation to various groups of visitors; 2) select appropriate instructional methods so that visitors can understand the concepts; and 3) help visitors advance to higher stages of intellectual development.

Most of us have noticed that some visitors have difficulty understanding certain concepts, such as the reason for day and night, or the causes of the moon's phases. Explaining all the astronomical terms repeatedly, using clear diagrams, and spending extra time with these visitors still may not help.

Individuals who have not yet developed the *reasoning skills* required to understand the concepts presented in a planetarium program are likely to leave frustrated with their inability to understand science, and may be less interested in attempting to understand scientific concepts in the future. Therefore, as planetarium instructors, we must examine how the visitor sees the planetarium program, so that we will be able to present concepts in a fashion suitable for the visitors' reasoning abilities.

In each of the first three sections of this module you will examine one of the basic reasoning abilities important for understanding astronomical concepts:

A. Visualizing how objects and events appear from different frames of reference;
B. Classifying phenomena; and
C. Explaining phenomena scientifically.

In Section D of this module, we provide suggestions for how to help visitors develop these abilities through planetarium experiences.

A. Frames of Reference

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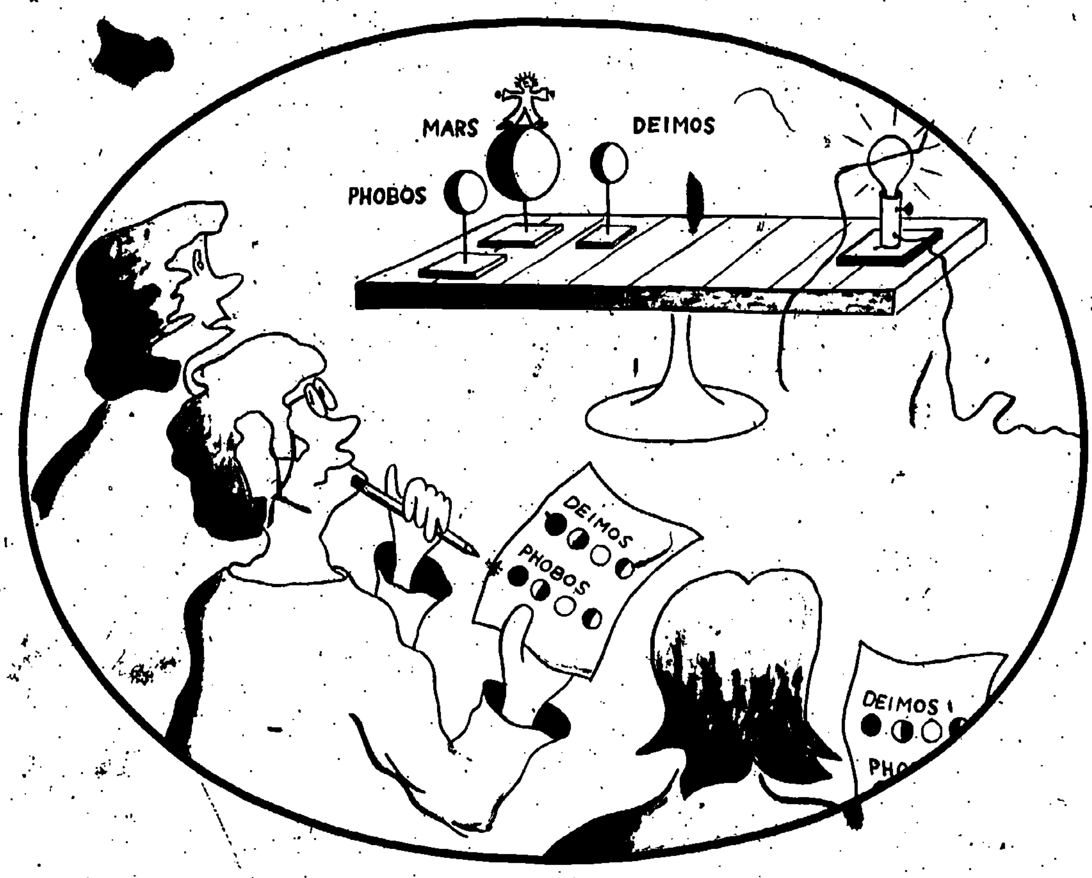
We often show pictures of models and diagrams projected onto the dome: the earth as seen from space, the earth, sun and moon as seen from above the plane of the ecliptic, and so on. To learn some of the ways visitors may interpret such diagrams, begin by solving the problem on the next page.

THE MARTIAN DILEMMA

"Deimos and Phobos, the two moons of Mars, have phases just as our moon has. Please look at the model and determine what phase each moon is in for the person who is observing from the surface of Mars. Circle your response."



Deimos

A B C D

Explain how you figured out your answer: ______________________

____

____

Phobos

A B C D

Explain how you figured out your answer: ______________________

____

____

Examine the following answers to the Martian Dilemma Problem given by college students. Then, answer the two questions at the bottom of the page and compare your results with other individuals in the workshop.

PHOBOS PROBLEM

Student #1 Answer: "B" Explanation: "I imagined myself on the surface."

Student #2 Answer: "B" Explanation: "My point of view--I just reversed what I saw."

Student #3 Answer: "B" Explanation: "Put myself on Mars in my imagination."

Student #4 Answer: "D" Explanation: "Observing shadows on models."

Student #5 Answer: "D" Explanation: "Moon is moving towards sun."

Student #6 Answer: "D" Explanation: "Because Phobos is in the direct sunlight and not in front of Mars."

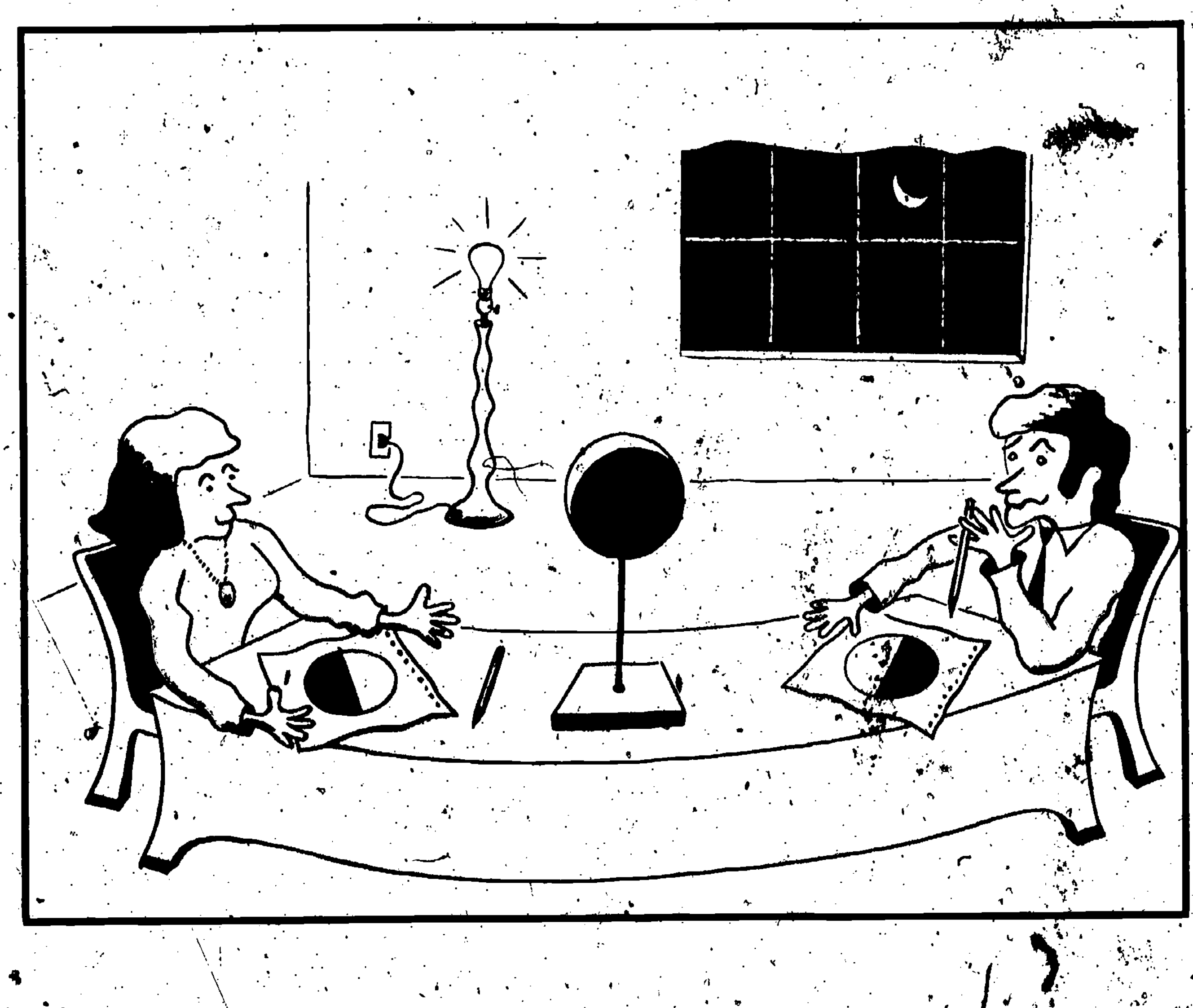
1) Identify the differences in thinking between the first three students and the last three students.

2) Suggest several concepts that are traditionally introduced in the planetarium that may be difficult for the last three students.

One of the most useful perspectives for appreciating how visitors understand the planetarium program has emerged from a half-century of research pioneered by Swiss psychologist and epistemologist Jean Piaget (zhan pee-ah-zhay) and his colleagues. These investigators have studied how people solve problems like the Martian Dilemma.

Piaget noted distinct differences in people's abilities to perceive a situation from a point of view different from their own. In our example, the three individuals who gave correct answers and explanations to the Martian Dilemma Problem could perceive this unfamiliar setting by imagining themselves in a different frame of reference. In contrast, the other three individuals' thinking was dominated by what they saw directly from their own frame of reference, or by information not relevant to the problem.

A further experiment can provide more information about the visitors who could not solve the problem simply by looking at the model of Mars and its moons. Distribute "moons" (styrofoam balls on simple wooden stands) to pairs of individuals who had difficulty with the Martian Dilemma Problem. Illuminate the room with a single "sun" (lamp) and ask each pair of visitors to place a moon between them and draw what they see. When they compare drawings, they will see that their views of the moon are reversed. They may also change seats to see if their partner really observed what he or she drew. Now, some individuals will be able to apply this concrete experience to successfully solve the Martian Dilemma Problem. Others will again give only what they see from their own point of view for an answer.



According to the approach taken by Piaget and his colleagues, these differences in ability to perceive a situation from a different point of view indicate three levels of intellectual development. An individual who cannot perceive that there is a different point of view from his own is operating at the *egocentric level* (also known as the intuitive level). Egocentric here should not imply selfishness, merely that a person at this stage assumes that everyone sees the same thing he or she does. If direct experience with concrete objects and events, such as a model, helps a person to accept a different viewpoint from his own, then he or she is operating at the *concrete level*. Finally, if the person can imagine a different point of view just from looking at a diagram or hearing a description, he or she is operating at the *formal level*.

In general, young children operate entirely at the egocentric level. Beginning about age 8 or 9, many children can perceive a different point of view through concrete experiences. The potential for formal level thinking does not appear until sometime during high school. (See Summary Table A.) Piaget also developed categories to describe the behavior of younger children, but we will not describe these categories in this workshop.

Summary Table A. Frames of Reference
Egocentric Level (starts about age 4)-- can imagine only one's own point of view.
Concrete Level (starts about age 8 or 9)--can imagine another viewpoint, but only after a concrete experience.
Formal Level (starts about high school age)--can imagine a situation from different points of view.

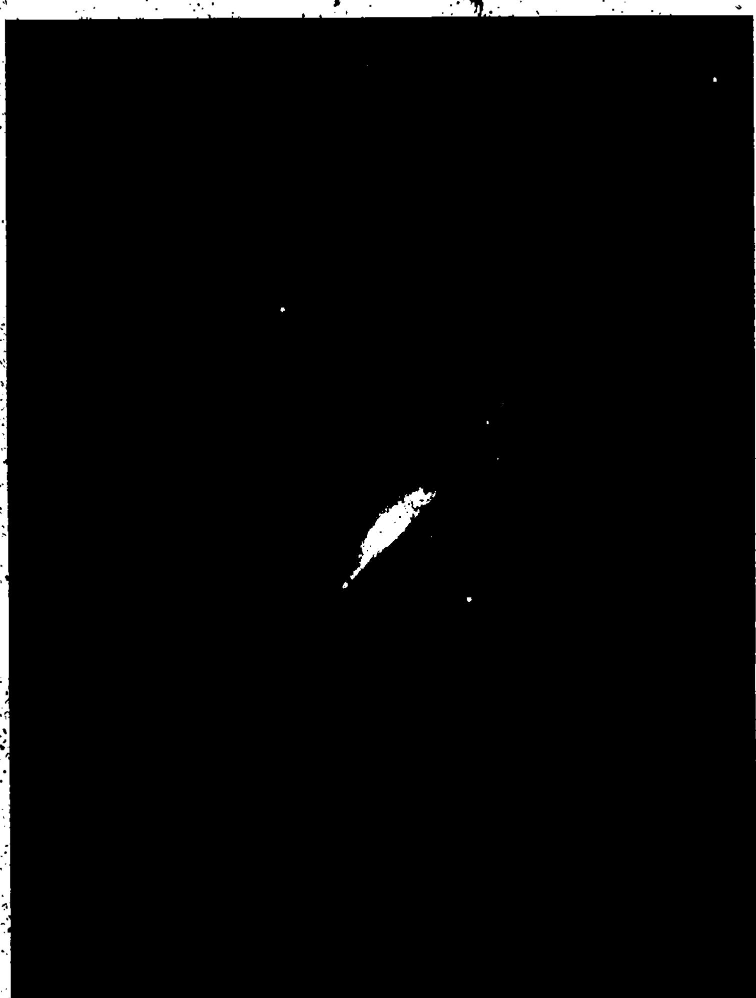
Although a person's general reasoning ability may be sufficiently advanced to permit understanding a point of view different from his own, he or she will not always achieve that understanding. Whenever the situation is too complex, or the subject matter is unfamiliar, even adults begin at the egocentric level. This pattern is evident in some of the college students' responses to the Martian Dilemma Problem.

It is usually necessary to ask the visitors questions during a program to find out how they are understanding the content of the program. If you find that the visitors are operating at the egocentric level, you may decide to present the topic from the visitors' point of view. It may even be necessary to abandon the attempt to communicate a particular concept altogether in favor of other concepts that can be readily communicated egocentrically or concretely in the time available.

1) Turn back to the cartoon at the beginning of this module. At what level is the Wizard reasoning in the second frame? At what level is he thinking in the last frame? ______________

____

2) Based on the reasoning levels summarized in Table A, examine the astronomical concept illustrated below, and suggest a strategy for communicating this concept to a *concrete* level planetarium visitor.



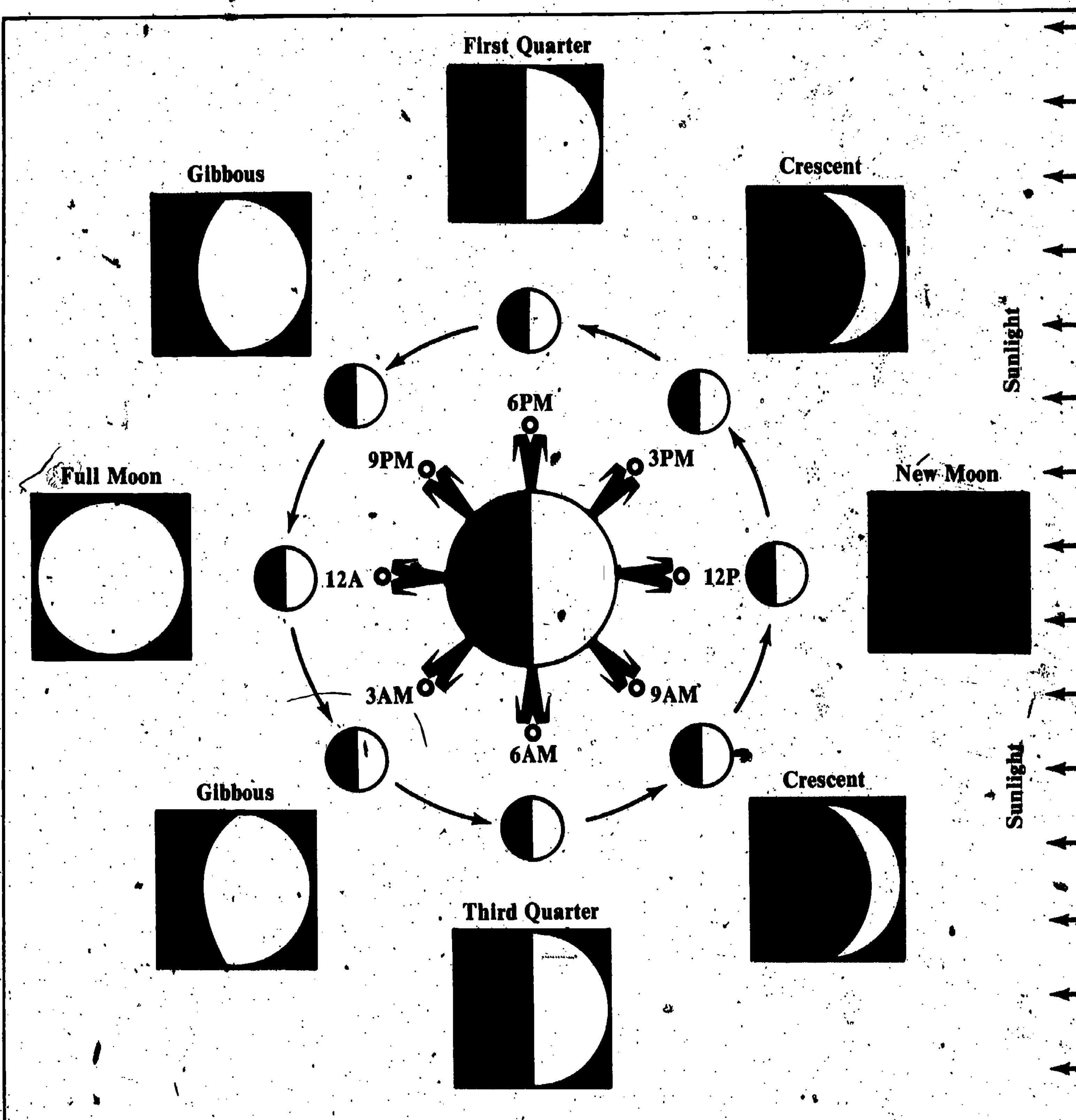
(Photographs courtesy of Lick Observatories.)

CONCEPT: The two galaxies in these photographs actually have the same spiral shape. However, the galaxy shown on the left is viewed from the side, and the galaxy at right is viewed from above.

RECOMMENDED STRATEGY: ____

____

In many astronomy textbooks, diagrams like the one below are used to explain the phases of the moon.



What level of reasoning is required to understand this diagram? ______________

Explain your answer. ______________

____

B. Classification Skills

A great deal of the information that we present in the planetarium requires the visitors to understand how certain information is arranged and how it relates to other information (for example, the classifications of stars and planets; and the differences between nebulae, star clusters, galaxies, and sub-classes of these objects). How do visitors perceive our descriptions of the way these objects are classified?

Children at the egocentric level can attend to only one aspect of a situation at a time, so they cannot systematically classify a large number of objects. They can, however, notice if two objects are similar or different.

When encountering a new set of objects, a person who is capable of operating at the concrete level begins by perceiving similarities and differences. Then he or she may be able to separate these objects into several groups according to shape, color, or some other single trait.

A number of additional classification skills develop throughout the concrete stage. These skills include the ability to sort according to a single trait, to arrange objects along a continuum (from big to small, hot to cold, etc.) and to recognize that an object may belong to more than one class (e.g. realizing that our Sun is also a star, or that Earth is in the solar system and in the galaxy at the same time).

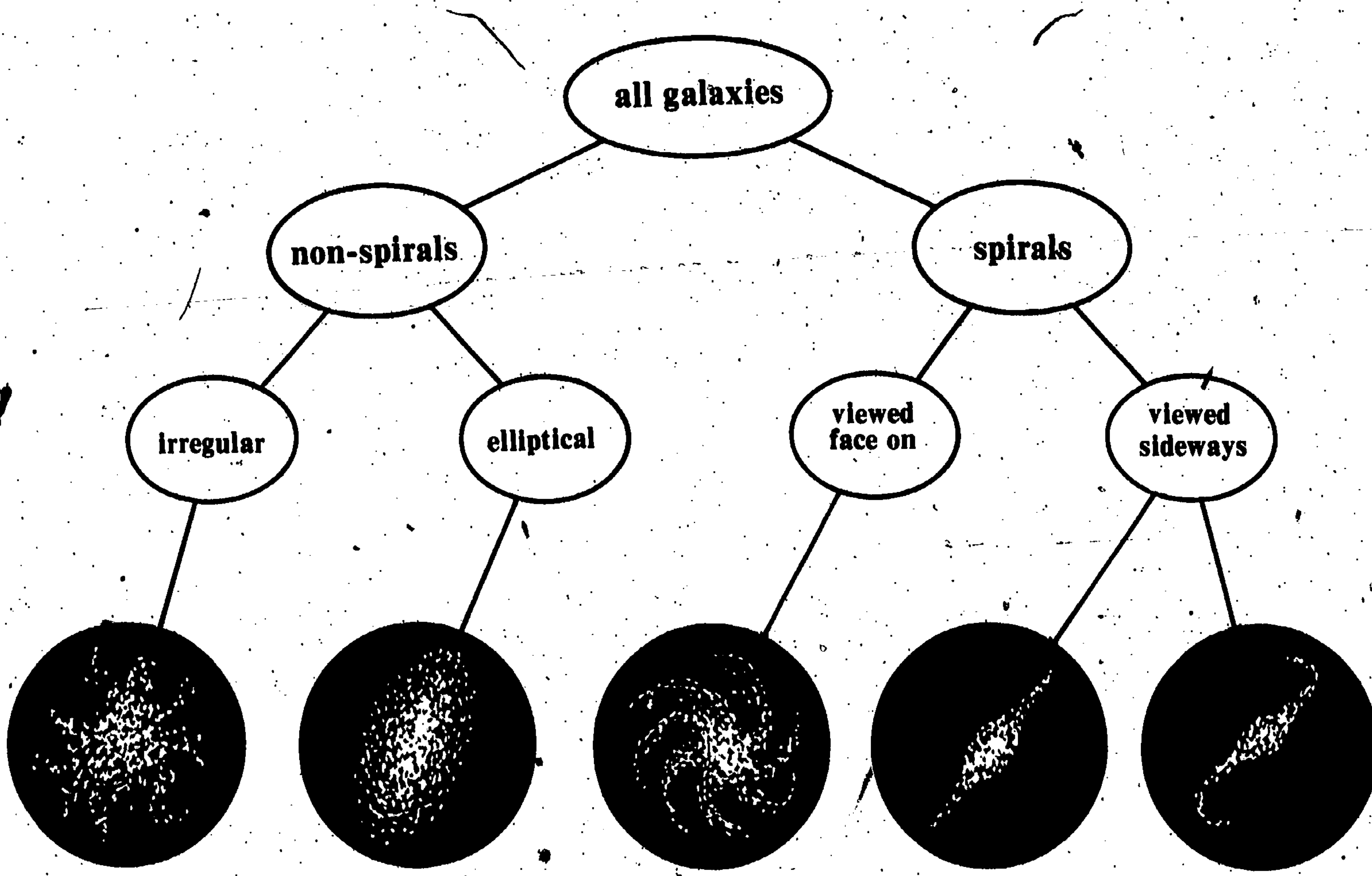
Constructing hierarchies of classes and then rearranging the objects into different hierarchies is a formal level classification skill that does not fully develop until high school age. With sufficient preparation, a high school senior might well be able to understand how astronomers classify galaxies, nebulae, and clusters, and then subclassify these into various types (e.g. open or globular clusters), but most elementary school students would find this hierarchy of definitions too complex, no matter how clearly the lesson is presented.

Summary Table B. Classification Skills
Egocentric Level (starts about age 4)--can notice similarities and differences, and can only classify after much trial and error.
Concrete Level (starts about age 8 or 9)-- beginning with classification by a single trait, can later recognize that objects may belong to more than one class, and can arrange objects along a continuum.
Formal Level (starts about high school age)-- can arrange objects in a hierarchy and then rearrange the objects in a new hierarchy.

Presenting classification schemes that most of your visitors are able to use is essential if they are to comprehend your program. The different levels of classification reasoning are demonstrated in the solutions to the following problem.

Planetarium visitors were given pictures of galaxies and asked to classify them any way they wished. Below each response, please indicate the reasoning level that each visitor used in order to give that response.

1. "Basically, there are two kinds of galaxies; spirals and non-spirals. The spirals might be seen face-on or sideways, and the non-spirals might be either elliptical or irregular in shape."

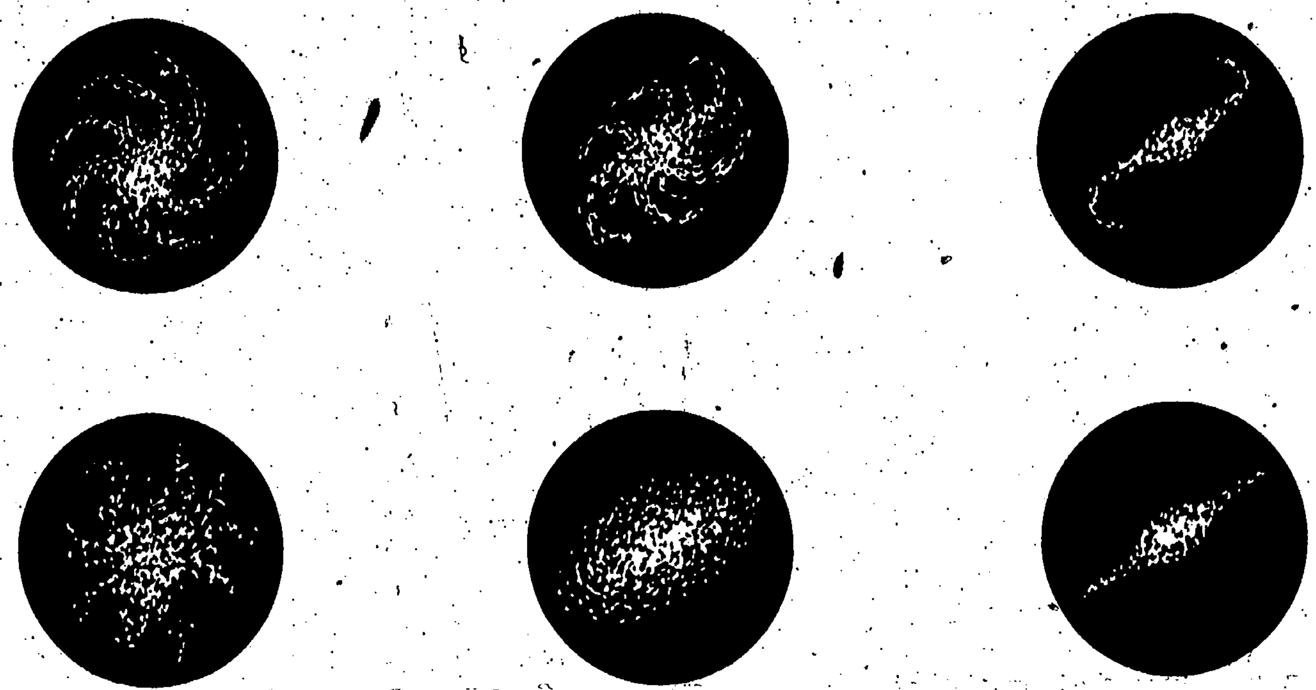


Level ______________________

Please explain your answer. ______________________

____

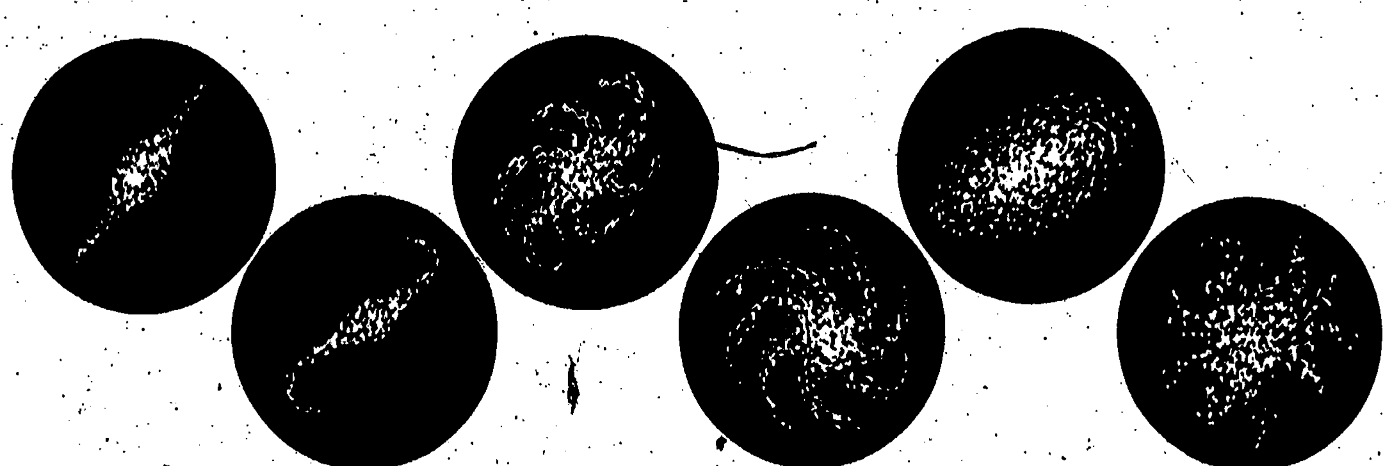
2. "The pictures in the top row are all spirals and the pictures in the bottom row are not like spirals. Also, the ones here (on left) are rounded, the middle ones are egg shaped, and the ones here (on right) are skinny."



Level ______________________

Please explain your answer. ______________________

3. "In order from nicely shaped galaxies towards more squiggley galaxies."

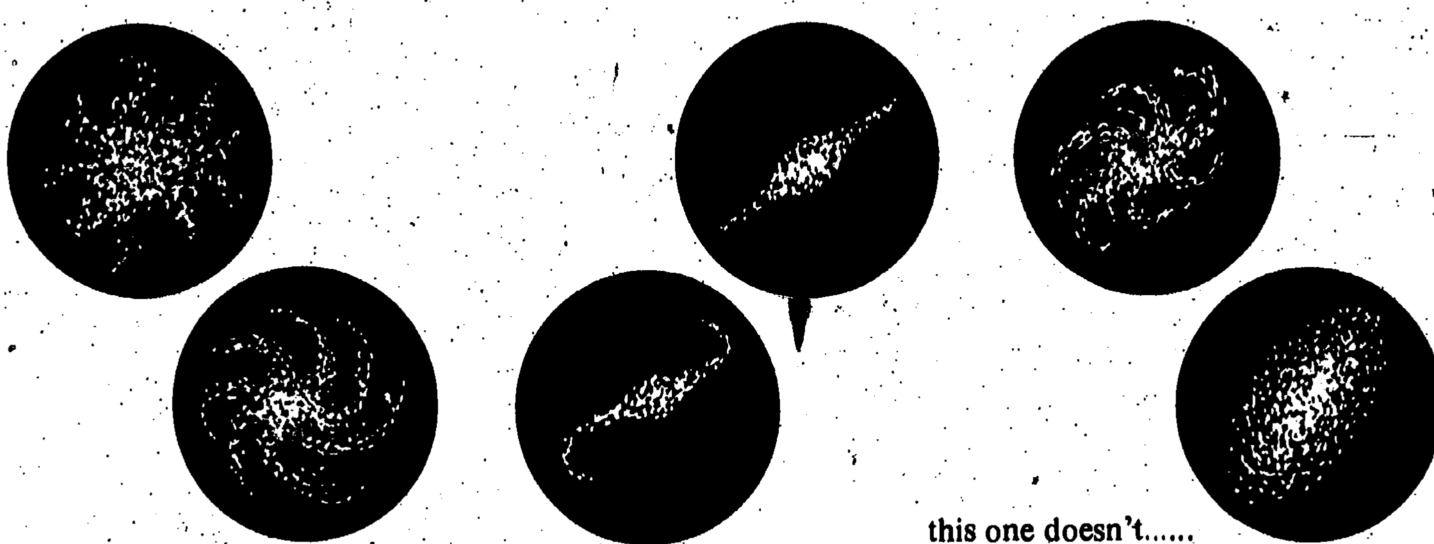


Level ______________________

Please explain your answer. ______________________

____

4. "These are roundish... these are longish... this has arms while



this one doesn't......

the top one has curvy arms and the bottom one doesn't...

and these are sort of alike."

Level ______________________

Please explain your answer. ____

____

C. Scientific Explanation

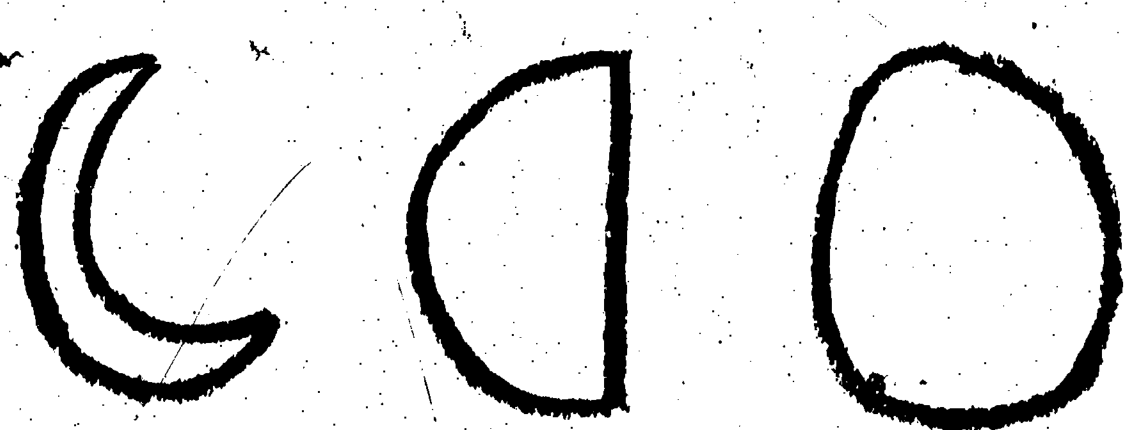
Planetarium instructors frequently provide explanations of physical phenomena: why there is day and night; why the moon goes through phases; why the stars shine; and so on. Presenting explanations at a level that most of your visitors understand will enhance comprehension of the program as a whole. We can classify people's abilities to understand scientific explanations into egocentric, concrete, and formal level responses. A summary is given in Table C.

Summary Table C. Scientific Explanation

Egocentric Level (starts about age 4)--attributes motives and purposes to inanimate objects, or assumes all phenomena are produced by human actions for human purposes, e.g. "The sun comes up so we'll feel warm."
Concrete Level (starts about age 8 or 9)-- more complex relationships between various elements familiar to the individual can now be used to explain phenomena. New observations can be appropriately used in revising explanations.
Formal Level (starts about high school age)--can extend explanations to predict observations and objectively compare one's own explanations with alternatives by controlling variables and making probability arguments.

The distinction between the levels given in Table C is illustrated by several students' answers to the following problem. Begin by writing your own answers.

A teacher asked her students to draw what the moon looked like. Some students drew it as shown on the left, others drew it as shown in the middle, and still others drew the moon like the picture on the right.



Are these pictures all of the moon? If yes, then explain why the moon has different shapes at different times.

____

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Now consider the following responses to the same question by some school children. How do their notions of a "scientific explanation" differ from your own? (Refer to Table C for definitions of levels of reasoning.)

Joe, 8 years old.

Interviewer: How can you explain these different shapes, Joe? *Joe:* It divides itself in different shapes.... *Interviewer:* Does it ever put itself back together again? *Joe:* In the daytime. In the nighttime it divides itself again. *Interviewer:* Why is it that you can only see this part (pointing to crescent) or that part (pointing to half disk) at a time? *Joe:* Cause it's been divided up.

At what level of reasoning is Joe's answer? ______________________

Explain. ______________________

____

Derek, 9 years old.

Derek: Because every month the moon, the clouds come over half of it. And then when the moon is full there's no clouds around it. In a year then it goes back to normal. *Interviewer:* Do the clouds stay that way all night? Or do they move around so you see it all different ways in one month. *Derek:* No, it stays that way for a month.

What level of reasoning is Joe's answer? ______________________

Explain. ______________________

____

Herbert, 13 years old.

Herbert: Because at different days, like a quarter moon, full moon, half moon, just changes its position. *Interviewer:* How does changing its position change its shape? *Herbert:* Cause, all right, if it spins around a kind of fog or mist can get on this part, and it will sort of look like a quarter moon.... *Interviewer:* How does one side get light and the other side get dark? *Herbert:* Maybe cause reflections can't see the dark side, the sun, but reflections can see the light side. *Interviewer:* On here (pointing to the full moon) where is the dark side? *Herbert:* In back. *Interviewer:* In this picture (pointing to crescent) where do you think the sun is? *Herbert:* Over in this direction. Like the sun is right here and it's showing that part (indicating correct position of sun).

What level of reasoning is Herbert's answer? ______________________

Explain. ______________________

____

Tina, 10 years old.

Tina: Something like its our planet or another planet covering half of it or the sun or something covering parts of it... Yeah, our planet. *Interviewer:* How does our planet get up there in the sky? *Tina:* Well, like I'm looking at it cause the *shadow* of the earth is on that part of it. *Interviewer:* In this picture (pointing to half disk) where do you think the shadow of the earth is? *Tina:* There is no moon like that. *Interviewer:* You've never seen a moon like this? *Tina:* There's no such thing as that kind. It can only be curved, because the planet's round and the moon's round so the planet can't be straight on one side to do that.

What level of reasoning is Tina's answer? ______________________

Explain. ______________________

____

The visitors' responses quoted above are typical of a large number of interviews recorded in 1978 at the Lawrence Hall of Science. They are also quite similar to the views expressed by children in the same age groups that were reported by Piaget fifty years ago. Since many of those interviewed in our study reported learning about the moon at museums and planetariums, and could list dozens of facts about recent lunar explorations, their failures to provide adequate explanations for the phases of the moon cannot be attributed to lack of exposure to the correct concepts.

Joe's explanation illustrates a mode of reasoning common to the egocentric level child. Egocentric explanations attribute motives and purposes to inanimate objects, or assume all phenomena are produced by human actions for human purposes. This mode of thinking is called "animism," and reflects the child's egocentrism. Because the child has intention and purpose, he assumes everything else has these attributes as well.

Derek's explanation is more advanced than Joe's since it involves only natural phenomena. However, like Joe, he accepts a simple association as an adequate explanation. Since many children have noticed clouds covering things like the sun and moon, it is not surprising that this explanation is the most common among children of this age. Like Joe, Derek extends this idea to invent an explanation, but has little concern for the need to reconcile new observations. What is important for Joe and Derek is that their explanations make sense from their own points of view, indicative of egocentric reasoning.

Herbert seems to have the right idea from the very beginning when he claims that the moon "just changes its position." However, when asked to explain his ideas more fully he at first slips back to an explanation like that given by Derek, in which fog or mist covers the moon to cause the phases. Then he switches back to the more advanced explanation involving reflected light coming from the sun. Furthermore, Herbert demonstrates that he can visualize the relationships by correctly explaining where the sun must be in order to produce the lunar phase that we see. These more complex relationships are concrete level explanations.

Although Tina begins with the idea that something is covering up the moon, she quickly proceeds to an explanation which involves a relationship among the bodies involved. She has a clear image of the earth's shadow and can visualize the moon's movement through it. It is apparent that Tina can recall seeing that a shadow has the same shape as the object. She also attempts to analyze her response to see if it takes into account all three moon pictures, a quality of formal level reasoning. When Tina realizes that her explanation doesn't fit the straight shadow on one of the moon pictures, she rejects the picture as a fabrication! This distortion of reality is quite common when people encounter the unexpected.

Both Herbert and Tina use concrete reasoning, and in attempting to extend their explanations, suggest the beginnings of formal abilities. Note that Tina is only ten. This emphasises the fact that individuals vary considerably not only in their rate of physical development, but in their rate of intellectual development as well.

A formal level explanation would be demonstrated by the ability to draw or interpret fully a diagram of moon phases like that shown earlier in this module.

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ARE DELETED.

D. Applying the Theory

In this module we have analysed the reasoning strategies of individuals in order to develop guidelines you can use for selecting topics and presentations that particular groups of visitors can understand. You can also use these tools to help provide the kind of experience that can help visitors advance to a higher level of intellectual development.

Piaget refers to this process of intellectual advancement as "self-regulation." According to the theory, self-regulation begins when an individual first uses his present reasoning strategy to attempt to solve a problem. When the present reasoning strategy clearly fails to produce a satisfactory solution, the individual has the opportunity to modify his or her reasoning. If the problem is not so far beyond the individual as to be frustrating, a more advanced and successful strategy may result. For example, a person who has difficulty with the Martian Dilemma begins by drawing the moon just as he sees it. If the individual then is surprised to find out that other individuals at different positions drew quite different pictures, his reasoning strategy will be challenged. The opportunity will then exist for the person to develop a more advanced strategy.

The most important aspect of this process is that *the visitor constructs a more effective strategy on his own.* Telling the visitor in detail how to solve the problem will not promote self-regulation, although hints may help once the visitor begins to seek new strategies himself.

To summarize the process of self-regulation: It is necessary to begin with ideas which are familiar to the visitors so they can use their present reasoning strategies. By introducing a moderate state of disequilibrium, that is, where their present reasoning doesn't work, you will present a situation in which the visitors will be especially susceptible to helpful suggestions from you or other visitors about how to rethink their approaches to problems. If, however, the level of difficulty is too great, frustration may occur, and the visitors may avoid the situation in the future. When the level of difficulty is just right, the visitors will be able to construct for themselves new reasoning strategies that they will continue to use in the future.

To apply this theory to planetarium programming, you may wish to keep in mind the following general points:

1) Many of your visitors, including adults, will approach astronomy problems with concrete or egocentric strategies. They will not become involved in the program unless they can start at their own level.

2) Some topics can be understood using concrete or egocentric approaches, while others require formal reasoning in order to be understood. Consequently, by carefully selecting topics you can design programs which begin at the level of your visitors.

3) If visitors can become involved in a topic at a level which is comfortable for them, and then are challenged by slightly more complex or unexpected information, they may experience intellectual growth. In other words, experiences like these not only help the visitors understand particular concepts in astronomy, but may also improve their abilities in such general areas as using frames of reference, classifying objects and events, and formulating scientific explanations.

For easy reference when planning planetarium programs, the following page contains a summary of the Piagetian levels of reasoning for the three ability areas discussed in this module. You should now be able to use this list to "rate" any presentation as requiring egocentric, concrete or formal level reasoning. This approach can help you develop or revise programs to be more appropriate for your visitors.

SUMMARY OF PIAGETIAN LEVELS OF DEVELOPMENT			
	Egocentric Level *starts about age 4*	**Concrete Level** *starts about age 8 or 9*	**Formal Level** *starts about high school age*
Frames of Reference	Can imagine only one's own point of view.	Can imagine another viewpoint, but only after a concrete experience.	Can imagine a situation from different points of view.
Classification Skills	Can notice similarities and differences, and can classify only after much trial and error.	Can classify by a single trait, recognize that objects may belong to more than one class; and arrange objects along a continuum.	Can arrange objects in a hierarchy and then rearrange the objects in a new hierarchy.
Scientific Explanations	Attributes motives and purposes to inanimate objects, or assumes all phenomena are produced by human actions for human purposes, e.g. "The sun comes up so we'll feel warm."	More complex relationships between various elements familiar to the individual can now be used to explain phenomena. New observations can be appropriately used in revising explanations.	Can extend explanations to predict observations and objectively compare one's own explanations with alternatives by controlling variables and making probability arguments.

The following problem provides an opportunity to integrate all of the information in this module.

TEACHING PHASES OF THE MOON

Suppose your goal is to design education experiences so that by the time a child reaches high school he or she will be able to provide a formal level explanation for the phases of the moon. Based on your knowledge of the various levels of reasoning ability, please outline the experiences and explanations you would provide during an individual's development to reach your goal.

FIRST GRADE

A. Experiences and explanations in the planetarium: ____________________

____

____

B. Experiences and explanations in the classroom: ____________________

____

____

C. Experiences outdoors: ____________________

____

____

FIFTH GRADE

A. Experiences and explanations in the planetarium: ____________________

____

____

B. Experiences and explanations in the classroom: ____________________

____

____

C. Experiences outdoors: ____________________

____

____

TENTH GRADE

A. Experiences and explanations in the planetarium: ______

______

______

B. Experiences and explanations in the classroom: ______

______

______

C. Experiences outdoors: ______

______

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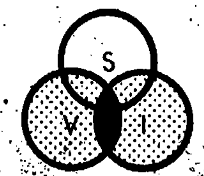
NOTES:

Module 5



QUESTIONING STRATEGIES

The objectives of this module are to introduce you to a scheme for classifying questions, to provide practice in identifying types of questions, and to illustrate how to draw profiles of the types and sequences of questions that you ask during a planetarium program. These tools can help you increase the value of dialog you hold with the visitors.

When properly phrased, your questions motivate and sustain interest, develop and modify attitudes, stimulate fresh ways to deal with ideas, and elicit specific cognitive processes such as recalling, inductive and deductive reasoning and speculating.

Although asking visitors questions is a valuable educational technique, it is not a common aspect of most planetarium programs. It may not be practical when audiences number in the hundreds. For a "school show" with one or two classes attending or even public shows in small planetariums, questions can be a simple and effective means of increasing visitor participation. The socratic organization plan discussed in Module 3 relies on your ability to question the visitors skillfully.

This module is designed to help you develop an effective questioning strategy. Section A provides a useful set of categories for examining question types. Section B applies these categories to dialog from a real planetarium program. Section C suggests strategies for sequencing questions. Section D provides a convenient form for planning or reviewing questioning strategies. Sections E and F apply a similar analysis to the instructor's responses to visitors' answers.

A. Categorizing Questions

A question is a question is a question until one recognizes differences among them. Different classes of questions require different classes of answers. Suggest a few tentative categories to classify these questions:

[1] What does a light-year measure?

[2] What topics would you like me to cover in our next planetarium show?

[3] Did you hear my last question?

[4] Based on your observations of the setting sun during the last two weeks, where do you predict it will set one week from now?

[5] Would you like to be an astronomer when you grow up?

[6] Planets certainly aren't as hot as stars, are they?

Categories	*Example Numbers*

The value of categorizing questions is to increase your awareness of how different questions can stimulate different kinds of thinking by the visitors. One question may flex their memories, another may challenge them to deeper thought, while a third may encourage them to make their own value judgments. This range of mental activity is certainly worth cultivating.

Most planetarium instructors' questions do not achieve this range. A research study by John T. Curtin (reference on page 109) of 38 planetariums found that 98 percent of the questions instructors asked of visitors required only information recall. By examining your own mix of questions, you will be able to increase the range of questions you ask, and thus increase the range of mental processes stimulated by your planetarium programs.

Questions can be assigned to many valid sets of categories. The categories you have proposed are very likely to be represented in the following classification scheme developed by Lawrence Lowery. As you've probably observed in devising your own categories, no scheme is likely to be entirely satisfactory to everyone, but the particular categories below are the result of much testing and revision, and are quite useful.

TYPES OF QUESTIONS					
Narrow		Broad		Other	
Direct Info	Synthesizing	Open-ended	Feeling	Rhetorical	Managerial

Narrow Questions

A narrow question has a certain "correct" answer or a limited number of acceptable responses related to it; when you ask a narrow question, you are hoping for a response that matches something you know. There are two types of narrow questions: direct-information questions and synthesizing questions.

a. *Direct-Information Questions*

These questions require the visitor to recall information or to recognize information that is readily at hand.

Examples:

"Which planet is farthest from the sun?"

"What does a light-year measure?"

"What did Viking discover about life on Mars?"

Such questions are useful if you want the visitor to recall a fact, define a term, or identify something seen before. Responses to direct-information questions will often be one word or short answers. Questions that can be answered "yes" or "no" usually fall into this category.

As part of a strategy, direct-information questions can be used to find out what visitors know, to re-establish what has gone on in a previous experience, or to establish a base of information upon which new knowledge will depend. These questions are generally effective at the beginning of a program to "set the stage" or to emphasize certain observations before proceeding to analyze them.

b. *Synthesizing Questions*

These questions require the visitor to relate information in a specified way.

Examples:

"Based on your observations of the setting sun during the last two weeks, where do you predict it will set one week from now?"

"Using shadows on the moon's surface as a guide, which lunar features do you find to be the tallest?"

"If the astronaut is ten light-minutes away from earth, how long will it take to receive a reply to our message?"

Such questions are useful if you want the visitor to compare, contrast, associate, or state relationships.

To respond to synthesizing questions, the visitor must know certain facts, be able to associate and put them together, and describe the relationships in his or her own words.

Synthesizing questions can be used to help visitors pick out similarities and differences, classify, use previously learned information in a new way, or develop in his or her own terms an idea that you have suggested.

Broad Questions

A broad question has a wide range of acceptable responses; when you ask a broad question, you are hoping for unplanned, divergent outcomes. There are two types of broad questions: open-ended and feeling questions.

a. *Open-Ended Questions*

These questions allow the visitor to explore freely in his or her own terms, without restrictions and with only minimal guidance by you.

Examples:

"Why do you think ancient civilizations created their own systems of constellations?"

"What topics would you like me to cover in our next planetarium show?"

"What is your conclusion about UFO's after hearing these reports?"

Responses to open-ended questions are rarely predictable, and the methods visitors use to find answers are selected by the visitors themselves.

As part of a strategy, open-ended questions can broaden the field of study and suggest new approaches. Open-ended questions allow you to develop an investigation through questions that don't limit the possible solutions.

b. *Feeling Questions*

Feeling questions ask the visitor to express an emotional attitude rather than make a purely objective response.

Examples:

"How did you feel when you first looked at the rings of Saturn through a telescope?"

"How do you feel about the amount of money being spent on space exploration?"

"Would you like to be an astronomer when you grow up?"

Such questions are useful if you want the visitor to formulate an opinion, share feelings, or become aware of the feelings of others.

To respond to feeling questions, the visitor must believe that he or she is in a trusting situation--one in which responses will be accepted and not criticized.

Other Types of Questions

There are at least two other kinds of questions commonly used in the planetarium: rhetorical questions and managerial questions.

a. *Rhetorical Questions*

These questions are used to reinforce a point or to provide emphasis.

Examples:

"Earlier, I told you that a light-year is a measure of distance and not time, right?"

"That is true for most of us, isn't it?"

"Planets certainly aren't as hot as stars, are they?"

When such questions are asked, responses are not really expected although responses are sometimes given.

Other questions can function rhetorically when you supply the answer or when the question is not followed by enough time for visitors to respond.

b. *Managerial Questions*

Managerial questions are used to keep things moving smoothly.

Examples:

"Can everyone hear?"

"Will you please raise your hand if you wish to speak?"

"Who needs more time to find their constellation?"

B. Practice in Classifying Questions

A method that you might find helpful when trying to identify and classify questions is to decide first whether the question is narrow, broad, or other. If it is narrow, decide whether it is direct-information or synthesizing. If it is broad, decide whether it is open-ended or feeling. If it is other, decide whether it is rhetorical or managerial.

When deciding between direct-information or synthesizing questions, you might find it helpful to analyze what type of thinking the question requires: 1) recall and recognition of information (direct-information); or 2) analysis of clues and/or induction to arrive at a particular answer or idea (synthesizing). If the question is broad, you might ask yourself if the question requires: 1) free and undirected investigation (open-ended); or 2) personal opinions and emotional responses (feeling).

During the workshop, differences of opinion will often occur about how a given question should be classified. This is because it is sometimes difficult to know what the questioner's intent was. However, discussing these differences of opinion can be very useful both to familiarize yourself with the various categories, and to recognize the ways your planetarium visitors can misunderstand what is expected of them.

Please classify the ten numbered questions on this transcript. Record your decisions by checking the appropriate boxes on the following page. The first two are already marked on the chart as examples.

I: "Good evening. As our planetarium sky darkens, can anyone recognize the Big Dipper?" (1)

V: "Oh, I see it." "Yeah, I see it too."

I: "Okay, will you please take this light pointer and show the rest of us where the Big Dipper is?" (2)

I: "Thank you. Well, that's the Big Dipper. Just about all of the stars that we can see in the sky belong to groups like the Big Dipper; and people have been naming the constellations for just about as long as there have been people. Why do you think people do that?" (3)

V: "Worship."

I: "Okay, worship; that's a good possibility. What's another?" (4)

V: "To go places."

I: "How would knowing the constellations help you to go places?" (5)

V: "You'd like to know which way to go from the stars. Directions."

I: "Yes, knowing the constellations does help you find your way. Does anyone know how to use the Big Dipper to find which way is north?" (6)

V: "I do, I think."

I: "Okay, will you show us please?" (7)

V: "It's this bright one at the end of the handle of the big dipper, the North Star."

I: "You've got the right idea, but the wrong star. These two stars at the end of the bowl point to the North Star, right here. Then, once you've found the North Star, look down at the horizon just below it. That direction is north. Okay?" (8)

I: "We've discussed at least two reasons that ancient people might have named the constellations: for worship, or religious reasons, and to find directions. How do you feel when you locate something you're familiar with, like the Big Dipper in the sky?" (9)

V: "Like I just saw a friend." "Good."

I: "I'll tell you what. I will give each of you a star map and let you find the constellations right here in the planetarium. Is there anyone who has not yet received a star map?" (10)

	TYPES OF QUESTIONS					
	Narrow		Broad		Other	
	Direct Info	Synthesizing	Open-ended	Feeling	Rhetorical	Managerial
1	✓					
2						✓
3						
4						
5						
6						
7						
8						
9						
10						

Assuming this section of a planetarium program was typical of the entire program, please analyse the instructor's questioning strategy:

1. Is the range of question types and the kinds of thinking they stimulated satisfactory? How would you change the mix? ____________________

2. What specific parts of this series of questions could be improved? ____________________

3. What other general comments or suggestions for improvement can be offered to the instructor in this case? ____________________

C. Sequencing Questions

Questions you ask your visitors may be placed in different sequences to achieve different objectives. There are many possible questioning strategies, but you will probably find it helpful to identify just a few that work well for you. Here are two examples:

One strategy begins with narrow questions to give the visitors an opportunity to show what they already know, or to make some very simple observations. Then, after some of the facts have been established, you can ask synthesizing questions to lead the visitors to make comparisons and notice relationships. Once they understand the basic ideas through these narrow questions, the visitors can be led to think more creatively about the topic through open-ended and feeling questions. This strategy is illustrated by the following sequence of questions asked by a planetarium instructor during an activity in which the visitors observe light sources through hand-held diffraction gratings passed out during the program:

	Direct Info	Synthesizing	Open-ended	Feeling
1. What was the main color that you observed in the hydrogen gas? What colors do you recall from the helium gas tube?				
2. How do the colors of helium differ from those of hydrogen?				
3. What colors do you see in this artificial star?				
4. From your own observations, what kind of gas do you think this star is made of? How did you determine that?				
5. How might this technique of studying stars help astronomers learn more about the universe?				

Classify each of the above questions by checking the appropriate column. Then, draw a line between the checkmarks. This line is a visual representation of one questioning strategy. Do the same for the other sets of questions on the next two pages.

A different strategy can involve the visitors in open-ended thinking from the outset. These broad questions can be followed by synthesizing and direct information questions to examine the implications and details of the topic. This strategy is illustrated by the following sequence of questions asked after a planetarium dramatization of several classical UFO sightings:

	Direct Info	Synthesizing	Open-ended	Feeling
1. Do you feel that most people who report UFO's are being honest and report exactly what they see?				
2. What are some different explanations you can think of to explain these unusual sightings?				
3. What further information would you need to decide if a weather balloon or plane is involved?				
4. If you observe a UFO, what information will you write down?				

Now develop your own questioning strategies for the two problems that follow.

Problem #1: Suppose you have just presented a public program summarizing the US space program. List a sequence of questions that would lead the visitors to consider the potential uses of a permanent space colony.

	Direct Info	Synthesizing	Open-ended	Feeling
1.				
2.				
3.				
4.				
5.				

Problem #2: Suppose you have just presented a planetarium program in which you illustrate many of the characteristics of the planets. List a sequence of questions that will allow the visitors to discover for themselves why some planets have craters and others do not.

	Direct Info	Synthesizing	Open-ended	Feeling
1.				
2.				
3.				
4.				
5.				

D. Recording and Improving your Questioning Strategies

The methods described in the preceding pages of this module can be directly applied to planning planetarium programs. However, even the best-planned programs take unexpected turns. To improve your questioning strategies for such real-time situations, it can be very valuable to audiotape one or two of your planetarium programs and then analyze your "live" verbal interactions with the audience.

When you analyze your own audiotape, it will not be necessary to make a complete written transcript. It will be useful, however, to write out and number each question. Then you can use the form below to record the kinds and sequences of questions that you used during the program. Comparing the question patterns with your objectives for each part of the program will help you decide if you should change your questioning strategies.

	TYPES OF QUESTIONS					
	Narrow		Broad		Other	
	Direct Info	Synthesizing	Open-ended	Feeling	Rhetorical	Managerial
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

E. Responding Strategies

Using Wait-Time

Most instructors wait only one or two seconds after asking a question in a class before they either: 1) call on another person; 2) ask another question; or 3) give the answer to the question themselves. Perhaps many feel that unless someone is talking, no one is learning.

Research indicates that if you wait a bit longer after a question is asked, there are observable differences in the behavior of the people being asked the question. For example, if you wait only a short time--one or two seconds--then one-word visitor responses result. These quick responses are often guesses, and are seldom complete sentences or contain complete thoughts. If, however, you wait for a longer period--four to six seconds--visitors tend to respond in whole sentences and with complete thoughts. There is increased speculation in the visitors' thinking, and they tend to justify answers more fully.

Sometimes a four to six second waiting period seems like an eternity, but wait-time research suggests great value in adjusting to this pattern. For more information about this research, see references to Moriber, 1971, and Rowe, 1969, in the annotated bibliography (page 111).

Responding to Visitors' Answers and Comments

No matter how carefully a sequence of questions or activities is planned and executed, no significant thinking will occur if the visitors are worried about feeling "wrong" or "stupid" in front of others. How you react and respond to their ideas early in the planetarium program is crucial to the degree of participation you can expect during the remainder of the program.

Your response to a visitor's comment should be in harmony with the question or task that preceded the comment. For example, if you ask a narrow question (direct information or synthesizing) a positive or negative comment on the visitor's answer is expected and appropriate. However, if you ask a broad question (open-ended or feeling), neither praise nor criticism is appropriate and tends to inhibit further participation. A more appropriate response to an answer to a broad or feeling question would be an accepting response. Three kinds of accepting responses are described in the following paragraphs:

Passive acceptance is a response which lets the visitor know that he or she has been heard, but without giving a value judgment about the quality of the statement. Examples of passive acceptance are:

"Um-hmmm." "Okay." "That's a possibility."

Active acceptance involves rephrasing, translating, or summarizing what a visitor or several visitors have said or done. This kind of response demonstrates not only that you have heard the visitor's message, but also that you have understood it. This type of response is non-judgmental and encourages further participation. Examples of active acceptance are:

"What I hear you saying is that water on Mars could have soaked into the ground, so there may be Martian life underground."

"These four people seem to feel that the reddish star moved, but at least one person disagrees. Perhaps everyone should watch this one star next time to try and decide whether or not it moved."

Empathic acceptance involves feelings as well as ideas. By giving an empathic response, you indicate that you have heard and appreciate the visitors' feelings, emotions, or behaviors. Examples are:

"I understand why you are upset with money wasted on poorly-planned government programs, including some space research."

"Don't feel embarrassed about having difficulty understanding Einstein's theory of relativity. In many ways it is contrary to common sense."

Replying to Visitors' Questions

Often slides, activities, or discussions provoke questions from the visitors during the planetarium program. Whether or not the questions are pertinent to your next point, they usually are related to the topic--at least in the visitor's mind. It is important, therefore, to satisfy the visitor's need for information, while maintaining the general flow of the planetarium program. This is hardly an easy task, but the following suggestions may help:

1) Sometimes a short, factual answer is all that a visitor really wants. For example, in response to the question "How far away is the moon?", you might resist the temptation to define mean distance and instead reply: "about a quarter of a million miles away."

2) You can sometimes invite audience participation by admitting you can't answer a visitor's question. For example: "I don't know what Native Americans called the Big Dipper. Does anyone else know?"

3) When the visitor really has the means of answering his or her own question, you might use the opportunity for further instruction. For example: "You can answer that yourself by looking at your star map. Which part of the horizon is Leo closest to? Okay, then that's the direction you must look tonight to find Leo the Lion."

F. Using Responding Strategies

Listen to an audiotape of a planetarium show that you presented. (You can use the same tape that you made to study your questioning strategies.) This time, attend to the responses that you made to the visitors' comments, ideas, and questions. Classify each response by checking the relevant box below.

Responsive Behaviors		Tallies
wait time	adequate	
	should be longer	
response to visitors' answers and comments	praise	
	criticism	
	passive acceptance	
	active acceptance	
	empathic acceptance	
replies to visitors' questions	supplied answer	
	"don't know"	
	suggested strategy	

1. Are most responses in harmony with the types of questions asked? ____________

2. Which kinds of responses were used most frequently? ____________

3. How did visitors react to different kinds of responses? ____________

____

____

4. Are there specific situations in which a different response might have encouraged more participation? ____________

____

____

WIZARD OF ID —By Parker and Hart

Module 6

ACTIVITIES FOR THE PLANETARIUM

This module will enable you to select, adapt, and invent activities that visitors can perform during the planetarium program.

Hearing about science, seeing it illustrated, and talking about it are fine--but few experiences of hearing, seeing, or talking can equal the excitement of actually *doing* science.

The core of a "participatory oriented planetarium" (P.O.P.*) program is an activity that involves the visitors in the process of science. By discovering something about the universe through their own actions, the planetarium visitors come closer to the real experience of science.

Activities provide several opportunities for learning that are not available in a program that is purely didactic. As an instructor, you can observe the difficulties your visitors encounter, giving you valuable feedback on how well you are communicating (see Module 1). The *visitors* have more opportunity to become directly involved with the *subject* and to interact with the *instructor* (as discussed in Module 2). Including activities in the program enables you to organize the planetarium experience in a variety of ways (as discussed in Module 3), and perhaps most importantly, concrete experiences are often essential for people of all ages to understand information in an unfamiliar area (as discussed in Module 4).

* The POP acronym was coined by several proponents of the technique during the August 1975 Planetarium Association of Canada meeting, in Toronto.

The original members of that POP group were Jeanne Bishop, Dale Etheridge, Samuel Farrell, Jane Geoghegan, Ron Hartman, Paul Knappenberger, Randy Mullin, Tom O'Brien, Ron Olowin, Dennis Schatz, Lee Simon, and Roger Woloshyn.

We will examine a range of activities, some suitable for general public shows, and others developed for students at specific grade levels. Activities can be used for single-visit programs as well as for multiple-unit classes.

Section A describes three typical activities that have been used successfully in single-visit programs for the public and for schools. Section B suggests how to use our categories of organization, reasoning ability, and question strategy to help you select activities appropriate to any audience. Finally, Section C provides details on 20 planetarium activities.

Planetarium visitors observing gas discharge tubes through diffraction gratings. After seeing the characteristic colors of hydrogen, helium, mercury vapor, and argon, the visitors can identify the composition of an unknown "star."

A. Inventing Activities

You can invent an activity by thinking about how the scientific information that you wish to present was discovered in the first place. Then, imagine how some aspects of that discovery could be shared by the visitors. For example, in planning a program about Mars, we began by thinking about how astronomers have made discoveries about Mars in the past. Eventually, we decided on three activities that would enable the visitors to rediscover information about Mars from the viewpoint of astronomers living at widely separated historical periods.

The Mars discovery activities form the core of the planetarium program, "The Red Planet Mars," included in Appendix D. Below, we have briefly summarized three activities from that program. After reading each example, think about how you might use a similar approach to communicate concepts that are of current interest to you.

Example #1
Find the Planet Activity

The instructor explains that the ancient Greek astronomers did not have telescopes, so to them stars and planets looked just the same. They observed, however, that a few "stars," including Mars, wandered among the other stars from night to night. They called these "wanderers," or in Greek, "planetes," which is the origin of our word "planet."

To discover the planet Mars in the planetarium sky, the visitors are asked to find a reddish or orangish star. After three Mars candidates are pointed out by the visitors using a portable light pointer, the instructor asks how we might tell which of these stars is a wanderer. "See what the sky looks like a few nights from now," "Compare with the stars around it," are suggestions from the audience.

Next, the instructor divides the audience into three groups, each assigned to observe one of the three candidate stars. After simulating several weeks of elapsed time (by turning daylight up and down several times and advancing Mars inconspicuously), the instructor asks each group to report on whether or not its star "wandered" among the background stars. During two or three such observation periods, the visitors have an opportunity to check each others' results, and eventually agree on which of the three candidate stars is really Mars.

In the above activity, the visitors are not told by an authority which of the brilliant red stars above them is Mars. They discover it through their own collective efforts. This kind of activity not only teaches specific facts (planets were defined and detected by motion against background stars), but may make a significant improvement in visitors' attitudes toward science in general. Here is a chance for people who may be shy or frustrated about science to experience success: They can *do* science!

What other naked-eye phenomena can visitors to your planetarium discover, with planning and guidance from you?

Example #2
Mapping Mars
Through A Telescope

After the telescope was invented, a great deal more information about Mars became available. To enable visitors to experience both the satisfaction and some of the difficulties encountered by Mars observers like Percival Lowell, visitors are asked to draw a map of Mars while looking at an image projected onto the dome. To simulate the effects of the Earth's atmosphere, the image of Mars first passes through a rotating plastic disc unevenly smeared with vaseline. One fairly clear spot on the disc provides one especially clear moment of "seeing" every minute.

When the visitors are finished drawing, they are invited to compare maps with their neighbors'.

Planetarium Activity: Mapping Mars Through A Telescope

Visitors find that some maps indicate straight lines and markings on the surface of Mars, while other visitors' maps show no such features. Discussions naturally develop about whether these features are "real" or due to observer error or the distortion caused by the Earth's atmosphere. The instructor facilitates discussion among the visitors to decide whether or not specific features really exist on the image of Mars they have been observing. An opaque projector is used to show several visitors' work during the discussion. The general idea of controversy in science can be examined.

What other observations can your visitors make through simulated or real instruments in your planetarium?

Example #3
Exobiology Activity

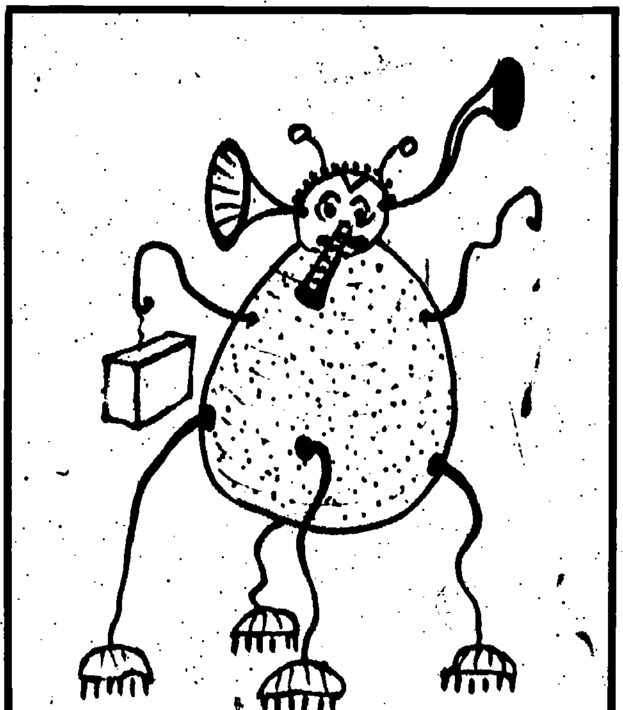
The Mapping Mars Activity in the previous example enables the visitors to *experience* the difficulties encountered by astronomers during the first half of the twentieth century. The Great Canal Debate which raged among the scientific community at that time was a direct result of the ambiguous data obtained by observing Mars through the earth's atmosphere. In the Exobiology activity, the visitors are invited to play the role of exobiologists who worked during this period, when the existence of Martian canals was a serious possiblity.

If there were canal diggers, then how did they survive under conditions which Earthlings would consider hostile? The visitors each sketch their ideas about possible creatures that were naturally adapted to survive in: 1) lower gravity; 2) thinner atmosphere; and 3) much colder weather than we experience on Earth. There is no single "right answer" to this activity, since many different ideas are acceptable. This activity demonstrates the potential for creative play in science, guided by the rational evidence, but open to imaginative invention.

What other designs, models, or inventions can visitors create that are relevant to astronomy or space travel?

Here are some beings from the planet Earth.

Invent a being from a Mars-like planet which has: 1) weaker gravity, 2) thinner atmosphere, and 3) colder weather than Earth.



The left-hand picture is provided to visitors for the exobiology activity. The box at right was completed by one of the visitors.

B. Classifying Activities

In addition to inventing new activities for a particular program you wish to produce, it is often possible to select or adapt activities that have been developed by others. Collections of ideas for planetarium activities may be found in *Under Roof, Dome, and Sky*, issues of the *Planetarium Directors' Handbook*, the *Planetarian*, and a variety of other sources (see Appendix C, Bibliography, sections 1,3,4, and 5 for detailed references). Twenty additional ideas may be found in the next section of this module.

After selecting or inventing a small group of activities that might be incorporated into a particular program, we have found it useful to begin program planning by categorizing each activity according to the ideas presented in the previous three modules: organization scheme; reasoning ability level; and questioning strategy.

The different classifications are useful in determining the suitability of an activity for a particular audience and purpose, and to maintain variety. The categories are not ironclad, especially for activities that have several parts and can be presented in many ways.

1) *Patterns of Organization* as described in Module 3 help you to visualize the ways that the visitors and instructor interact during the activity. Thinking about the possible choices of patterns (i.e. didactic vs. socratic, small group vs. individual task, group meeting vs. informal discussion) may also suggest ways of modifying the activity and may help you work the activity into your overall program.

Most activities are task-oriented (either individual or small group), but can also be classified as didactic ("Watch what I project on the dome right here") or socratic (instructor leads individual visitors step-by-step through an activity).

To practice classifying activities, list the *dominant* pattern of organization for the three Mars activities described in the previous section.

Activity	**Pattern of Organization** *(didactic, small group or individual task, informal discussion, group meeting, or socratic)*
Find the Planet	
Mapping Mars	
Exobiology	

2) *Reasoning Levels*, described in Module 4, help you to consider the level of reasoning ability (egocentric, concrete, or formal) that the visitors must use in order to perform the activity. Thinking about how to classify it may also suggest ways to modify the activity to make it understandable to a broader range of visitors.

How would you classify the three Mars activities according to the minimum intellectual level required to perform them as intended?

Activity	Reasoning Level *(egocentric, concrete, or formal level)*
Find the Planet	
Mapping Mars	
Exobiology	

3) *Activity Strategies* form a third dimension for classification. Since each activity poses a question for the visitors to answer, we can classify each activity by using the same categories developed for "questioning strategies" in Module 5 (direct information, synthesizing, open-ended, and feeling).

Decide what *Activity Strategy* dominates each of the three Mars activities by thinking about the kind of response expected of the visitors. In a direct information activity you expect them to report a fact they immediately observe or recall. A synthesizing activity requires a result obtained by follow-

Activity	Activity Strategy *(direct information, synthesizing, open-ended, or feeling)*
Find the Planet	
Mapping Mars	
Exobiology	

ing a prescribed strategy. Open-ended activities have many acceptable procedures and/or results, while feeling activities allow for the visitors to express emotions.

Now compare the way you have classified the three Mars activities with the way other people in the workshop classified them. The comparisons probably illustrate that some latitude in interpreting categories is unavoidable. Slight differences in interpreting of category definitions, or in the particular objective you stress for each activity, can result in different choices. We hope you agree, however, that the general outline is helpful. A program that is mostly individual task, formal, and synthesizing, for example, would be useful for quite a different purpose from one that is mostly small group task, concrete, and open-ended.

C. A Collection of Activities for Planetarium Programs

On the following pages are twenty ideas for activities that can be performed in the planetarium. They were contributed by the participants in the first five trial workshops that were held during the summer of 1978. These activities can be adapted and combined to produce a variety of planetarium programs, or they may serve as a springboard for entirely new ideas.

To make it easier to use this collection of activities, we begin this section with a two page index. To locate ideas that relate to a particular subject, refer to the major topic categories.

Part I activities present a number of phenomena like the planets, meteors, comets, and variable stars, which the visitors study by plotting their observations on maps and charts. Part II concerns distance measurements to the stars. The activities in Part III relate to scientific communication. Part IV includes activities with phenomena related to the daily rotation of the earth, and Part V includes activities related to phenomena that require a year or longer to observe, like the seasons and precession.

The index provides further information about each activity in the three columns following the activity names. The first column lists the Pattern of Organization, the second lists the Reasoning Level required of the visitors, and the third lists the dominant Activity Strategy. As illustrated in Section B, an individual activity may be categorized in more than one way, depending on how you present it to the visitors, or the kind of responses you are willing to accept.

Title	Organization Pattern	Reasoning Level	Activity Strategy
Part I PLOTTING CELESTIAL OBJECTS AND EVENTS			
#1 Invent a Star Identification System	small group task	concrete	synthesizing
#2 Using Your Fist as a Measuring Tool	individual task	concrete	synthesizing
#3 Plotting the Paths of Meteors	individual task	concrete	synthesizing
#4 Retrograde Motion of Mars	individual task	concrete	synthesizing
#5 Plotting the Path of a Comet	individual task	formal	synthesizing
#6 Observing a Variable Star	individual task	concrete to formal	synthesizing
Part II DISTANCE TO THE STARS			
#7 How Far Away is that Star?	individual task	formal	synthesizing
#8 Using a Blink Comparator	individual task	concrete	direct info
Part III SCIENTIFIC COMMUNICATION			
#9 Mythology: Explaining the Unexplainable	socratic and group meeting	concrete	synthesizing and feeling
#10 Design a Message for CETI	individual task	concrete	open-ended

Part IV DAILY MOTION			
Title	*Organization Pattern*	*Reasoning Level*	*Activity Strategy*
#11 How Does the Sun Appear to Move?	individual task	concrete	direct info
#12 How Do the Stars Appear to Move?	individual task	concrete	direct info
#13 How Can You Tell Time by the Stars?	individual task	formal	direct info
#14 How Can You Tell Your Latitude by the Stars?	individual task	formal	synthesizing
Part V YEARLY MOTION			
#15 Long Days, Short Days	individual task	egocentric	direct info
#16 Where Will the Sun Rise and Set in Different Seasons?	individual task	concrete	direct info
#17 How Does the Sun's Path Change With the Seasons?	individual task	formal	synthesizing
#18 Different Seasons, Different Stars	individual task, and socratic	formal	direct info
#19 Find Your Zodiacal Constellation	small group task	concrete	direct info
#20 Precession of the Earth's Axis	individual task	formal	synthesizing

Activity #1 INVENT A STAR IDENTIFICATION SYSTEM

recorded by Lee Ann Hennig

Objectives: The visitors will invent a system which can be used by anyone to identify stars in a given constellation.

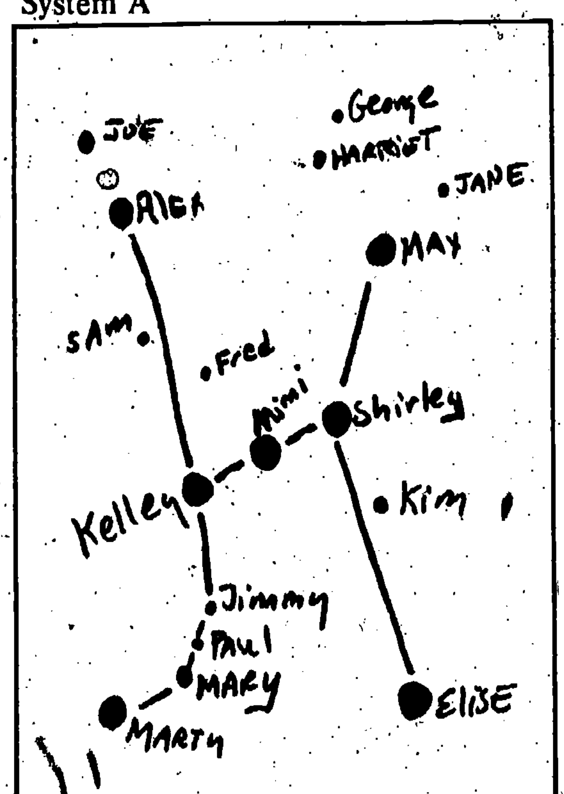
Materials: clipboard, pencil, and blank sheets of paper for each team. Reading lights.

Procedure: The instructor divides the visitors into an even number of teams, and assigns a constellation to each team by circling constellations with a light pointer in the planetarium sky. Each team is asked to invent a system for identifying individual stars in the constellation, so that anyone else can use the system to locate a particular star from a verbal designation. Reading lights are turned on so the visitors can write while viewing their constellations.

After each group decides on a system, they are asked to record it on paper and exchange with another team that has finished. To test the effectiveness of their system, each team is asked to specify one particular star according to the method they devised. The other team has to figure out the system, identify the correct star, and point it out with a light pointer to show they understand how the system works.

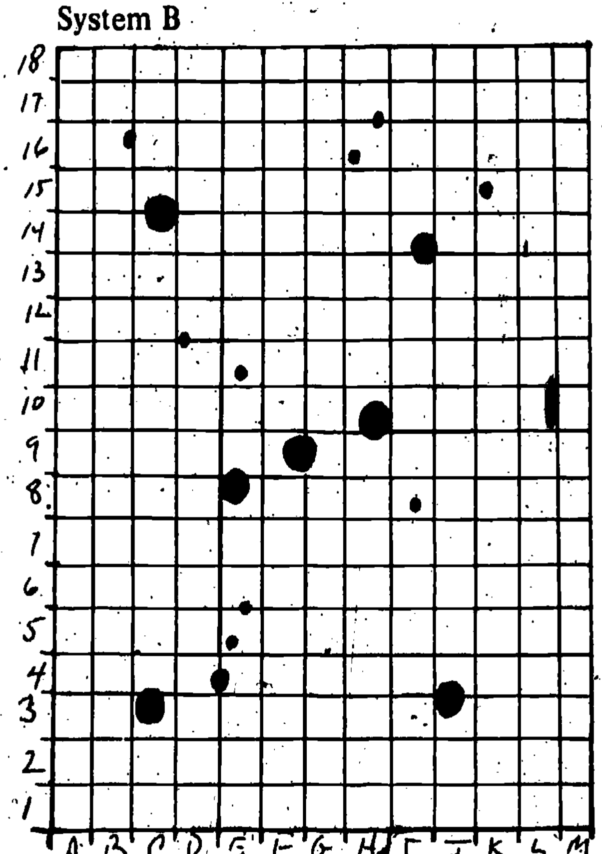
At the end of this phase, the instructor asks the visitors to be seated, and asks each team to describe the system they invented. Visitors from the team that used each system can comment on how well it worked and can suggest improvements. This discussion can lead to the various uses for such systems, and then to the "standard" star identification systems that astronomers have agreed to use (right ascension and declination, magnitude and color systems, galactic coordinates, etc.)

System A



Problem: "Find Mimi."

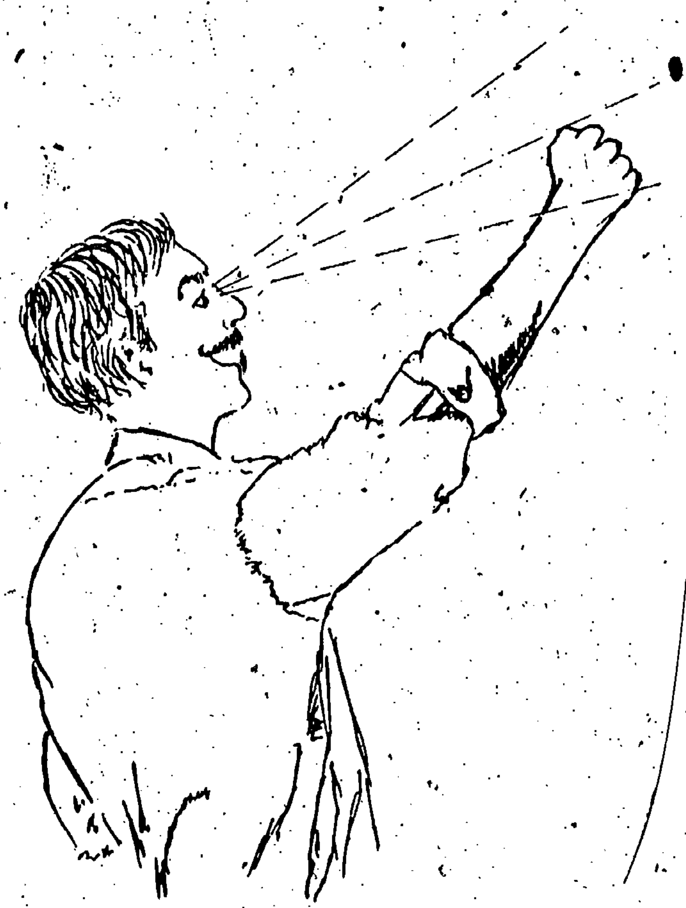
System B



Problem: "Find Star 11 E."

Activity #2 USING YOUR FIST AS A MEASURING TOOL

recorded and illustrated by Bill Lowry



Objectives: The primary objective is for the visitors to be able to use their own fists to measure the angular separation of two points in the sky. Other objectives include: learning the notion of measurement by comparison with a standard; the concepts of "angle" and "degree"; and the inverse relationship between the angular size of a given object and its distance from the observer.

Materials: Planetarium projector set with stars on, moon high in the sky, and light pointer ready.

Procedure: The visitors are introduced to the need for angular measurements by a series of questions: "The planetarium dome is close enough to touch. What about the outside sky? Suppose I wanted to point to a particular star. In the planetarium I can use my flashlight pointer, like this; but will this pointer work outside? Why not? Well, suppose I tell you the star is to the east of the moon. Does that help?" When the visitors realize that they need a way to measure a certain distance to the east, the instructor explains how to use fists for this purpose; "Reach out with one hand and point to the moon. Now ball up your hand to make a fist, like this. Close one eye, and line up the bottom of your fist with the eastern side of the moon. Just to the left of your thumb is the star I want you to look at."

Next, the instructor presents a problem which requires the visitors to "stack" one fist on top of another to complete the measurement. For example, the visitors could now measure the altitude of the moon above the horizon in "fists." Remember that the distance to the target from the observer will affect the measurement in the planetarium, so it is important that the moon is at the zenith to minimize the differences in the visitors' measurements.

A third activity involving measurements in "fists" begins by dividing the visitors into several teams to measure the distance between two stars in the planetarium sky. Members of each team take turns standing on the same x-spot, and each team averages its results. If the two stars are near the horizon, and each team is successively further away, the visitors can compare the results of each team and discover for themselves the dependence of this measurement on distance in the planetarium.

It is instructive to follow up an activity like this by having visitors go outside and find that real celestial objects are so far away that measurements in fists (like the height of the sun above the horizon) *do not* depend noticeably on where the observer stands. With this understanding of how fists can function as measurement tools, visitors can measure a large variety of positions and events (see for example the *Elementary Science Study* unit, "Where is the Moon?", (referenced in Appendix C, Bibliography, Section 3.)

Activity #3 PLOTTING THE PATHS OF METEORS

recorded by Dean Zollman and Ken Wilson

Objectives: The visitors will observe meteors in the planetarium sky and plot meteor paths on a sky map. From the paths they record, the visitors will be able to distinguish two kinds of meteor patterns--those which appear to radiate from a single point in space (called a "meteor shower"), and those which appear to be random. Some visitors will be able to explain what causes these patterns.

Materials: 1) For each participant: one all-sky map for current season, clipboard, straightedge, and two differently colored pencils (any two colors will do as long as they can be seen and distinguished in the reading light); 2) reading lights so the visitors can observe meteors and see their sky maps simultaneously; 3) a commercial or home-made meteor shower projector; 4) a light pointer; and 5) [optional] an opaque projector for comparing visitors' data.

Procedure: This activity begins with instruction and practice in using the sky map (see procedure for "Constellations Tonight," in Appendix D). During this portion of the activity, the visitors identify a bright star that will later be used as the radiant of the meteor shower.

As the constellation finding part of the activity winds to a close, the instructor uses his or her pointer to make a bright streak across the sky: "What was that? A falling star? Stars don't really fall. Today, let's use the scientific name for falling star--a meteor. Meteors are bits of rock and metal that are floating around in space, and fall to earth from time to time, burning up in our atmosphere as they fall."

Then, the instructor asks the visitors to watch the sky very closely, and to record the location and direction of any meteors they see by drawing a long arrow on their sky maps to represent the path of the meteor. The instructor uses his or her light pointer to create three or four random meteors. "To find out what part of the sky the meteors are coming from, use your straightedge to extend the arrow backward on your map. Do these meteors seem to come from any special point, or from different places?"

Next, the instructor turns on daylight and explains that we will watch for meteors on a different day of the year, in hopes of seeing more of them. He again darkens the dome, and turns on the meteor shower projector. He allows time for ten or twelve meteors to be recorded by visitors, using another color pencil. "Now extend the arrows backwards with your straightedges. Do they seem to come from one point or from all over? Does anyone have any idea why we saw more meteors tonight, and why they seem to come from one point in space?"

To explain the radiant of meteor showers, an orrery or slides may be used to show a swarm of meteoroids orbiting the sun. When the earth passes through one of these "gravel pits in space" at the same time each year, we observe a meteor shower on earth. The meteors seem to come from one point in space for the same reason that parallel railroad tracks or telephone poles seem to meet at one point on the distant horizon. This is an illusion called "perspective." Random meteors do not belong to swarms, but float singly in space, and may appear to come from any direction.

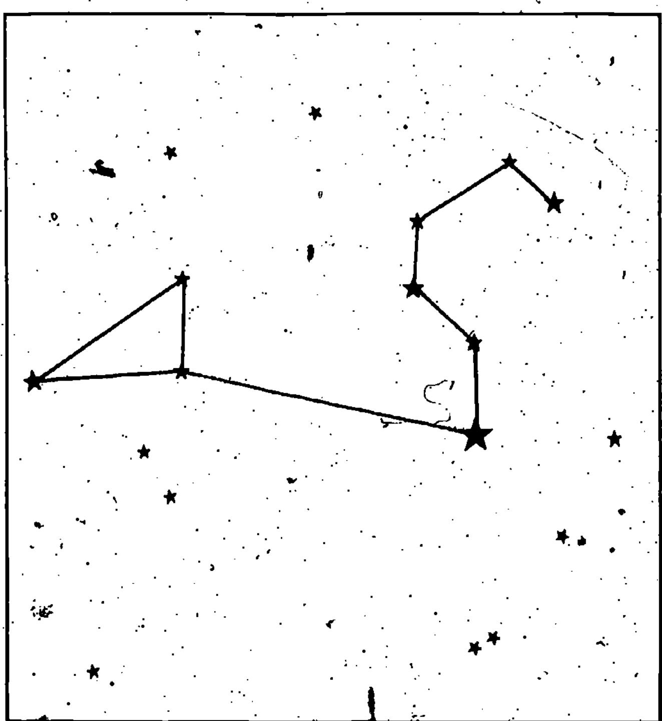
[Note: For visiting astronomers, distinguish between meteor, meteoroid, and meteorite.]

Activity #4 RETROGRADE MOTION OF MARS

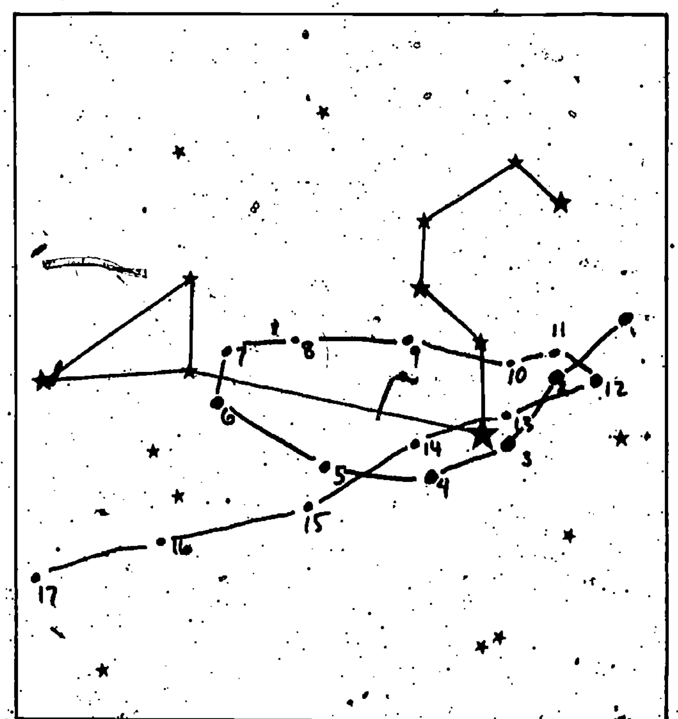
recorded by Garry Beckstrom

Objectives: The visitors will plot the successive positions of Mars over a two or three month period. From their data, the visitors will learn that the path of a planet sometimes appears to form a loop among the stars. Some visitors will be able to explain this apparent motion as due to the Earth passing Mars in its orbit.

Materials: 1) For each participant: a sky map of a small region of the sky, clipboard and pencil; 2) reading lights so visitors can see the stars and their maps at the same time; 3) a planetarium projector and a commercial or home-made Mars projector; and 4) [optional] an opaque projector for comparing visitors' data.



Visitor's data sheet for this activity is a sky map of the constellation Leo.



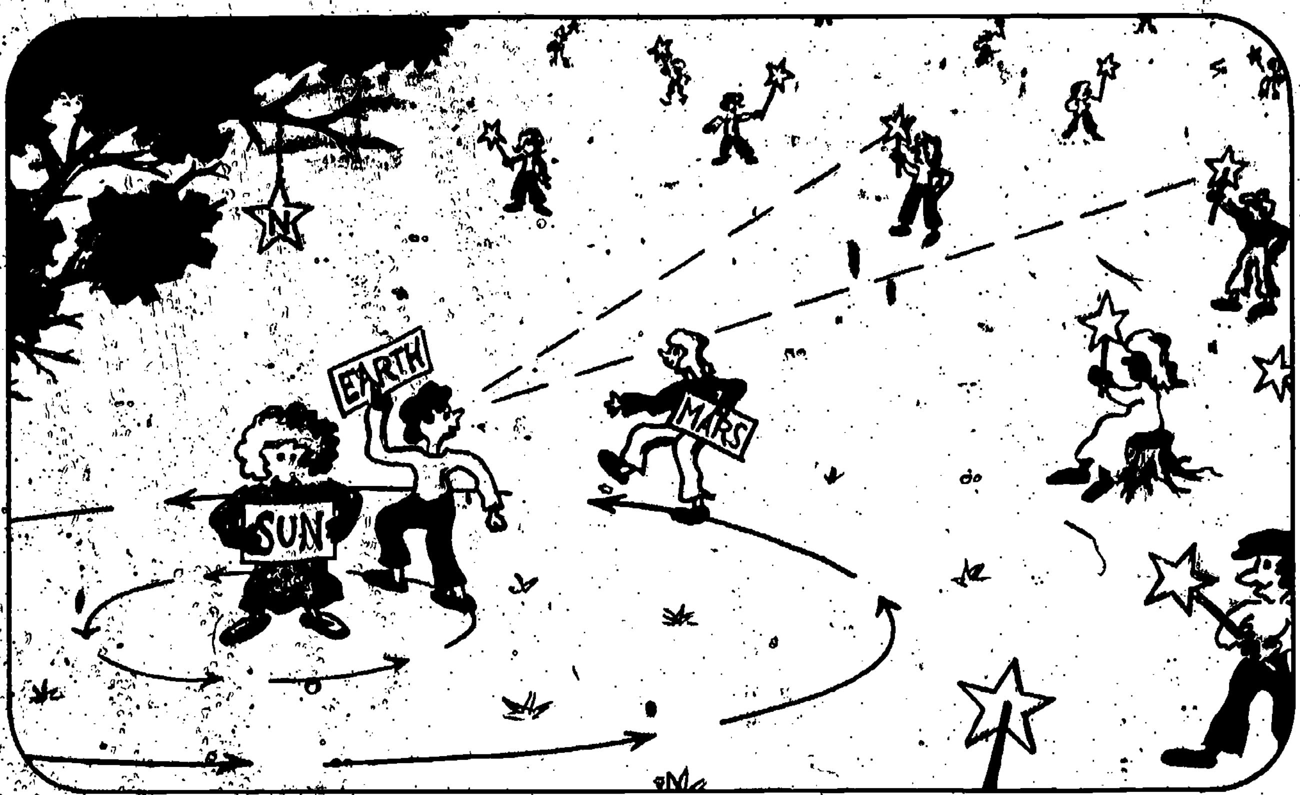
One visitor's record of Mars' path over a 17 week period.

Procedure: As described in "Constellations Tonight" (in Appendix D), the visitors begin with instruction and practice in how to use the star maps, with the Mars projector off. Then, the instructor turns up the daylight and explains that "We will now go backwards in time to when Mars last appeared in the constellations on your maps. As I turn down the lights, see if you can find what appears to be a bright, reddish star, and mark its position on your map with a dot. Write the number '1' next to the dot."

After the instructor checks to be sure that everyone has correctly identified Mars, he turns up daylight and advances annual motion one week (or some other convenient interval). As the sky darkens, the visitors mark the new position of Mars on their maps with a dot, and write the next integer. The process is repeated until Mars completes its retrograde loop and begins to move out of the mapped region.

After visitors complete their plots, the instructor asks the visitors to connect the numbered dots with one line, showing the path of Mars, and to compare the paths with their neighbors'. Then, the instructor asks for volunteers to describe the path of Mars. Finally, the instructor asks the visitors if they can think of several different explanations for the looped path.

This activity can be followed with activities to show the geocentric (epicycle) explanation, and the modern heliocentric explanation (that retrograde loops occur when the Earth passes Mars). Having the visitors model the two systems with their own bodies and actually observe retrograde motion can be very effective. *Project Physics* film loops provide very clear explanations of retrograde motion in both the geocentric and heliocentric models. (see reference to Holton in Bibliography, pg. 108).



Activity #5 PLOTTING THE PATH OF A COMET

recorded by Edna DeVore

Objectives: The visitors will observe a comet in the planetarium sky and plot its path on a star map. From this experience they will learn that comets travel in curved paths around the sun, getting brighter as they approach it and dimmer as they move further away. The visitors will also note that the comet tail always points away from the sun.

Materials: 1) one sky map, clipboard and pencil for each visitor; 2) planetarium projector set just after sunset so visitors can see the stars and the glow from setting sun; 3) reading lights so visitors can observe the comet and see their sky maps at the same time; and 4) a commercial or home-made comet projector that can be adjusted in brightness and position.

Since an all-sky map for the particular season is distorted near the horizon, it may be best to prepare a special map showing only the portion of the sky where the comet is to be projected--covering about 90 degrees to 120 degrees in azimuth. Horizon references like trees or the cardinal points may also be included.

Procedure: Before the comet-hunt activity, the visitors must learn how to use the star maps by locating constellations in the planetarium sky. Especially for younger visitors, it may be helpful for them to draw constellation outlines on their star maps, so that the comet may be plotted against an easier frame of reference than the stars alone.

The instructor invites the visitors to join in a "comet-hunt" by watching for a fuzzy object in the sky. As the instructor gradually turns up the brightness of the comet projector, one or two visitors will spot the comet and point it out to the rest of the visitors. When all of the visitors have located the comet, they are asked to draw it on their maps, showing its general appearance and location.

Next, the instructor turns up daylight, and explains that we will hunt for the comet again a whole week later, also at sunset. While the lights are on, the instructor advances the comet and makes it a little brighter. As the daylight is dimmed, the visitors again spot the comet and draw it on their maps. This process is repeated several times.

As the instructor advances the comet, he or she directs it in a large circular arc around the sun. The instructor increases the brightness, revealing the comet's tail as it nears the sun, then dims it as the comet moves away from the sun. In addition, the comet projector is oriented so that the tail always points away from the sun.

When the visitors finish plotting the comet's path, the instructor winds up the activity with a series of questions: "How did the brightness of the comet appear to change? How can you describe its path through the sky? What did the tail look like? How did it change? Which way did the tail point?" Then, after discussing the observed facts, the instructor may provide answers for visitors' questions about the nature of comets, and the reasons why they move as they do, get brighter near the sun, and have tails that always point away from the sun.

Activity #6 OBSERVING A VARIABLE STAR

recorded by Cary Sneider and Alan Friedman

Materials: 1) A slide showing five numbers that can be projected over part of the constellation Leo to label the magnitudes of five stars [Figure A, projector 1]; 2) a projector to place a variable brightness dot of light in Leo with similar fuzz and color to the planetarium stars. Any single or multiple slide projector can be used as long as its brightness is variable. A piece of aluminum or plastic serves as a slide, and a hole is drilled in the slide to make a star of average diameter. [Figure A, projector 2]; 3) a brightness vs. time graph, clipboard, and pencil for each visitor [Figure B]; and 4) a set of slides that will help the visitors apply the binary star model to their observations [Figure C]. To buy materials, see page 96.

Objectives: The visitor will observe a variable star in the planetarium sky and learn how to: 1) measure its brightness by comparing it to standard stars nearby; 2) record its brightness for several nights on a brightness vs. time graph; 3) discuss star's "light curve" by comparing observations with other visitors; and 4) interpret the light curve by inventing different models of the star, and seeing how the models fit the data.

Procedure: The instructor points to a star in the constellation Leo and explains that "Two photographs of this star, taken on different nights, show that it seems to vary in brightness compared with the surrounding stars. It's our job, as variable star observers, to find out if the star is really changing in brightness, and if so, how it changes."

So that the visitors can measure the brightness of the star, the instructor projects numbers 1 through 5 next to certain stars in the constellation Leo. The numbers correspond to the approximate magnitudes of these stars. The visitors are invited to estimate the brightness of the suspected variable by deciding which numbered star is closest in brightness to the variable.

After the visitors understand how to measure the brightness of the star, and have made their first estimate, the instructor brings up daylight and hands out brightness vs. time graphs. The instructor demonstrates how to use the graph by projecting a slide which shows his first night's observation plotted on the graph.

While the visitors are graphing their first observation, the instructor resets the brightness of the variable star projector (Figure A), then dims the daylight for the second night's observing. The visitors estimate the brightness of the variable, and the instructor turns up daylight again so visitors can add another data point. This process continues until the 12th "day." By setting the dot projector in a pre-determined pattern, the instructor can simulate any desired light curve. The sequence of magnitudes--1,1,3,5,3,1,1,1,2,3,2,1--will result in the light curve pictured in Figure B.

When the visitors are finished, they draw a line through the plotted points and compare with their neighbors' results. The instructor helps the visitors describe the light curve by asking leading questions: "Are there any dips in brightness? How many of you find the first dip to be as low as star 2? 3? 4? 5? I notice that nearly all of you said

Figure A. Arrangement of materials for "Observing a Variable Star."

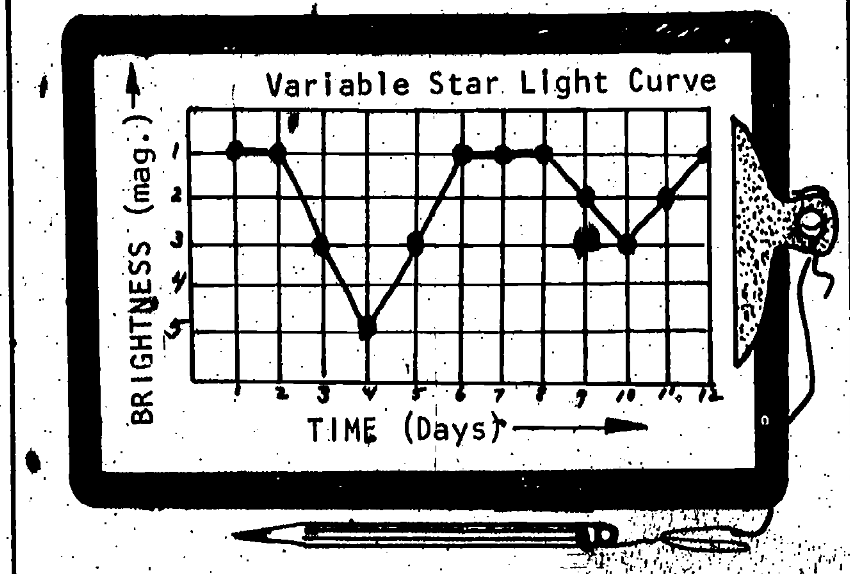


Figure B. Visitor's Data Sheet

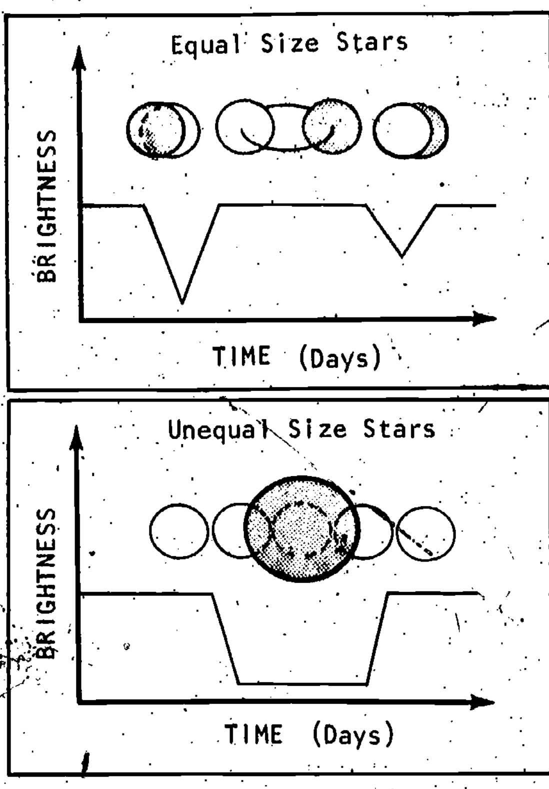


Figure C. Sample slides for interpreting "eclipsing binary" light curve.

4 or 5. What do you think we should agree on as the best estimate for the brightness of the first dip?"

After the visitors have discussed the shape of the light curve, they are invited to explain it. Often visitors mention clouds or pollution that might cause the changes in brightness. Some visitors suggest that the star itself might be changing, or that one or two large planets might be orbiting it, and blocking off some of the light now and then. For each suggestion, the instructor asks how the idea might be tested. Clouds or pollution, for example, might be expected to affect all of the stars in the region and be present only irregularly. A star's intrinsic brightness could vary regularly or irregularly, and the large planet model would predict a pattern of identical dips to repeat. If there is time, the visitors can continue observing for another twelve days and discover that the pattern of alternating deep and shallow dips is repeated, or the instructor can just say that the pattern has been studied by other astronomers who find it repeats over and over.

Frequently, the visitors propose the eclipsing binary star model--that two stars are circling each other. If the visitors do not generate this possibility, the instructor can suggest it and show drawings to illustrate what we could infer if we assume that the variable dot of light we see is really two stars very close together. The difference between depths of the two dips, for example, can be explained as due to the difference in brightness between the two stars. The sharpness of the dips can tell us about the relative sizes of the stars, and the time between the dips can tell us how long it takes for the stars to circle each other (see Figure C). The visitors can measure each of these quantities from their own data.

Comments: We have used this activity satisfactorily in a single-visit program, ("Black Holes and Other Strange Stars") for junior high to adult audiences, and with gifted youngsters in upper elementary school. The activity is particularly valuable because amateur astronomers contribute seriously to the progress of astronomy by keeping track of variable stars, through the American Association of Variable Star Observers.

The variable star light curve pattern in Figure C is actually quite unrealistic. Changes have been exaggerated to make measuring the curve easy for beginners. Typical light curves for eclipsing variables show changes of tenths or hundredths of magnitudes, not several magnitudes. Since the magnitude scale is also logarithmic, there are complications in finding individual magnitudes. A simple, totally eclipsing binary could not have the pattern shown--the second dip would be much shallower.

Activity #7 HOW FAR AWAY IS THAT STAR?

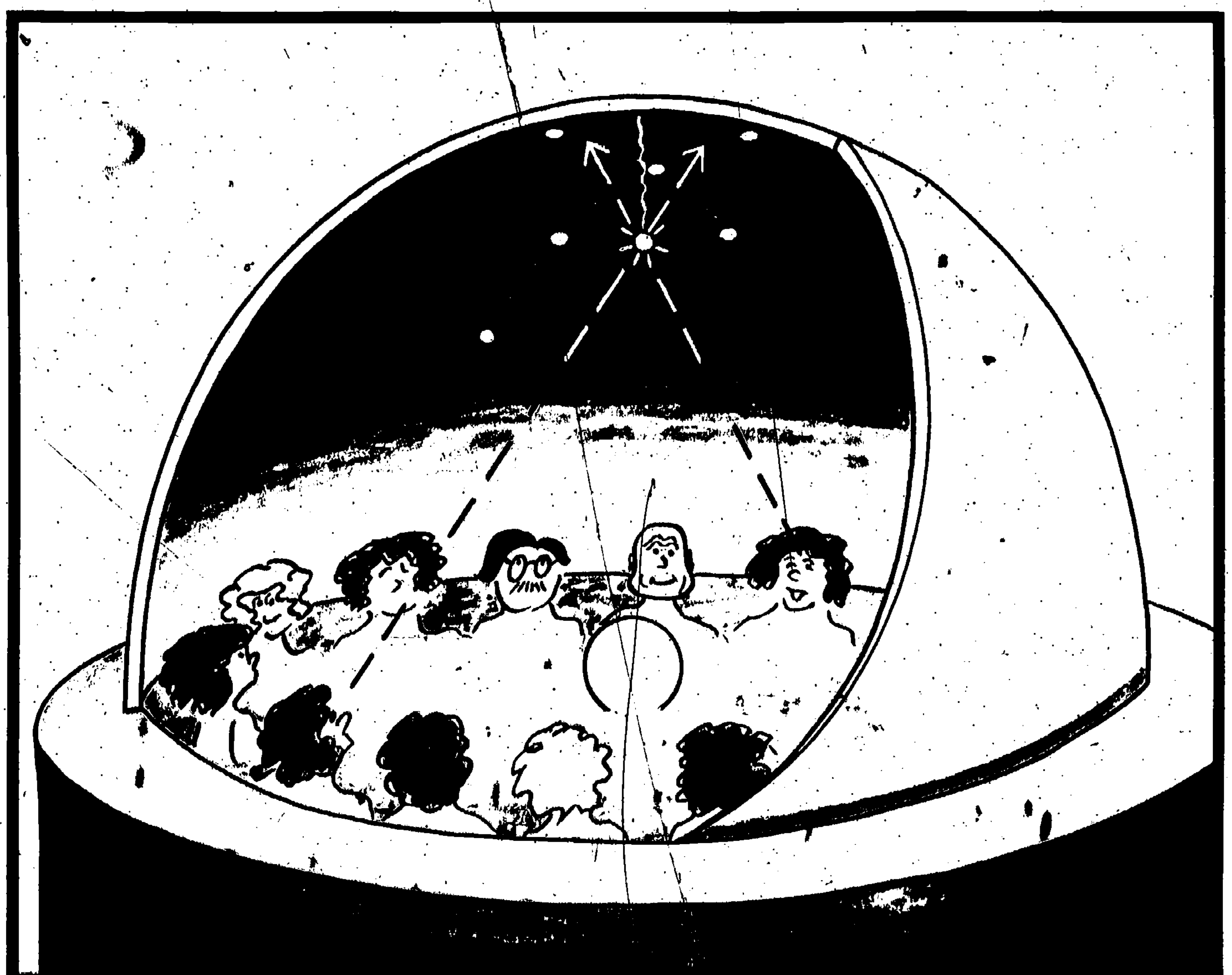
recorded by Mark Sonntag

Objectives: The visitors will learn how to measure the parallax angle of a nearby star, and how to use this angle to compute the star's distance from the sun.

Materials: 1) star map showing the region around the zenith, a clipboard, and pencil for each visitor; 2) reading lights; 3) a large data display board which is an enlarged version of the zenith star map superimposed over a grid of concentric circles; 4) two slides which show how the parallax angle relates to the data board and how to compute the distance to the star; 5) a "grain of wheat" bulb suspended on a wire about a foot below the zenith of the planetarium dome (the bulb's brightness is controlled by a rheostat on the instructor's console); and 6) a fairly dim, diffuse light bulb representing the sun, in the center of the planetarium.

Visitors should be able to move if necessary so that they are all roughly equidistant from the center of the planetarium.

Procedure: This activity begins by familiarizing the visitors with how to use star maps to locate constellations near the zenith. The instructor can introduce the main topic with a brief historical sketch of the celestial

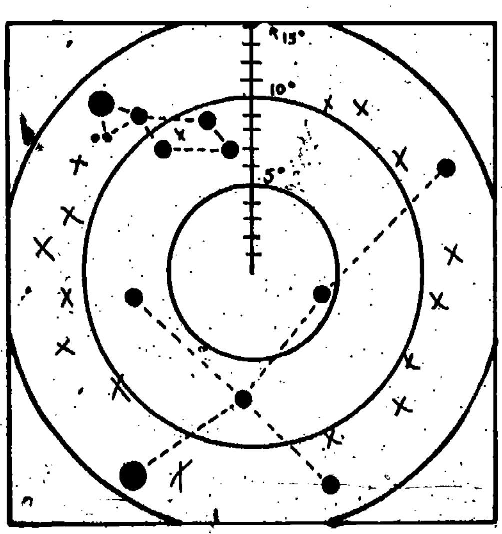


sphere concept: that all stars are at the same distance, attached to a huge sphere. The only way to test this idea was to see if at least one star could be found which was closer than the others.

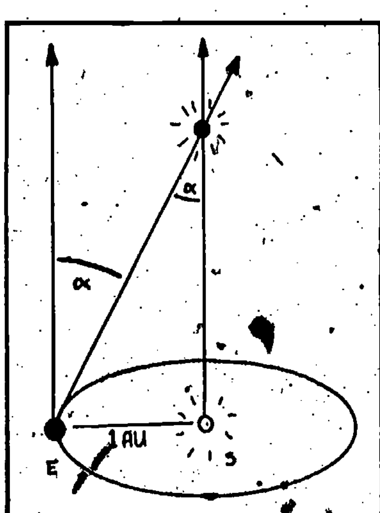
Before explaining how to measure a star's parallax to determine its distance, the instructor might ask an open-ended question about how we might measure the distance to a star. The activity begins as the instructor turns on the grain of wheat bulb and asks the visitors to observe it by moving their heads from side to side. The visitors may be invited to describe how the star seems to move back and forth among the other stars, indicating that this one star, at least, is closer than the others. The instructor explains that "Since the real stars are so far away, we have to move our heads several million miles in order to see even the closest stars appear to move back and forth. For that large motion, we take advantage of the earth's yearly orbit around the sun."

The instructor explains that "In order to find the distance to that star, we will pretend that the bulb in the center of the room is the sun, and each of you is an observer on the earth at a different point along the earth's orbit. The distance of each of you to the sun is 93 million miles. For simplicity, we'll call that distance one astronomical unit, or 1 AU, and use that as our celestial yardstick. To begin, please mark an "X" on your maps where that closer star appears against the background stars."

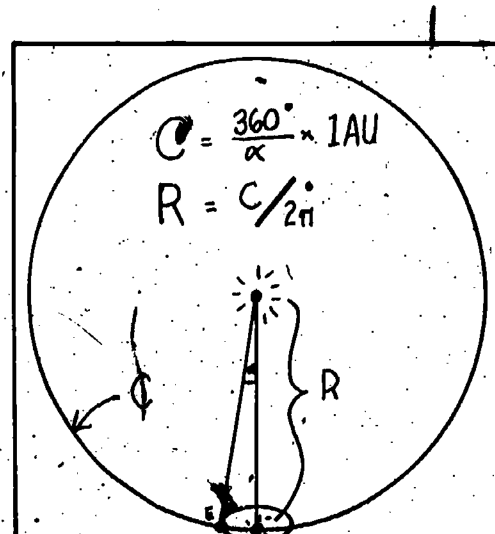
After visitors complete the task, they come up to the data board, two or three at a time, to place their "X"s on the board. These "X"s will form a rough circle, and the angular size of the circle can be measured by noting the closest concentric circle. The instructor displays the next slide which shows that the angle they measured is equal to the parallax angle of the star. Finally, the last slide asks the visitors to imagine a gigantic circle with the star in the center. The parallax angle is used to determine the circumference and that figure is used to find the radius, which equals the star's distance in AU's. (This method for computing the parallax is conceptually related to Eratosthenes' method for computing the radius of the earth. It is described in "Charting the Universe," The University of Illinois Astronomy Program, Harper & Row, New York, N.Y., 1969, pp. 30-33, 63-73.)



Group data board



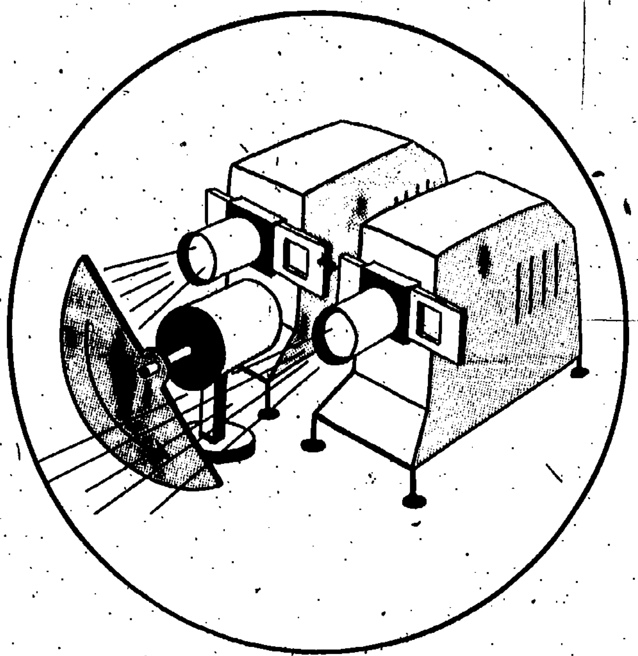
Parallax angle

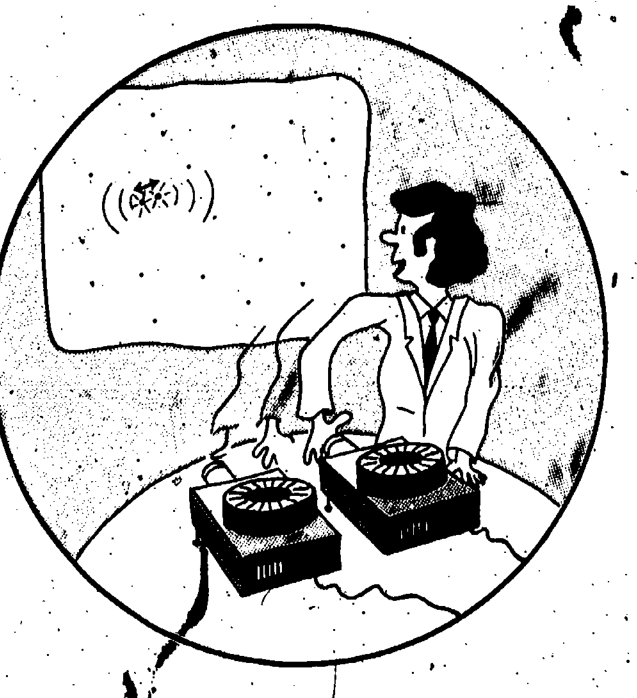


How to compute distance

Activity #8 USING A BLINK COMPARATOR

recorded by Kingsley Wightman





Objectives: The visitors learn how to use a blink comparator to detect the motion of an object among the many bright stars that are visible. Visitors will also learn that this method is actually used by astronomers to discover new objects, like asteroids, and to measure the distance to stars which are not too far away.

Materials: 1) two slide projectors; 2) two slides of the same star field taken an hour, week, or even a year apart which reveal the motion of an object (such as an asteroid or planet); and [optional] two slides which are taken six months apart that reveal the parallax of two stars of different distances. (Slides may be simulated views if necessary. The first two slides are placed in the projectors, and the projectors are adjusted so the star fields are superimposed); and 3) an occulting device placed between the two projectors so that the shutter interrupts the beams alternately, causing first one picture then the other to be projected in rapid succession. (This device is described in "Blink for a Nova" by Ben Mayer, *Astronomy*, pp. 34-37, May, 1978.) Although a motorized shutter is most convenient, the instructor can also use his or her hand as a shutter.

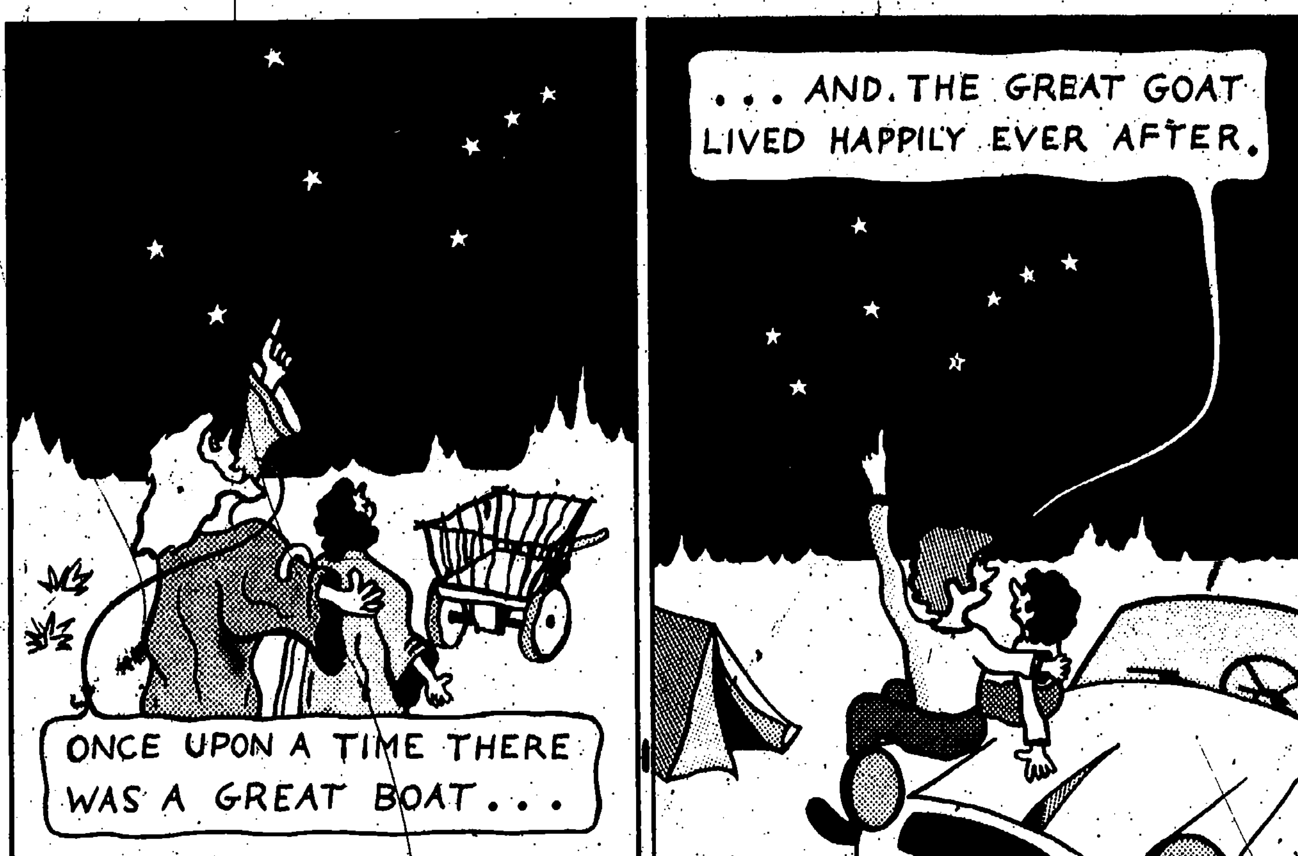
Procedure: The instructor begins by introducing the problem to discover new asteroids by observing their motions. The problem is that asteroids look exactly like stars! Then the instructor describes the "blink comparator" by pointing out the two slide projectors, and explaining that each projector shows a photo of the same part of the sky, but taken at different times.

The instructor then turns on both slide projectors, blocking one of them with his hand (or moving the motorized shutter by hand). He asks the visitors to watch carefully for changes as he covers the first slide projector and exposes the second. Usually, visitors will not be able to see any change at this point, so the instructor tries it again, switching a little faster. Finally, when the instructor is switching or "blinking" back and forth rapidly, the visitors will easily be able to detect movement of a single asteroid, even among a field of several hundred stars.

This instrument can also be used to detect the *apparent* motion of a star due to the earth's yearly orbit around the sun. (See Activity #7 for a quantitative approach.) To understand the principle of "parallax," each visitor is asked to hold his or her thumb at arm's length, and pretend that it is a star. By looking at it with one eye, and then the other, the visitors can see it appear to "jump" back and forth. This occurs because our eyes are separated by a couple of inches. We can effectively separate our eyes by a couple of hundred million miles by blinking once now, and again in six months when the earth is on the other side of the sun. This large separation makes our instrument sensitive enough to measure the distance to stars very far away. To demonstrate, the instructor places two new slides in the projectors, taken six months apart, which show two stars with noticeable parallax motion. The visitors must identify the star which is closer to us.

Activity #9 MYTHOLOGY: EXPLAINING THE UNEXPLAINABLE

recorded by Gerald Mallon



Objectives: The visitors will have an opportunity to help create a myth to explain rationally a situation, and then to see how the myth is distorted as it is passed on orally from generation to generation. After the program, the visitors will be able to define a "myth" in their own words and identify the problems of transmitting information without written records.

Materials: 1) writing paper, clipboard, and pencil for each visitor; 2) a light pointer or two; 3) slides depicting various cultural myths that were created to explain celestial phenomena.

Procedure: The visitors learn what myths are by listening to examples provided by the instructor. They briefly discuss the similarities and differences in the myths, paying particular attention to the way the myths explain natural phenomena.

Then the audience is divided into small teams of up to six visitors, and each team is asked to invent a myth about the following situation: "You are part of an ancient culture that suddenly experienced a very long and severe drought. This drought lasted several months during the summer, when the Milky Way is seen high overhead. The constant cloudless nights afforded a clear view of the sky every night. After these many months, the rains finally came and the drought ended. Your challenge is to invent and record a myth to explain what happened."

Two or three of these myths can be read by visitors who helped to invent them. One of the myths which is *not* read aloud is reserved for the next part of the activity. The instructor asks for three volunteers who did *not* invent or hear that myth to leave the planetarium for a few minutes. A fourth volunteer is then given these instructions in the planetarium: "The speaker will tell you the myth once. You are not permitted to ask questions or to have the myth repeated. Try to remember as much of the myth as you can. After listening to the myth, you will be asked to tell it to someone else."

As the myth is read, the other visitors are told to listen carefully as each person retells the myth, and note any changes that occur as the myth is transmitted. Once the first volunteer has heard the myth, the second volunteer is brought inside and given the same instructions listed above. Another volunteer is then brought inside, and so on until the last volunteer has heard the myth. The last person should retell the myth to the entire audience.

Finally, the original myth should be repeated for all of the volunteers and other visitors to hear. The instructor then leads a discussion about how the myth was changed: "Did rational explanations become irrational? How did influences from our own culture cause changes? How reliable are myths concerning what ancient people really believed about the cosmos?" After recapping the important points raised by the visitors, and discussing a good definition for "myth," the instructor encourages the visitors to continue studying myths from ancient cultures and locating those celestial phenomena that they attempted to explain.

Activity #10 DESIGN A MESSAGE FOR CETI

recorded by Bill Kinsella

Objectives: After this activity the visitors will be more aware of qualities that characterize human culture and the problems of communicating these qualities without using verbal language.

Materials: 1) a large clipboard with several sheets of paper (about 16" x 20") for each team of 5-6 people; 2) reading lights; 3) [optional] a radio observatory panorama and dramatic tape recording (see below); and 4) a slide of an imaginary message received from the aliens.

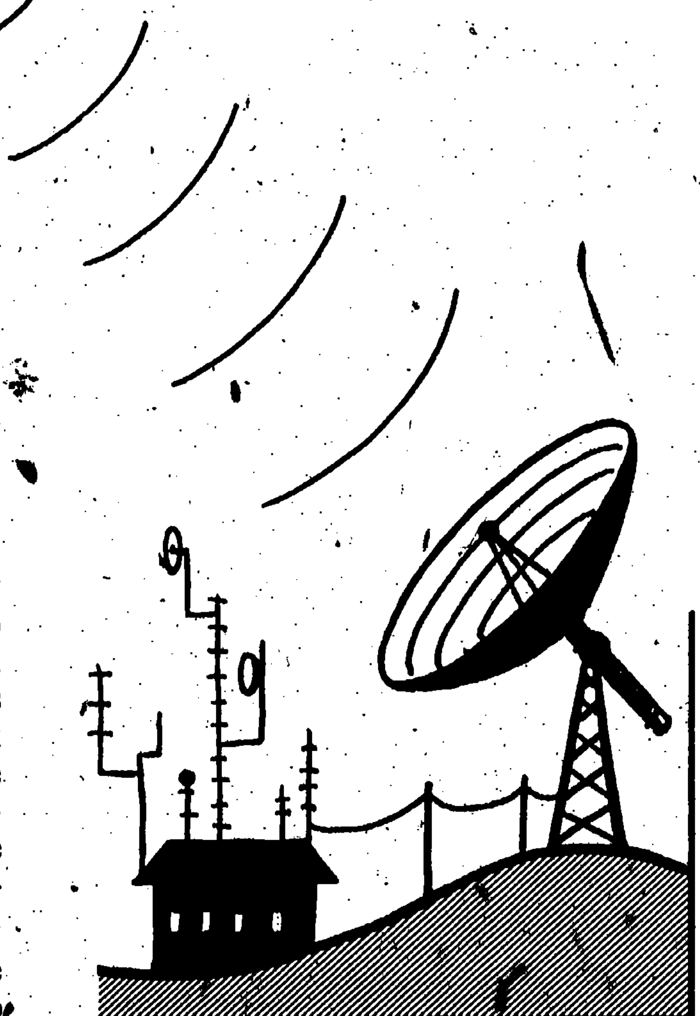
Procedure: The program begins with projected images of newspaper headlines proclaiming: MESSAGE RECEIVED FROM OUTER SPACE! As the images are projected on the dome, a dramatic taped news broadcast begins: "Just hours ago, astronomers announced that unusual signals were received from the region of space around the star Zeta Orionis. We now take you to the National Radio Observatory for an on-the-spot report..."

The visitors are transported, via panorama projection, to the radio observatory, ~~where an astronomer (the planetarium instructor)~~ points out the star, Zeta Orionis, in the night sky. The astronomer may also discuss what conditions might be like for a planet orbiting a star like Zeta Orionis, and describe some of the problems of interstellar communication. The messages received from the aliens can also be presented, or this topic can be avoided to leave the audience free from suggestions that might influence their later activity.

Next, the astronomer invites the visitors to participate in a historic task--to design a message which will be sent back towards Zeta Orionis. The instructor divides the audience into small groups of five or six visitors, and asks each group to list five important subjects that should be communicated to the aliens. The reading lights are turned on, and paper and clipboards are distributed to each team.

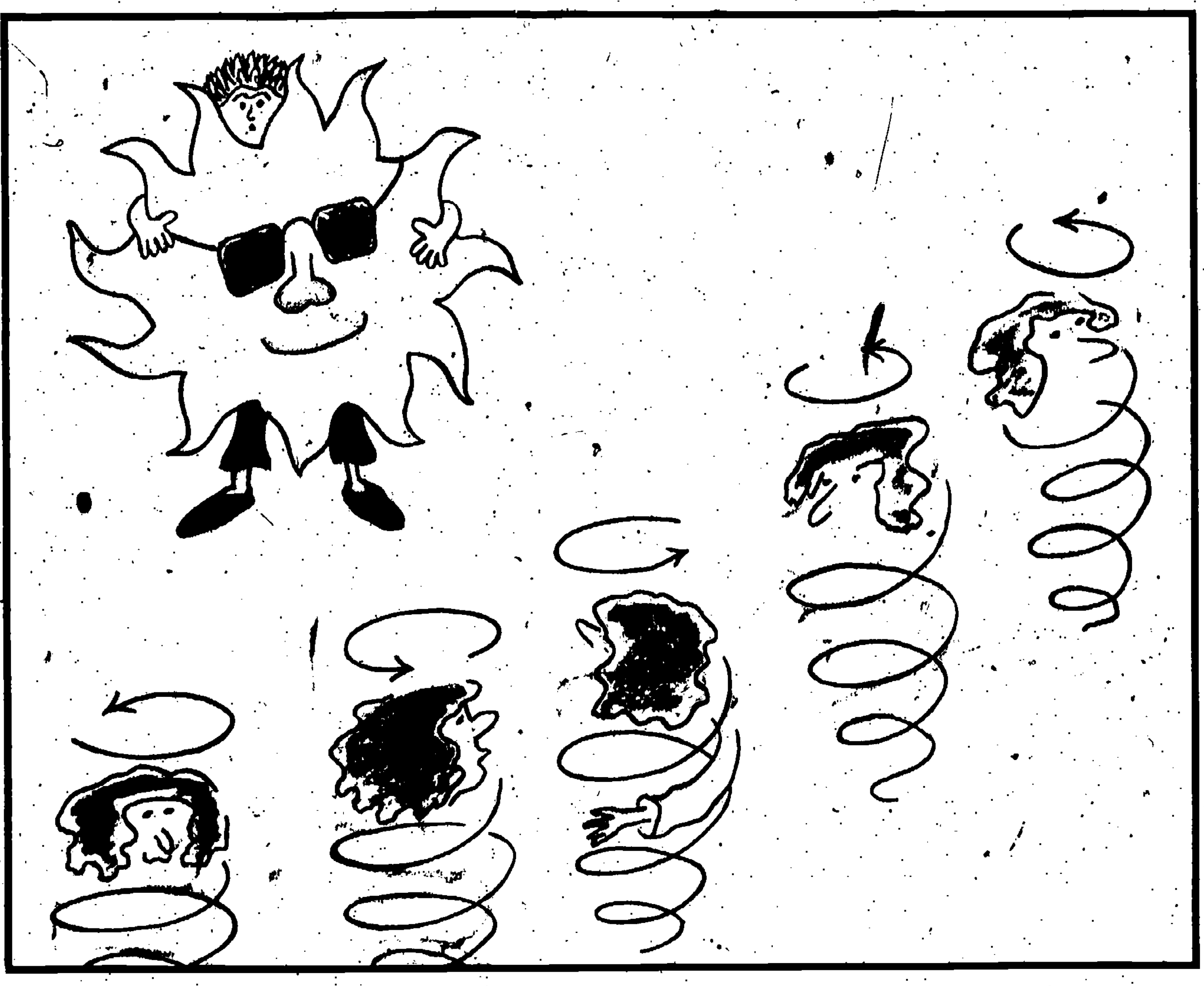
After all groups finish, the lists are posted and a volunteer from each group briefly explains why each subject was included. The instructor then invites each group to select one of the subjects listed and design a way to communicate the chosen subject as a picture. The picture will later be scanned by TV camera and transmitted to the aliens on the same channel as the message they sent to us.

When the completed messages have been posted, the astronomer can provoke an interesting discussion by inviting visitors to interpret each others' messages before asking for the designers' intentions. The activity can end with an open-ended discussion about the possibilities of life on other planets, and the problems of communicating with extraterrestrials. The program can also be supplemented with a slide presentation of the messages that have already been sent (e.g. the Pioneer plaques, and the message beamed towards M13 by the Arecibo radiotelescope) and long-range plans for NASA's CETI project (Communication with ExtraTerrestrial Intelligence.)



Activity #11 HOW DOES THE SUN APPEAR TO MOVE?

synthesis of two similar activities
recorded by Jack Pemberton and Bill Lawson



Objectives: The visitors will learn that the sun rises in the East each day, "moves" across the sky, and sets in the West. So, by observing the sun, we can find East and West, wherever we are. The visitors will also learn that even though it looks like the sun is moving, what we see is the effect of the earth turning around once a day.

Materials: 1) planetarium projector set for just prior to sunrise; 2) "Mr. Sun," a large circular piece of yellow cardboard with a face wearing sunglasses painted on it; and 3) [optional] a stool which swivels.

Procedure: After a brief discussion about what directions are and how they are useful, the instructor explains that the sun can be used to find East and West.

"Let's pretend that it is early morning and we are outside waiting for sunrise." *Star lamp on low; dim cove lights to leave some blue light.* "Point to where you think the sun will come up." *Bring up twilight and then brighten cove lights; notice if most of the visitors are pointing towards the twilight.* "Why did you point in that direction? Does anyone know what that direction is called? That's right, EAST. Now let's see if you are right." *Bring up sun and give visitors time to cheer.*

"Now, where to you think the sun will set? What direction do you call that? Right, WEST. Since we can make things happen faster in the planetarium than they happen in the real sky, let's find out if you're right." *Rotate diurnal motion until the sun is on the Western Horizon.*

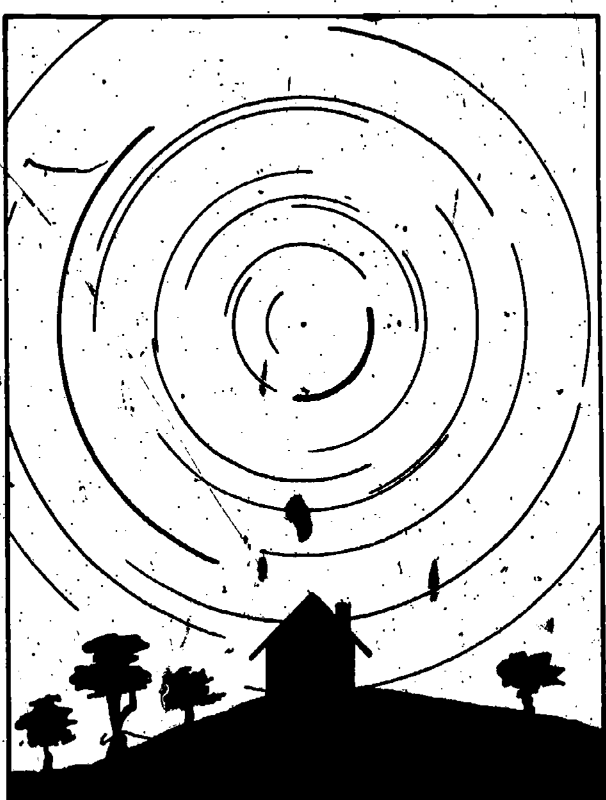
The instructor then expresses disbelief that the big sun could actually move all that distance, and asks if anything else might explain the daily motion of the sun. After listening to the visitors' ideas, the instructor introduces "Mr. Sun" who can be identified by his sunglasses. A visitor is asked to help by holding Mr. Sun so everyone can see him. All of the visitors are asked to stand up and pretend that their heads are "Earth." The instructor demonstrates how the earth turns in space by spinning on his or her axis, and asks the visitors to do the same. The visitors are then asked to watch Mr. Sun appear to rise and set as they spin around their axes each "day."

During the last part of this activity, the visitors sit down and watch the instructor model the earth. The instructor faces Mr. Sun and asks the visitors to imagine people living on the instructor's nose, and to think of what time of day it must be for those tiny people. As the instructor slowly rotates, he stops to ask the visitors what time of day it is for those people at several different spots. Finally, the instructor asks the visitors to imagine people living in the USSR to be on the back of his head, and to determine the time of day for them too. Further questions could involve people living on the instructor's left ear, right ear, etc.

An alternative method of modeling Earth is to ask a visitor to sit in a swivel chair. The instructor can then rotate the "earth" while leading the other visitors in a discussion as described in the previous paragraph. In any case, the visitors should see the sun rise and set from their own point of view, as they turn around, before they are asked questions about someone else modeling the earth.

Activity #12 HOW DO THE STARS APPEAR TO MOVE?

recorded by Carl Rump

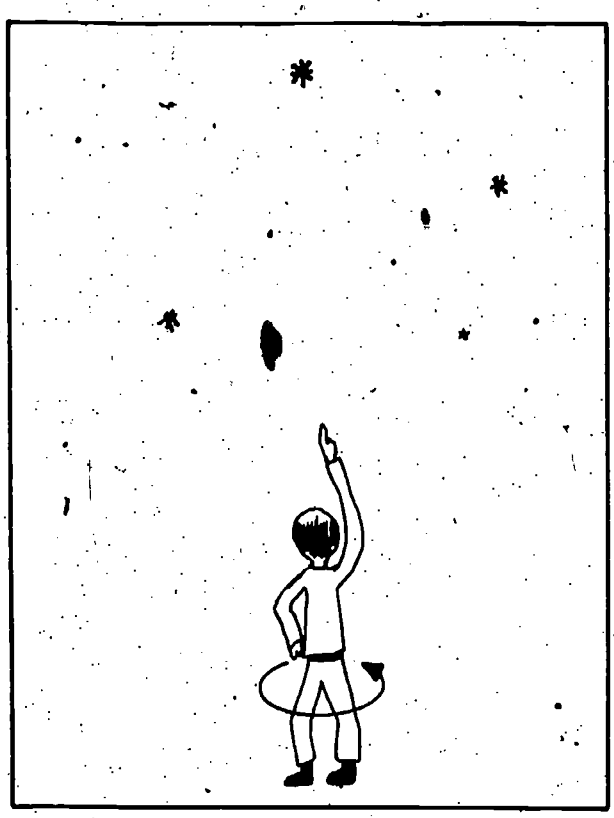


Objectives: During this activity the visitors learn that most stars appear to rise in the Eastern part of the sky and set in the Western part of the sky. Other stars do not rise and set, but move in circles around the North Star. The visitors learn that this apparent daily motion can be explained by the rotation of the earth.

Materials: No special materials other than the planetarium projector.

Procedure: This activity may be performed after instruction on the constellations, when the visitors can easily identify groups of stars. Sections of the audience are assigned to watch different groups of stars as the instructor speeds up time, to illustrate how the stars move during the entire night. The visitors share their observations, noting stars rising in the East, setting in the West, and moving in great circles around the North Star. Stars close to the North Star don't set at all!

Next, the instructor stops the motion of the planetarium projector, and invites the visitors to explain the motion of the stars by pretending to be the earth spinning in space. The instructor demonstrates how to point at a star directly overhead, and slowly turn in place while watching the stars appear to move in circles. The visitors are invited to do the same, picking any star directly overhead as their "pole star." After the visitors sit down, they share their observations, and volunteers attempt to explain the apparent daily motion of the stars.



Finally, the instructor can ask the visitors to name other spinning objects--wheels, merry-go-rounds, and so on. "What do these objects have in common?" *An axis.* "Where was your axis pointing when you turned around a few minutes ago?" *At a star overhead.* "Where is the earth's axis pointing as it turns in space.?" *At the North Star!* This notion can be demonstrated with a globe of the earth in the planetarium.

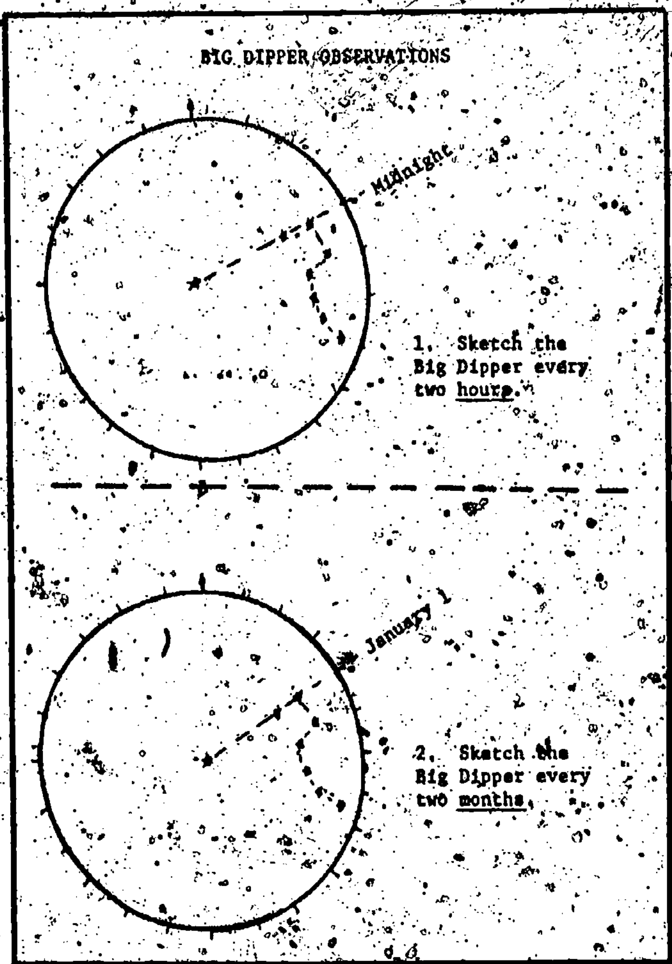
A group of visitors who easily grasp the relative motion of the earth and stars might be challenged to predict how the stars would appear to move if we observed from the North Pole of the earth. After permitting time for discussion about what to expect, the planetarium instructor sets the projector for 90 degrees N Latitude. The same procedure may be used for predicting how the stars would appear to move when observed from the equator.

Activity #13 HOW CAN YOU TELL THE TIME BY THE STARS?

recorded by Victoria Lindsay

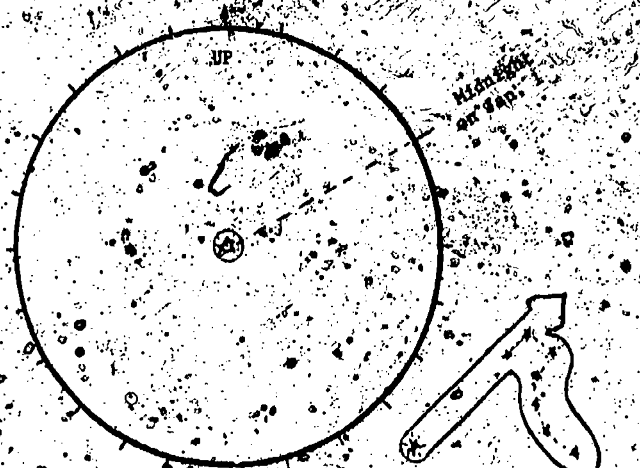
Objectives: The visitors will become familiar with the daily and seasonal motions of the circumpolar stars; discover the pattern and predictability of these changes; and learn about the process of telling time by the stars by constructing a star clock which uses the pointer stars of the Big Dipper.

Materials: 1) planetarium projector set for midnight, January 1; and 2) for each visitor: one brad, pencil, clipboard, scissors, and the following two activity sheets.



CIRCUMPOLAR STAR CLOCK

To make the clock, cut out the dipper below. The pointer stars are the hand for the clock. Place a brad through Polaris on the hand and Polaris on the clock face. (You may use gummed reinforcements to strengthen the place where the brad is inserted).



To use the clock:

1) Be sure you are holding the clock with "up" at the top. Find the dipper in the sky. Turn the hand until the dipper on the clock looks like the dipper in the sky.

2) Now count off 2 sections for each month past January. This is where the hand points at midnight for the time of year it is now.

3) To find the time of night, count the number of sections before or after this midnight position until you come to the dipper. The number of sections you count is the number of hours before or after midnight.

"Heigh ho! an' it be not four by the day, I'll be hanged; Charles' Wain is over the new chimney and yet our horse is not yet packed." In this quote from Shakespeare's *King Henry IV*, the wagon drivers are telling time by the position of Charles' Wain (wagon), an English name for the Big Dipper. To show how to use the Big Dipper to tell time, begin by having the visitors observe and sketch the position of the Dipper at two-hour intervals. Begin at midnight on January 1, and have them make three observations (until 6 am). Then, have the visitors observe and sketch the Big Dipper at two-month intervals: Midnight on March 1, May 1, and July 1. After each set of observations, stop and ask the visitors to discuss their answers to the following questions, first discussing hours, then months.

1) How far has the Dipper moved in six hours (months)?

2) How many hours (months) will it take to go all the way around?

3) How far will it move in one hour (month)?

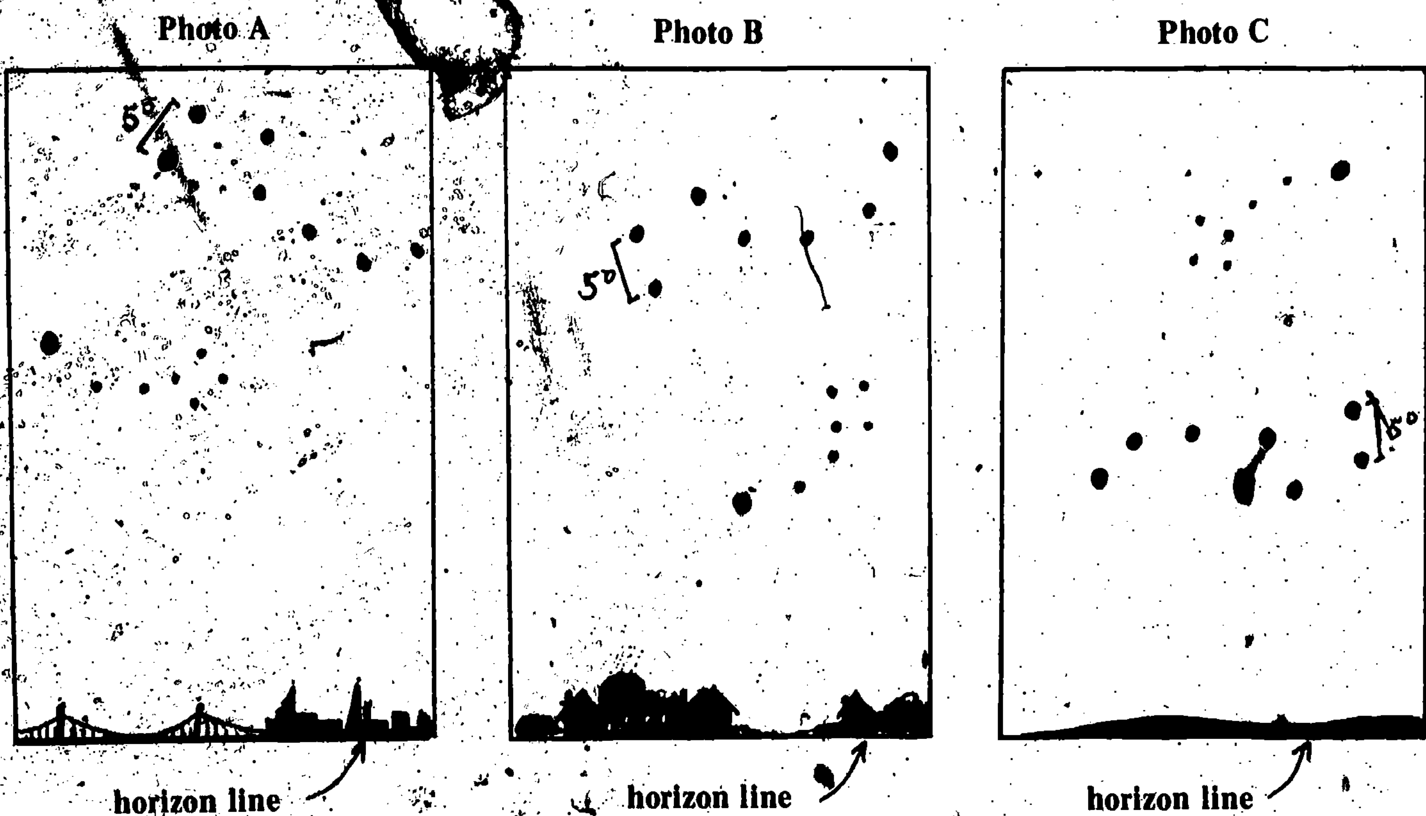
When the visitors understand how the Dipper appears to move from hour to hour and month to month, hand out the second sheet and follow the directions for building and using the star clock (above). This activity can also be done in the classroom by replacing the planetarium with an umbrella with stars painted or taped onto it, with Polaris at the top.

Activity #14 HOW CAN YOU TELL YOUR LATITUDE BY THE STARS?

recorded by Bill Kobel, Peter Chard, and Paul Taylor

Objectives: During this activity the visitors learn how to find their latitude by measuring the height of the North Star above the horizon.

Materials: 1) one globe of the earth; 2) a worksheet for each visitor with the following drawings; and 3) a clipboard and pencil for each visitor.



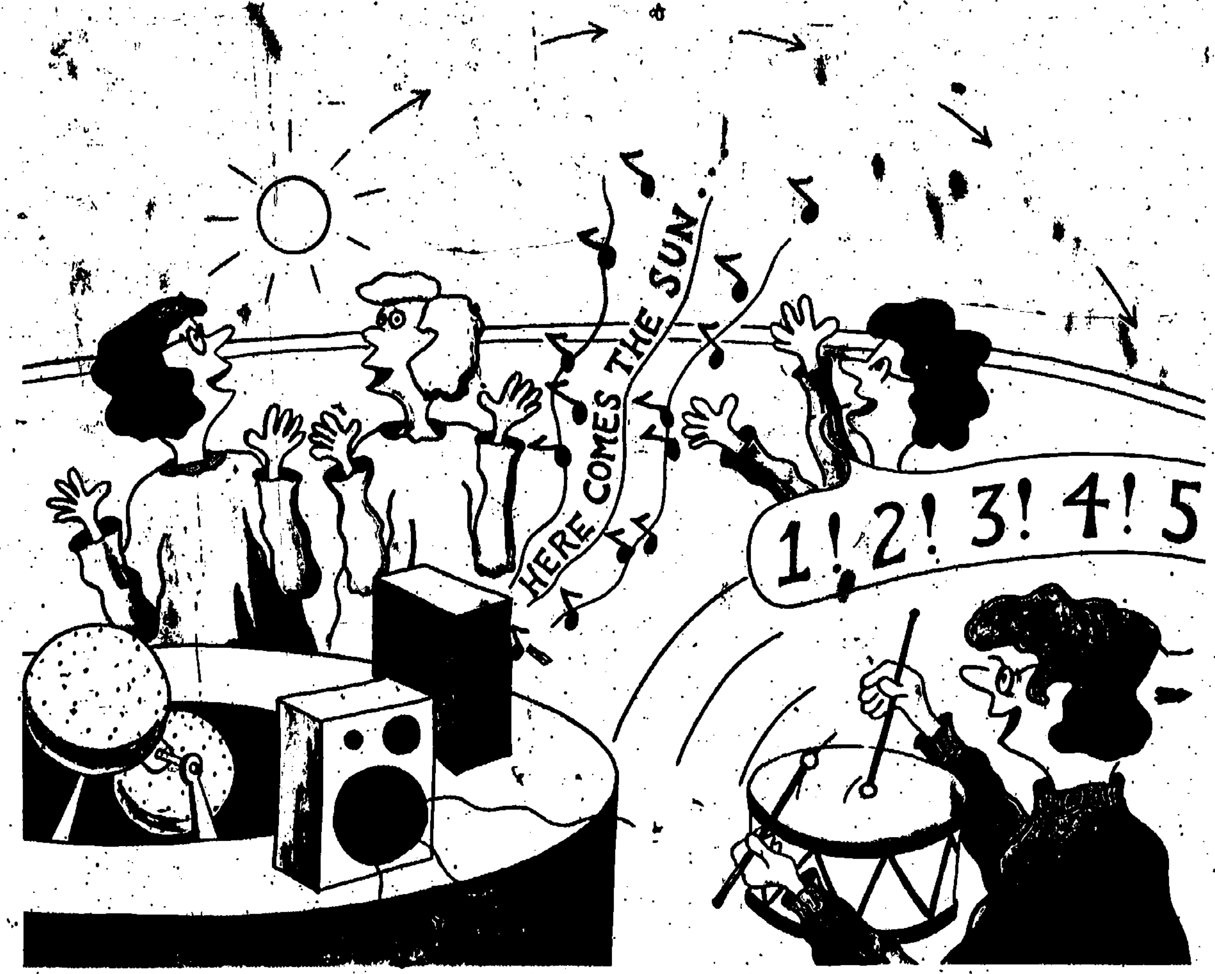
Procedure: For most groups of visitors, it is probably best to begin by reviewing the daily motion of the stars (Activity #12). The visitors should be able to explain that the earth's axis points to the North Star, and they should be able to predict that the North Star would appear overhead if we were at the North Pole of the earth, and at the horizon if we observed from the equator.

The instructor hands out worksheets and explains that "These are photographs taken by three different astronomers. What constellations are shown on each? Can you find the North Star?" Next, the instructor explains that each of the three photographers was standing at a different latitude on the earth (he or she demonstrates the meaning of latitude by pointing to different latitudes on the globe). "Can you figure out the exact latitude of each photographer's position from these pictures?"

After providing sufficient time for individuals to work on the problem, the instructor can invite visitors to work together, and/or give clues to help them solve the problem: "What do you need to measure? How can you measure in degrees on these photographs?"

Activity #15 LONG DAYS, SHORT DAYS

recorded by Sam Storch and Charles Neleson



Objectives: Prior to this activity, the visitors have learned that there are four different seasons, and that days are shortest in the winter and longest in the summer. During the program, the visitors measure the length of day for all four seasons.

Materials: A record or tape of music with rhythmic beats. An especially appropriate selection for young children is "What Is the Sun?" from the album *Space Songs.* For older children and adults, a metronome or clock may be more appropriate.

Procedure: The planetarium instructor begins by demonstrating a speeded-up solar day. To help the visitors understand the relation between the position of the sun and the time of day, the instructor might ask: "Is it morning or afternoon now? Where will the sun be when it is noon?"

Next, the instructor explains that he or she has set the planetarium projector to reproduce the first day of winter, December 22, and that the visitors will measure the length of that day by clapping their hands. The instructor then turns on the music and daily motion, and demonstrates how to clap with the beats while counting out loud. The visitors are given a short practice run, and the projector is reset to sunrise.

As the sun rises, the visitors begin to clap with the music, continuing until the sun sets. For upper elementary and older groups, the activity can be shortened by counting beats until the sun reaches the meridian and then multiplying by two. The solstices and equinoxes are chosen for this purpose since the differences are most extreme on those dates.

After the length of day is measured for all four seasons, the instructor leads a discussion to help visitors connect their observations with their own experiences. "During your summer vacation, are the days getting shorter or longer? Just before Christmas, are the days very short or very long? How about in the fall, when you start school--are the days longer or shorter than they are at Christmastime?"

Activity #16 WHERE WILL THE SUN RISE AND SET IN DIFFERENT SEASONS?

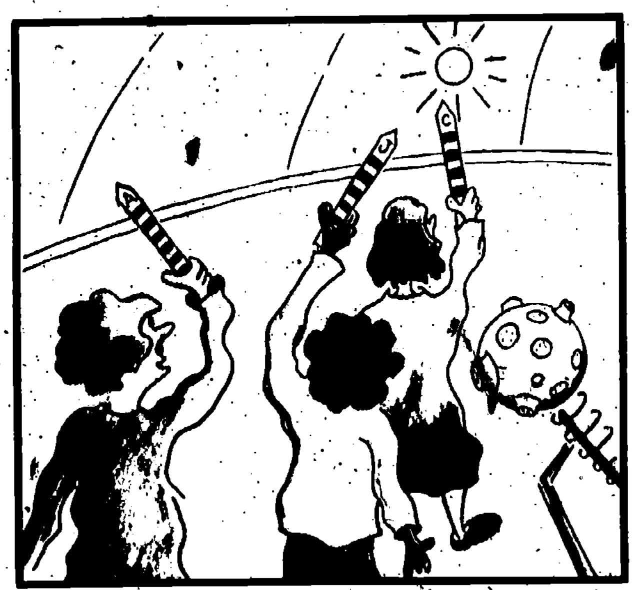
recorded by Charles Neleson and Sam Storch

Objectives: Prior to this activity, the visitors have learned that there are four different seasons. They may also have learned that the sun rises in the East and sets in the West. During this activity, the visitors learn that the rising and setting points of the sun are different for different seasons.

Materials: 1) Arrow pointers to be positioned on the cove of the planetarium dome by the visitors--these can be fashioned of cardboard and hung by means of hooks or Velcro fabric strips. Each pointer should be coded with a number or letter so each visitor can identify the pointer which he or she placed. For large audiences, groups of visitors can decide on the position of a single pointer. 2) Optional materials are azimuth marks every 15 degrees around the cove made with glow-in-the-dark tape, and data sheets for recording the positions of sunrise and sunset in degrees for each season.

Procedure: The instructor explains that the planetarium shows how the sky appeared that morning, just before sunrise. He or she invites the visitors to show where they think the sun rose that morning by placing pointers on the cove of the planetarium, just below the horizon. The four cardinal directions are displayed prominently so the visitors have a frame of reference.

As the sun rises in the planetarium, the visitors can see if their predictions were right or wrong. The same procedure can then be used to predict the sunset position.



This experience usually evokes quite a discussion since most people expect the sun to rise and set due East and West. This discussion can provide a lead-in for proceeding to the summer and winter solstices and the equinoxes to predict sunrise and sunset on those dates.

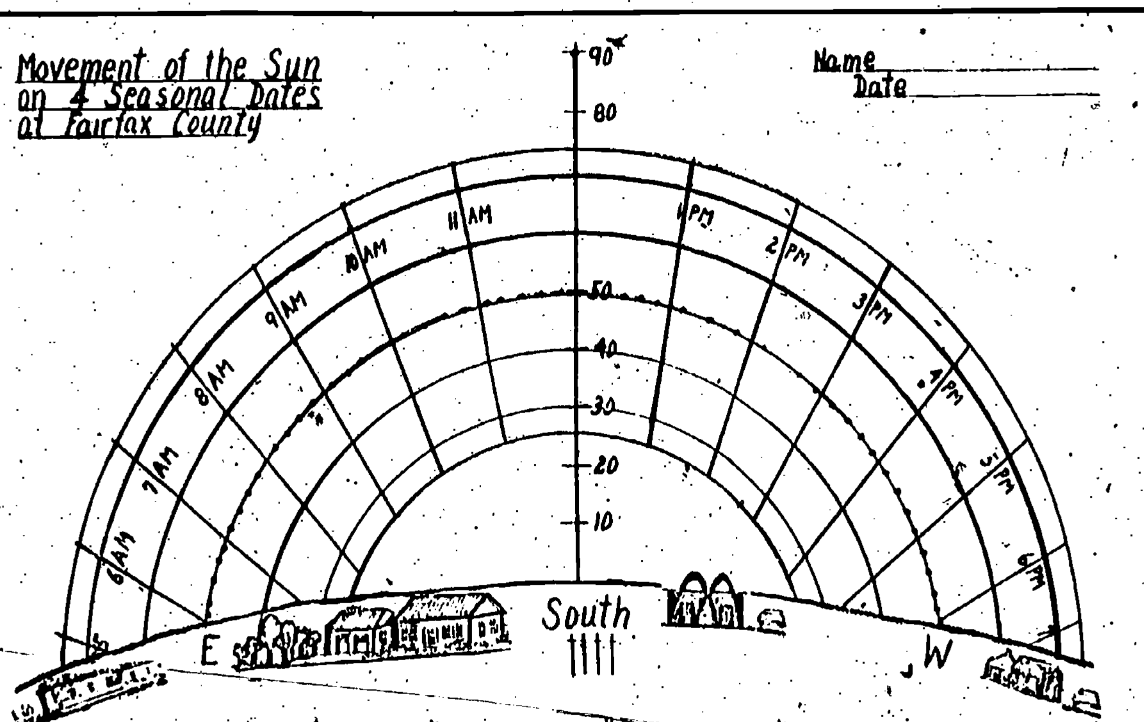
After this activity, the instructor may stimulate the visitors to think about how the rising and setting points change with the seasons with questions such as: "Where do you think the sun will rise next week? Next month? How long do we have to wait until the sun reaches its southernmost (or northernmost) rising and setting points? Is there another date during the year when the sun will rise and set in the same place as it did today?"

Activity #17 HOW DOES THE SUN'S PATH CHANGE WITH THE SEASONS?

recorded by Ellie Euler and John Kritzar

Objectives: During this activity, the visitors plot the daily path of the sun on the summer and winter solstices and the fall and spring equinoxes. From their own data, they learn that: 1) the number of daylight hours varies with the seasons; 2) the positions of sunset and sunrise vary with the seasons; and 3) the elevation of the noonday sun also varies with the seasons.

Materials: 1) a celestial coordinate projector; 2) one data sheet, pencil, and clipboard for each visitor. The sample shown below is adjusted for the latitude of 40 degrees N. For your latitude (call it "L"), the altitude of the sun at noon will be 90 degrees - L on the equinoxes, 90 degrees - L + 23.5 degrees on the summer solstice, and 90 degrees - L - 23.5 degrees on the winter solstice.



	DECEMBER 22		MARCH 21		JUNE 22		SEPTEMBER 23	
	TIME	DIRECTION OF SUN	TIME	DIRECTION OF SUN	TIME	DIRECTION OF SUN	TIME	DIRECTION OF SUN
SUNRISE								
NOON	12:00		12:00		12:00		12:00	
SUN SET								
HOURS OF DAYLIGHT		hours		hours		hours		hours
HOURS OF DARKNESS		hours		hours		hours		hours
MAX. HEIGHT OF SUN								

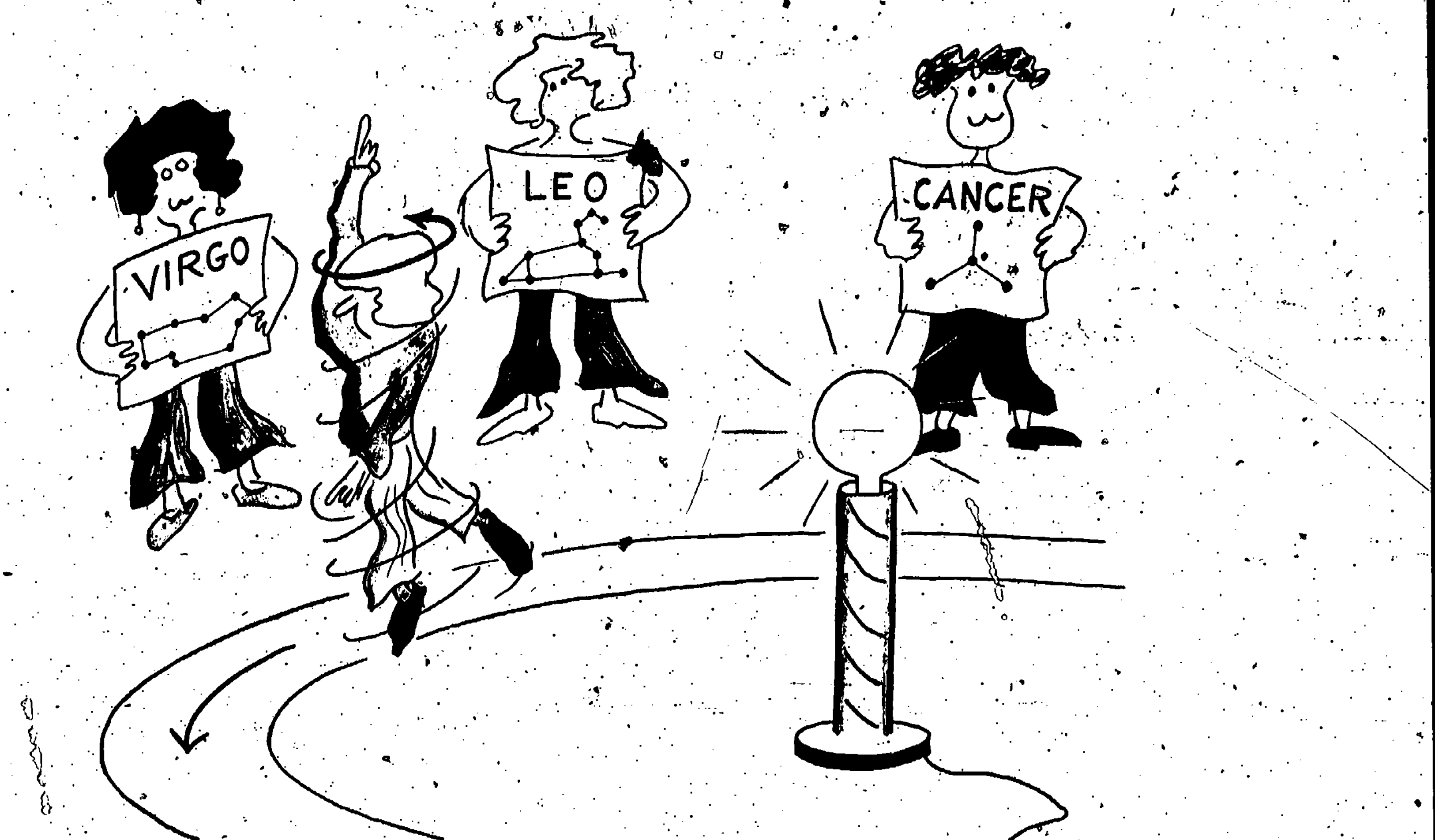
Visitor's data sheet for this activity by John Kritzar and Ellie Euler

Procedure: At the beginning of the activity, the instructor describes how to use the projection of the celestial coordinates to plot the position of an object in the sky on the data sheet. Then, the instructor explains that the planetarium shows how the sky will appear on the first day of winter (December 22) just before sunrise. The visitors are asked to place light pencil marks on their data sheets where they expect the sun to rise and set that day, and a third mark where they expect it to be at noon.

At the moment of sunrise, the instructor stops the projector for the visitors to check their predictions and mark the actual position with a small dark circle. The instructor advances the sun, and the visitors mark their data sheets at three or four other points, including noon and sunset. At the bottom of the page they write in the time and position of sunrise and sunset, the hours of daylight and darkness, and the maximum height of the sun. After a brief discussion, the activity is repeated for the summer solstice and the fall and spring equinoxes.

Activity #18 DIFFERENT SEASONS, DIFFERENT STARS

recorded by Keith Johnson



Objectives: During this activity, the visitors will find out why we see different constellations at different times of the year, and they will be able to visualize the earth's rotation (on its axis) and revolution (around the sun). They will also find out how a person's "sun sign" is determined and why it is most easily seen in the sky six months before or after the person's birthday.

Materials: 1) a 100-watt light bulb or other bright light in the center of the room (perhaps mounted on the projector pedestal); 2) twelve signs (about 16" x 20") with the names of the zodiacal constellations. These can be illustrated with the appropriate star patterns and mythological figures.

Procedure: The instructor asks for 12 volunteers whose birthdays coincide with each of the 12 zodiacal constellations. The volunteers stand in a large circle around the planetarium cove. It is probably easiest to do this by naming each constellation with its associated birthdates in order. If no one is present to represent a certain sign, then that position should be filled by someone else. The instructor distributes the signs to the 12 volunteers, making sure that the order is correct and spacings are even.

The instructor explains that the light bulb at the center of the room represents the Sun; and asks for one more volunteer to represent the Earth. That volunteer is asked to stand between the sun and Virgo. The instructor explains that "This is where the earth is located in Spring."

Next, the instructor addresses questions to the other visitors to help the earth volunteer decide how to model the Earth's daily and yearly motions: "If our volunteer's head represents Earth, and we are located near his (or her) eyes, how should he stand so it is daytime for us? Nighttime? How should he move so a whole week goes by? How should he move so a whole year goes by?" The instructor asks the Earth to model these motions as they are suggested.

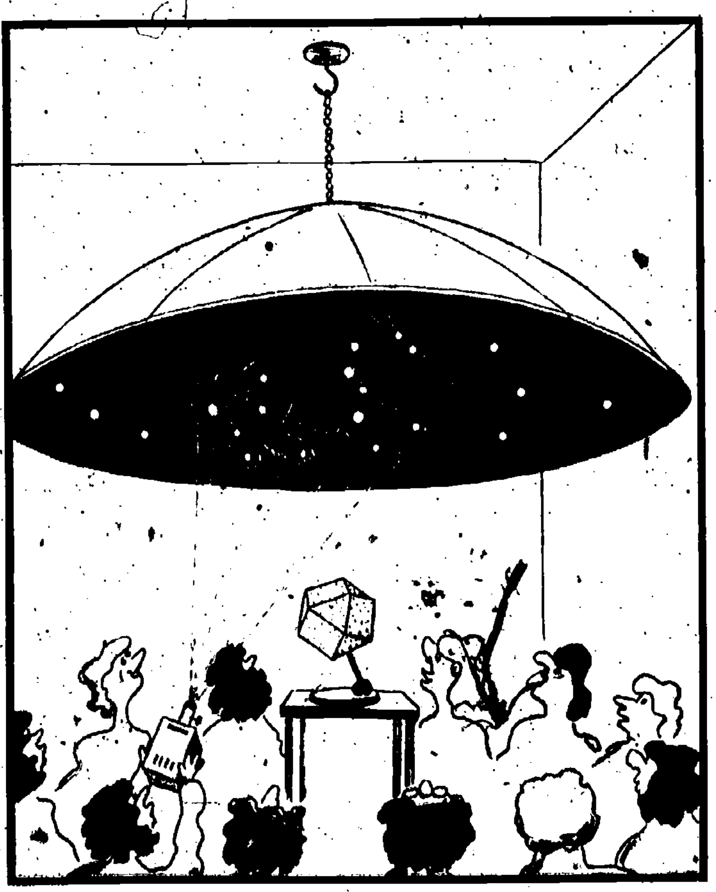
Finally, he asks the Earth to show where he would be in the summer, fall, winter and spring, without actually rotating 365 times.

On the Earth's second trip around the Sun, the instructor stops the Earth at each season and asks which constellations are visible at night. The Instructor can then ask the other visitors to explain why the other constellations are not visible at that time of year. If the visitors are interested in the astrological "sun signs," the instructor can ask the Earth to identify what constellation the Sun appears to be "in" during each part of the year. The visitors should be able to see for themselves why it is not possible to see a constellation while the Sun is in direct line with those stars.

Individuals who have difficulty understanding the concepts presented should have the opportunity to play the role of the Earth, so they can see the constellations for themselves. Since this activity can be performed in any classroom, teachers can provide this experience for their students before or after they come to the planetarium.

Activity #19 FINDING YOUR ZODIACAL CONSTELLATION

recorded by Kent Leo



Objectives: During this activity, each visitor learns how to use a star map to locate the position of his or her zodiacal constellation, or sun sign, and learns to associate a mythological figure with the pattern of stars. After this activity, the visitors will be able to find their constellations in the real night sky.

Materials: 1) a supply of inexpensive star maps for each season of the year; and 2) a small hand-held slide projector, and two slides for each zodiacal constellation: one with the star pattern, and one with a mythological figure drawn to correspond with the star pattern.

Procedure: The star maps are distributed according to birthdays. Those who have birthdays in the summer receive a winter star map; those with birthdays in the spring receive a fall map, and so on. The instructor asks the visitors to locate their astrological signs on the map, helping those who don't know their sun sign by asking for their birthdays.

The planetarium projector is set for the current season, and the instructor demonstrates how to use the maps. Those whose constellations are visible are asked to find their constellations in the sky, while visitors whose constellations are not visible are invited to help.

When several of the visitors have found their constellations, one volunteer is selected to point out his or her constellation in the sky. He is then given the hand-held slide projector and shown how to change the scale of the projected image by moving towards or away from the dome. He is then asked to superimpose the image of the star pattern over the constellation in the planetarium sky.

When the volunteer has succeeded in aligning the projector, he is shown how to move the second slide into position to display an artist's conception of the mythological figure over the star. This activity is repeated for each of the zodiacal constellations that are visible, and then the planetarium projector is reset for the next season. By the end of the activity, all of the visitors will have seen their constellation and the figure it is supposed to represent, and know when and how to look for it in the real sky.

NOTE: Due to precession, astrological signs have been shifted about one constellation from the actual star positions.

Activity #20 PRECESSION OF THE EARTH'S AXIS

recorded by George Reed

Objectives: During this activity the visitors discover that the Earth's axis will not always point towards the North Star, but is slowly changing its orientation in space (precessing) with a period of 26,000 years.

Materials: Reading lights, and a circumpolar star map, pencil, and clipboard for each visitor.

Procedure: The instructor begins by demonstrating the nightly motion of the stars around the North Star. If the visitors can explain this motion as the result of Earth's rotation on an axis which points towards the North Star (see Activity #12), then they are prepared to understand this activity.

First, the instructor defines the North Celestial Pole as "the position in the sky that does not appear to move as the earth rotates." The visitors are asked to distinguish this point from the North Star by carefully watching the motion of the North Star during rapid daily motion, and to plot the position of the North Celestial Pole as an "X" on their star charts.

Then the instructor adjusts the planetarium projector to show the sky as it will appear three thousand years in the future. He or she turns on daily ~~motion for~~ a few minutes so the visitors can locate the new position of the North Celestial Pole and plot this point on their maps. The process is repeated until 13,000 years have elapsed, and the visitors have plotted several "X"s.

At this point, the instructor leads a discussion about where the Celestial Pole may have been located in the years between the 3000-year stopping points. Most visitors will probably recognize a semi-circular pattern of "X"s, and be able to predict that the Celestial Pole will complete the circle in another 13,000 years. The visitors might be asked to place a light pencil mark where they believe the Celestial Pole will be in another 6,000 years, and the instructor can advance the projector to allow the visitors to check their predictions.

After this activity, the instructor can introduce an Earth globe and ask the visitors how it should be held in the planetarium to demonstrate the effect of precession. For advanced visitors, the instructor can explain that precession occurs because the earth is not a perfect sphere, but bulges around the equator. Therefore, the gravitational force between the earth and sun acts unequally on different parts of the earth, causing the axis to slowly change its orientation in space.

Module 7

PUTTING IT ALL TOGETHER

The objective of this activity is for you to review the techniques presented in this workbook and to apply them to planning and improving a planetarium program.

A. A Brief Review

Three ways of viewing components of planetarium programs have been presented in this workbook. These schemes are briefly outlined below. The classifications are not iron-clad distinctions, but are useful in helping match subject, visitor, and instructor to one another, and in maintaining variety.

Organization Patterns (Module 3)

1) *Didactic Organization*--Communication is entirely one-way: from the instructor to the visitors.

2) *Small Group Task Organization*--This organization allows visitors to interact with other visitors while working on a common task.

3) *Individual Task Organization*--Each visitor makes his or her own observation or solves a problem on his own.

4) *Informal Discussion Organization*--This pattern of organization allows free, uninhibited discussion by the visitors among themselves.

5) *Group Meeting Organization*--The group meeting is primarily problem-centered, with the instructor or a visitor acting as a facilitator.

6) *Socratic Organization*--The planetarium instructor takes the role of questioner and responder.

Visitors' Reasoning Skills (Module 4)

1) *Egocentric*--Visitors can imagine only their own point of view. They can notice similarities and differences. Simple associations and human motives are attributed to inanimate objects, e.g., "The sun rises so we'll feel warm."

2) *Concrete*--Visitors can imagine another viewpoint only after a concrete experience. Beginning with classification by a single trait, they can later recognize that objects may belong to more than one class and can arrange objects along a continuum. More complex relationships between various elements familiar to the individual can now be used to explain phenomena. New observations can be appropriately used in revising explanations.

3) *Formal*--Visitors can imagine a situation from different points of view. They can arrange objects in a hierarchy and then rearrange the objects in a new hierarchy. Visitors can extend explanations to predict observations and objectively compare their own explanations with alternatives by controlling variables and making probability arguments.

Questioning and Activity Strategies (Module 5)

1) *Direct Information*--The visitor recalls information or recognizes information that is readily observable.

2) *Synthesizing*--The visitor draws some relationships from information that was recalled or observed.

3) *Open-Ended*--The visitor explores freely and comes up with one of a wide range of acceptable solutions.

4) *Feeling*--The visitor makes a judgment based on feelings.

5) *Other*--Rhetorical and Managerial.

B. Applying the Techniques

Outlining a Program

You can use the convenient chart on page 88 to outline a planetarium program in its formative stages. First, list each component of the program in the *Subject* column. Then, for each component, consider the form of *Organization*, the dominant *Questioning or Activity Strategy* (if appropriate), and finally the *Reasoning Skills* required of the visitors. The flow of the program can be judged by reading down each column. For example, does the sequence of subject matter ideas make sense from the visitors' point of view? Do the changing patterns of organization during the program provide variety and focus? Does the range of activity and questioning strategies allow the visitors to participate in several ways that further your objectives? Are the reasoning demands appropriate for the visitors who you expect will attend this program? Finally, does the latter part of the program encourage intellectual growth by challenging visitors to understand at a level slightly above their current reasoning ability?

Planning and Improving Verbal Interaction

As you plan the program script, consider sequences of questions that would most effectively communicate the content of the program. Then, try out the program with a live audience as soon as possible, even before all of the special accessories and artwork are down pat. Audiotape one presentation and analyze the questioning and responding strategies as discussed in Module 5. Especially listen to the visitors' responses to questions and tasks that are intended to involve them in thinking at a high level. If the response is not what you expected, you may wish to reconsider the developmental level of the visitors as discussed in Module 4. You may decide to simplify the task, make it more challenging, or change your strategy for communicating that subject to the visitors.

Providing Supplemental Classroom Activities

All of the techniques presented in this workbook can be applied to developing classroom activities to complement planetarium programs for school groups or community organizations (like Scouts). Materials can be distributed to teachers to enable them to do activities with their students either before or after they attend the planetarium program. These activities can teach the same subjects from new points of view. They can extend the visitors' skills through games, simulation activities, small group problem-solving, or other structures that work especially well in classrooms or outdoors. The planetarium programs included in Appendix D are each followed by two classroom activities. These have been field-tested in 5th and 6th grade classrooms, and the results of quizzes indicated that the activities were effective in communicating the subject matter listed under "Objectives" of each activity.

Systematic Assessment

Once the initial development work is done, the planetarium program can be improved periodically by checking with the visitors. Visitor *satisfaction* can be checked at the end of the program by circulating comment cards on which visitors can say what they liked and didn't like about the program. Visitor *learning* can also be checked by pencil-and-paper, or interview tests with items which indicate whether or not the objectives of the program were met. For school groups, tests can be given to teachers to administer to their pupils a few days later. Feedback on visitor learning *and* satisfaction can serve as a rich source of information to improve specific parts of the planetarium program.

OUTLINE FOR PLANETARIUM PROGRAM ENTITLED:________________

Time	*Subject*	**Organization** (didactic, socratic, individual or group task, group meeting, or informal discussion)	**Strategy** (activities or questions are direct info, synthesizing, open-ended, or feeling)	**Reasoning** (requires egocentric, concrete, or formal level reasoning)

Appendix A
GETTING A WORKSHOP TOGETHER

1. Planning the Workshop

Once you have looked over the *Planetarium Educator's Workshop Guide*, we hope you will want to get together with other planetarium educators to try out the techniques described, discuss what happens, and come out with some ideas that are helpful to you. The surest way to do that is to start getting a workshop together yourself.

People

The first thing you need is more people. We've enjoyed workshops with as few as 10 people, or as many as 75. A dozen or two seems optimal. You can find other planetarium educators conveniently assembled at regional planetarium association meetings and International Planetarium Society meetings. If you live in a large metropolitan area, you may also have a local planetarium society, or you might just call up the planetariums in your area and see if folks would like to get together for a workshop. Every member of the International Planetarium Society has received a copy of this book, so there should be some curiosity abroad already.

Time

The full workshop, including everything in this book, requires about 20 hours to complete. A sample three-day agenda will be described later. But we have also done single-afternoon workshops, using only a fraction of the material. You might want to pick out the sections you personally want to examine, and just try those. Or you might consider a series of mini-workshops, each a few hours long, to be held at quarterly planetarium association meetings, or at some other periodic function. The only caution we have to offer is not to try presenting any Module (except Module 2) in less than an hour and a half. It can be done--but only by sacrificing discussion, and presenting the material in a straight lecture format. That deprives everybody of the crucial experience of trying out and criticizing these techniques.

Expert Leaders

These do not exist. So many skills are used in planetarium education, and there is so little in the way of laws of learning (in contrast to laws of physics, for example) that there are no Authorities. There *are* resource people who might have particular talents to offer your workshop, and their role will be discussed in a moment. But the best leader for one of these workshops is somebody who will be an active participant, and who will be skeptical and curious, just like the other workshop participants--somebody like you.

Leaders do have to make arrangements, gather materials, and call the workshop to order. As a planetarium educator, you are expert at doing that kind of service for planetarium visitors, and it is no more difficult to do so for other educators. Read through this book, decide what you would like to try, and you are ready to be a workshop leader. As a practical matter, you might want to find a colleague who will share the tasks with you.

Resource People

We have tried to make this workbook self-contained, so that you can organize a workshop without previous experience with the techniques examined. There are no experts on all of the matters in this book, but there are people with experience in particular areas, such as the theories of intellectual development (Module 4). A faculty member of a nearby university's department of psychology or education would probably be flattered to be invited to give a short presentation on that topic to your workshop. But remember that the workshop modules are designed to be practical to planetarium folk, and only by trying out the exercises themselves will participants be able to decide if the theories are useful in their planetariums.

For additional help, we recommend that you contact one or more of the planetarium educators who have experienced the full three-day version of this workshop. They undoubtedly have feelings and recommendations to share with you. Those alumni might even be talked into helping you run a workshop. A full list of trial workshop participants, alphabetically by state, can be found on pages 99-103 of this book.

Space

Any planetarium will do nicely. A workshop could even be held without a planetarium, but techniques for creating planetarium programs are certainly taken more seriously if they are tested in the real place. Some modules can also be done in an ordinary classroom, however, where discussion may be more convenient. When we have offered this workshop, we have done Modules 1, 2, 4, 5 and 7 in a classroom, and Modules 3 and 6 in a planetarium.

Materials

Each module requires some supplies or materials, but mostly just pencils, paper, and people. Details for each module are listed in section 3, below.

Each participant should also have a copy of the relevant printed materials from this book. Most planetarium educators have copies of the book already. For those who do not, more copies are available from the International Planetarium Society (see the back of the title page for the address).

You can also make your own copies from this book. Please see the permission notice, also on the back of the title page. There is no charge for using this material, but we do want to know that it *is* being used, so please write and tell us, as requested.

2. Sample Agenda For a Three-Day Workshop

Below is a sample agenda for a full workshop. Whether or not you do one this long, the time allocated to each module may be helpful.

A few items on the agenda don't appear in the workbook. At the end of each day we had a "wrap-up" of the day's activities. This was an opportunity for the workshop leaders to summarize the material covered, and to express their own views on its importance. Each workshop leader (and each author of this book) has his or her own opinions, and as a reward for all the work that goes into handling a workshop, a chance to make personal summaries is nice. It's the participants' personal summaries that ultimately count, however.

On the afternoon of the first day, we discussed plans for "participant-designed activities." This was a popular feature in which the participants worked together in small groups to present short visitor-participation activities that they use, or think they could use. (During the five trial workshops that were held during 1978, twenty different activities were presented. These activities have been incorporated into module 6 of this workshop guide.)

The participant-designed activities were presented on the final day of the workshop. After live demonstrations in the planetarium, each of the activities was critically discussed in terms of the strategies presented in the workshop. The discussions proved to be a most effective way of reviewing and clarifying the techniques as they apply in actual practice. After lively discussion, we arrived at a categorization of each activity, as shown on pages 56 and 57.

The presentation of "Red Planet Mars" on the morning of the second day also served as an example to be analysed by the techniques of the workshop. "Mars" is by no means a perfect program, but it is a practical example of a single-visit planetarium show with audience participation. Many of the strategies described in the workshop are used.

Friday

9:00AM	Welcome, coffee and donuts.
9:15AM	MODULE 1 **Communication.** Planetarium instructors have an opportunity to switch roles with visitors and experience different levels of instructor-visitor interaction.
11:00AM	MODULE 2 **Framework for Examining Planetarium Programs.** Participants describe their own goals and strategies for a planetarium program. Group discussion about goals (knowledge, skills, attitudes) and strategies to achieve them.
12:00PM	Lunch Break.
1:00PM	MODULE 3 **Organization Patterns.** Reassemble in the planetarium. A variety of ways to organize the planetarium experience for visitors is illustrated with excerpts from public and school programs used at the Holt Planetarium.
2:30PM	Break.
3:00PM	MODULE 4 **How the Visitors See It (Part I).** Activities, slides, and lectures present the different types of reasoning used by visitors at various stages of intellectual development. The implications for planetarium education of Jean Piaget's theory of learning are discussed. Specific examples are considered using concepts in astronomy and space science.
4:00PM	Wrap-up of day's activities.
4:30PM	Discuss plans for participant-designed activities.
5:00PM	Conclusion of first day's activities.

Saturday

9:00AM	MODULE 4, continued **How the Visitors See It (Part II).**
10:30AM	Presentation of a complete participatory program, RED PLANET MARS, followed by a discussion of the program.
11:45AM	Lunch Break.
1:00PM	MODULE 5 **Questioning Strategies.** Participants consider various ways of asking questions to stimulate the visitors' thinking.
3:15PM	Break.
3:30PM	MODULE 6 **Activities for the Planetarium.** Various categories of activities can be used, like the various questioning categories, to stimulate different kinds of thinking and learning. Examples previously demonstrated from RED PLANET MARS and Module 3 are discussed.
4:00PM	Participants work in small groups to plan their own 15 minute activity for presentation on Sunday.
5:00PM	Conclusion of second day's activities.

Sunday

9:00AM	Participants present and discuss their own activities.
12:30PM	Lunch Break.
1:30PM	MODULE 7 **Putting It All Together.** The activities presented in the morning are discussed and classified according to the categories developed during the workshop. Methods for designing a complete program and pre/post-visit activities are discussed, and a sample pre- or post-visit activity is presented.
3:00PM	Plans for local workshops. Participants discuss their own ideas about using the materials from this workshop, including presentation of their own version of the workshop for other planetarium educators.
3:30PM	Formative evaluation of this workshop.
4:00PM	Adjourn as a group. Workshop staff available until 5:00PM for individual consultation.

3. Notes on Presenting the Individual Modules

Here are suggestions for presenting each module. There are also answers to the questions in each. These answers are a consensus of the authors, but some of the answers are debatable. Many sections of this book rely on newly devised categories, and those categories are not water-tight definitions tested over generations. So you and the participants in your workshop may disagree with the answers given here. Our goal is to stir consideration and improvement of the techniques, categories, and ideas presented. A healthy amount of disagreement is welcome.

Module 1
Communication

This is a delightful and even amazing activity. You will find that you and the other participants very quickly get into the spirit of the workshop. We have also found this activity makes an excellent social ice-breaker.

For every three participants, you will need two crayons or felt tip markers, two manila file folders (to serve as "barriers"), and half a dozen sheets of blank paper. (We recycle used computer printout.) One participant has to play leader and post the master drawings. The masters should be prepared in advance. We usually use simple geometric patterns including some astronomical motifs like the ones shown in Module 1.

Several of the insights that can be gained from this activity are described in the module itself. The use of analogies almost always comes up. The need for instructor-visitor interaction to check on how your visitors are understanding and enjoying the program is another major topic.

One technique for communication that may arise is the use of an "advanced organizer." That's a short introduction to the overall message the instructor wishes to communicate to the visitor. Even in our brief exercise, however, this technique will often be controversial. If the advanced organizer is successfully done, it can make visitors feel more comfortable with what follows. If the advanced organizer is misinterpreted in any fashion, the rest of the lesson may be spent correcting the visitors' misinterpretation of what is supposed to be happening.

We hope you will enjoy Module 1 as much as we do, and at its end, your workshop participants will have a list of fundamental issues about communication in the planetarium.

Module 2
A Framework for Examining Planetarium Programs

This is a very "talky" unit and may take less time than any other module. There are two main functions of Module 2 in the context of the workshop. First, the module introduces the framework of *Subject-Visitor-Instructor.* Looking at interactions between pairs or all three is the basic pattern of the following modules.

The second function is to let the participants in your workshop describe to each other their own work and goals. We found that the remainder of the workshop went more smoothly if participants knew of their colleagues' interests.

The only materials you need for Module 2 are a blackboard and chalk, or an overhead projector and marking pen, for recording the participants' ideas.

This module occasionally catches fire if participants find they have basic philosophical disagreements. At one workshop, participants were equally divided between those who felt that classical, visual astronomy was the only legitimate subject for a planetarium, and those who felt that recent developments in astronomy were most important even if they were not related to what the basic planetarium projector could show.

While we have no resolutions to offer, we believe that the techniques in the workshop will help planetarium educators achieve their goals regardless of the particular subjects to be presented.

Module 3
Organization Patterns

Many participants found this the most exciting module because it immediately gets down to practical demonstrations of planetarium education techniques. This module takes more preparation than any other because the workshop leaders need to prepare the planetarium to present fragments of several different programs.

The fragments come from Activity #6, pages 66-67, and from the program "Constellations Tonight" in Appendix D. Please examine the materials and preparation needed which are fully described with the activity and the program write-ups.

We found it valuable to discuss the planetarium presentations in detail with the host planetarium staff several weeks before the actual workshop. For example, reading lights are needed for some of the activities. In some cases, the host planetarium already had under-the-cove lighting that was suitable. In other cases, we brought along extension cords and half a dozen clamp-on light sockets with red bulbs.

In any event, there was nearly unanimous agreement that the effort required for Module 3 paid off in insight and practical techniques.

The table that opens Module 3 is to be filled out by the participants as they finish each section of the module. The advantages and disadvantages of each technique will depend greatly on the particular program in which the technique is used, but here are some overall guidelines:

In the *Didactic Organization* the instructor can select and order all of the ideas to be included in the program, and present them rapidly and efficiently. The principal disadvantage is that the instructor may not know whether any of that information is reaching the visitor.

The *Small Group Task Organization* is a good way to start audience participation. This technique has the advantage of providing group support for visitors who might be intimidated if asked to do the task alone. A disadvantage is that small groups really must be small--preferably three to six people each--so that no visitor is lost in the group. With huge audiences, this may mean that there are too many groups and that the instructor cannot give each group time to report its results. As with all activity organizations, there is always the difficulty of finding an activity that is sufficiently challenging and at the same time practical for everyone.

In the *Individual Task Organization* each visitor's accomplishments can engender a sense of personal pride. Individual tasks work well with either small or large audiences. Hearing a visitor call out "I got it!" is a delightful confirmation of the benefits of this organization. A disadvantage of this technique is the possibility that some individuals may not succeed at their assigned task. This danger can be avoided by carefully selecting and testing each activity.

The *Informal Discussion Organization* gives visitors an opportunity to express their feelings and reduce the formality and rigid structure of the planetarium visit. Visitors also appreciate the opportunity to confirm their feelings about how a program or activity is going. This organization, however, gives you no guarantee of just what will happen, and indeed, whether the informal discussion is valuable or not may vary from group to group.

The *Group Meeting Organization* allows visitors to talk with each other in a controlled atmosphere with clear goals in mind. The group may amaze itself with its ability to find answers that no *one* member of the group could have determined alone.

The group meeting does require careful initiation and some skill on the part of the facilitator. The group may take a long or a short time to reach its conclusions, so this organization may not be easy to fit into a rigid time schedule.

The *Socratic Organization* is like the didactic in that the instructor controls the progress and the rate of information presented. Unlike the didactic organization, however, the questions and visitors' responses in the Socratic scheme allow some visitor participation and give the instructor continuous feedback on how well the responding visitors are following the program. This technique does require great skill on the part of the instructor so that the organization does not become too authoritarian and intimidating.

The authors' answers for the examples of organization skills on the last page of the module are: 1) Socratic, 2) Didactic, 3) Individual Task, 4) Small Group Task; 5) Group Meeting, and 6) Informal Discussion.

Module 4
How the Visitors See It

This is the most theoretical and perhaps the most fundamental module because it presents a serious philosophy about how people learn. The applications that have been found for these theories go far beyond the planetarium, and participants may find these ideas useful both inside and outside of a starry dome.

The required materials are those to set up the Martian Dilemma Problem. You will need three small spheres on stands. Styrofoam balls and cardboard or wooden mounts will do. You also need a small plastic or paper figure to stand on the Mars sphere and a bare light bulb to represent the sun.

Many of the questions asked in this module are answered in the text itself. On page 22, Question 1 should be answered Egocentric and Formal. For Question 2, a visitor would have to imagine himself observing the objects in each picture from within the plane of the picture itself to understand the *concept*. That's a formal level task, but it could be made concrete if a three-dimensional model of a spiral galaxy could be passed around the audience or if a continuously rotating projection could be shown so that the visitors actually see a single galaxy as their observation point moved in and out of the galactic plane. The figure on Page 23 clearly requires formal level reasoning because the sets of individual pictures can be understood only if the visitor realizes that they are presented from three different frames of reference.

In Section B, Classification 1 is Formal, 2 is Egocentric, 3 is Concrete, and 4 is Egocentric.

On page 31, the explainer in the first cartoon strip is thinking egocentrically. In the second cartoon, the wizard on the right is displaying formal reasoning.

Module 5
Questioning Strategies

Many participants found the strategies described here to be as useful in classroom work as in the planetarium. Questions and answers are useful both as an alternative to didactic lectures and as a means of finding out what your visitors or students know.

The main difficulty with this module is that the categories of questions are not iron-clad, and it's easy to get into arguments about how a particular question should be classified. However, the process of analyzing one's own questioning strategy is extremely useful even if the category system is not mathematically precise. This is another "talking" module, and no physical materials are required. On Page 41, we would classify the questions in the sample transcript as: 1) D, 2) M, 3) O, 4) O, 5) D, 6) D, 7) M, 8) R, 9) F, 10) M.

Module 6
Activities for the Planetarium

Module 6, like Module 3, gets down to practical examples of activities in the planetarium. Three sample activities are discussed, all from "The Red Planet Mars" program given earlier. Please consult page 161 for a list of materials that you will need. As in Module 3, it is especially important to consult with the host planetarium. For example, you must determine whether the planetarium projector has a satisfactory Mars for the first activity.

As noted on Page 91, we expanded this module by inviting participants to work on a "small group task" to develop and present an activity to their colleagues. We limited each presentation to fifteen minutes, followed by fifteen minutes of open discussion about how the activity might be expanded, improved, and incorporated into an entire program. For many of the participants, the presentation and discussion of these activities were the highlights of the workshop.

We would classify the three sample activities from "The Red Planet Mars" as follows.

Activity	Pattern of Organization	Reasoning Level	Activity Strategy
Find the Planet	small group task	concrete	synthesizing
Mapping Mars	small group task	concrete	direct info
Exobiology	individual task	concrete	open-ended

Module 7
Putting It All Together

Module 7 is a review of the entire workshop. To provide examples of how the concepts presented in the modules are applied, we found it useful to center discussion around the participants' activities, presented in Module 6.

Before beginning the discussion, draw an *Outline* like that on page 88, on a blackboard or overhead projector. In the left-hand column, list each of the activities that were presented. When the group assembles, start by briefly reviewing the categories developed in Modules 3, 4, and 5, which form the headings for the next three columns of the *Outline*. Then, present the "group meeting" task of classifying each activity according to the categories listed at the head of each column. Your job is to facilitate the discussion and list one or more answers for each cell in the *Outline*.

According to many of the participants, this final discussion was the most helpful of the workshop in understanding the implications of many of the techniques that were presented in previous sessions.

If there is sufficient time you might wish to present one of the pre-post activities that are described at the end of each of the planetarium programs in Appendix D. One of the most popular activities, that can be done in about a half-hour, is *Cosmic Creatures* described on pages 187-192.

Finally, we recommend that you prepare an evaluation form on which visitors can indicate what they liked and didn't like about each module. A summary of these evaluation forms will be very useful to you or to any of the participants who may wish to present a workshop in the future.

When Your Workshop Is Over

We'd like to hear what happened. Your experiences can help us improve these materials, and we'll pass your comments on (if you wish) to others who may be trying their own versions of the workshop. Our address is on the back of the title page.

4. Ordering Materials from the Lawrence Hall of Science

Slides and posters used in this workshop and in the model programs in Appendix D are available from the Astronomy Program at the Lawrence Hall of Science. As long as our stock lasts, we are providing these materials at our cost as a service to planetarium educators.

If you wish to order any of the materials below, please send a copy of this form with a purchase order, check, or money order made payable to "Regents of the University of California." If you wish larger quantities (for example, multiple classroom sets of the posters) please write for price and shipping cost information.

MATERIALS Available from the Lawrence Hall of Science (Order Form)			
Description	*Price*	*Quantity*	*Total*
Slide set for "The Red Planet Mars" -- 21 slides made directly from our original sources.	$15.75/set		
Four Kodalith slides, *Versions of the Big Dipper*, for the "Constellations Tonight" program. These slides are intended for use in a "brute force" projector, so you will have to vary the magnification to fit your planetarium.	3.00/set		
Poster for classroom activities to supplement "Constellations Tonight": a large September-October sky map.	.50		
Six posters for classroom activities to supplement "Red Planet Mars."	1.50/set		
Artwork and slides for Activity #6, "Observing a Variable Star"--clean copy of the visitor data sheet for reproduction, a Kodalith slide of the comparison star magnitude numbers, and 11 Kodalith slides illustrating eclipsing binary star light curves.	9.00/set		
TAX. California residents add 6% sales tax. BART counties, 6-1/2%.			
SHIPPING. Handling and shipping is included in the prices given above *except* for posters, which are mailed in a stiff tube. Each tube holds up to 12 posters and costs $3.00, including shipping.	3.00/tube		
TOTAL ⟶			

Prices and availability are subject to change without notice. Orders should be sent to Workshop Guide, Astronomy Education Program, Lawrence Hall of Science, University of California, Berkeley, California 94720.

Appendix B

1978 WORKSHOP PARTICIPANTS

CANADA

Claude Faubert, Ontario Science Center, 770 Don Mills Road, Don Mills, Ontario, Canada, M3C 1T3, (416) 429-4100

Allan Fawcett, Centennial Planetarium, Box 2100, Calgary, Alberta, Canada, T2P 2M5, (403) 264-2030

John Musgrave, Provincial Museum of Alberta, 23845 102nd Edmonton, Alberta, Canada, T5N 0M6, (403) 452-2150

PUERTO RICO

Delores Balzac, University of Puerto Rico, Physics Department, Mayaguez Campus, Mayaguez, Puerto Rico 00708, (809) 832-4040

USA

California

Edna K. Devore, Independence High School Planetarium, 1776 Educational Park Drive, San Jose, California 95133, (408) 926-1776

Alan J. Friedman, Holt Planetarium, Lawrence Hall of Science, University of California, Berkeley, CA 94720, (415) 642-0552

Jean Henry, Shreder Planetarium, Shasta County Schools, 1644 Magnolia Street, Redding, California 96001, (916) 244-4600

Victoria Lindsay, 404 Arballo Drive, San Francisco, California 94132, (San Francisco State University Planetarium), (415) 685-1230

Lawrence Lowery, School of Education, Tolman Hall, University of California, Berkeley, CA 94720, (415) 642-4206

James Park, San Luis Obispo Senior High School Planetarium, 1350 California Boulevard, San Luis Obispo, California 93401, (805) 544-5770

Richard Poremba, Astronomy for America, Inc., 9345 Easton Avenue, San Bruno, California 94066, (415) 871-0566

Steven Pulos, Holt Planetarium, Lawrence Hall of Science, University of California, Berkeley, CA 94720, (415) 642-3679

Sonia Silva, Science Center, Sierra College, 5000 Rocklin Road, Rocklin, California 95677, (916) 624-3333

Cary I. Sneider, Holt Planetarium, Lawrence Hall of Science, University of California, Berkeley, CA 94720, (415) 642-4429

Marvin J. Vann, Foothill College Planetarium, 12345 S. Almonte Avenue, Los Altos Hills, California 94022, (405) 948-8590

Don Warren, City College of San Francisco, 50 Phelan Avenue, San Francisco, California 94112, (415) 239-3242

Lori Warren, Rosicrucian Planetarium, 1342 Naglee Avenue, San Jose, California 95126, (408) 287-9171

Kingsley Wightman, Chabot Science Center, 4917 Mountain Boulevard, Oakland, California 94619, (415) 531-4560

Kenneth Wilson, Morrison Planetarium, Golden Gate Park, San Francisco, California 94118, (415) 221-5100

Kay Woolsey, Santa Barbara Museum of Natural History, 2559 Puesta del Sol, Santa Barbara, California 93105, (805) 682-4834

Colorado

Charles Percival, Venus Planetarium, 2525 Mountainview Drive, Pueblo, Colorado 81008, (303) 542-8077

Mark S. Sonntag, Fiske Planetarium, University of Colorado Boulder, Colorado 80302, (303) 492-5002

Connecticut

Rachel P. Fitch, New Canaan High School Planetarium, New Canaan, Connecticut 06840, (203) 966-9427

John F. Lindholm, 151 Deercliff Road, Avon, Connecticut 06001, (203) 677-2206, (Gengras Planetarium, Hartford; New Milford High School Planetarium, New Milford)

Delaware

Helen K. Moncure, Christiana High School Planetarium, Newark, Delaware 19713, (302) 731-2125

Florida

Nedra A. Lexow, Discovery, 231 S.W. 2nd Avenue, Ft. Lauderdale, Florida 33301, (305) 462-4115

Idaho

Steve Holland, Craters of the Moon National Monument, Rock Creek Nature Center, Box 29, Arco, Idaho 83213, (208) 527-3257

Indiana

Jennie Howe, Washington Township Planetarium, 1801 E. 86th Street, Indianapolis, Indiana 46240, (317) 259-5362

Kansas

Mary Jane Butler, Hutchinson Planetarium, 1300 North Plum, Hutchinson, Kansas 67501, (316) 662-2305

Dean Zollman, Department of Physics, Kansas State University, Manhattan, Kansas 66506, (913) 532-6798

Louisiana

Jesse W. Scott, Arabi Park Middle School Planetarium, Mehle Avenue and N. Rocheblave Street, Arabi, Louisiana 70032, (504) 271-0471

Maryland

Jane A. Bubeck, Patapsco Middle School Planetarium, 403 Old Frederick Road, Ellicott City, Maryland 21043, (301) 465-7121

David Candey, Jr., RD 7 Box 194, Elkton, Maryland 21921, (301) Maryland 20031, (301) 423-6565 (Oberlin College Planetarium, Oberlin, Ohio)

Lora Chamblee, RD 7 Box 194, Elkton, Maryland 21921, (301) 287-5321 (North East High School Planetarium)

Joseph DiRienzi, Kathleen Price Bryan Planetarium, N. Charles Street, Baltimore, Maryland 21210, (301) 435-0100

Massachusetts

W. Russel Blake, Plymoutn-Carver Planetarium, Long Pond Road, Plymouth, Massachusetts 02360, (617) 746-8450

Michael Burke, Plymouth-Carver Planetarium, Long Pond Road, Plymouth, Massachusetts 02360, (617) 746-8450

Jo Ann Coplin, Basset Planetarium, Department of Astronomy, Amherst College, Amherst, Massachusetts 01002, (413) 542-2075

Michigan

Garry Beckstrom, Exhibit Museum Planetarium, University of Michigan, 1109 Geddes, Ann Arbor, Michigan 48109, (313) 764-0478

Minnesota

Lawrence B. Moscotti, Como Planetarium, 780 W. Wheelock Parkway, St. Paul, Minnesota 55117, (612) 489-8035

Nebraska

Carl Rump, Dale Planetarium, Box 77, Wayne State College, Wayne, Nebraska 68787, (402) 375-2200

Dirl H. Steffe, Chadron State College Planetarium, Math and Science Building, Chadron, Nebraska 69337, (308) 432-4451

Nevada

Dave Hostetter, Fleischmann Atmospherium and Planetarium, University of Nevada, Reno, Nevada 89507, (702) 784-4812

New Jersey

Rosendo Abreu, C.S.D. Planetarium at I.S. 184, 523 44th Street, Union City, New Jersey 07087, (212) 993-2964

Higinio D. Rodriguez, C.S.D. Planetarium at I.S. 184, 523 44th Street, New Jersey 07087, (212) 993-2964

New York

Steven M. Bernstein, P.S. 24 Planetarium, 660 W. 236th Street, Bronx, New York 10463, (212) 220-8446

Victor Chung, Physics Department, City College of New York, New York, New York 10031, (212) 690-6879

Juan Fonseca, I.S. 184, 778 Forest Avenue, Bronx, New York 10456, (212) 993-2964

Michael Gosiewski, Marlboro Central High School, Cross and Plattekill Roads, Marlbore, New York 12542, (914) 236-4252

Tom Hamilton, Wagner College Planetarium, Grymes Hill, Staten Island, New York 10301, (212) 390-3010

Eugene G. Harple, Lindenhurst Schools Planetarium, 350 S. Wellwood Avenue, Lindenhurst, New York 11795, (516) 226-6536

Bill Kinsella, Schenectady Museum Planetarium, Nott Terrace Heights, Schenectady, New York 12308, (518) 372-3386

Kent T. Leo, 3850 Sedgwick Avenue, Bronx, New York 10463, (212) 292-0262 (I.S. 184--District 7)

Charles S. Neleson, 75 Jamaica Avenue, Plainview, New York 11803, (212) 229-5029 (Kryger Planetarium)

Murray Spindel, Freeport High School Planetarium, Brookside Avenue, Freeport, New York 11520, (516) 623-2100

Samuel A. Storch, Edwin P. Hubble Planetarium, E.R. Murrow High School, 1600 Avenue "L", Brooklyn, New York 11230, (212) 258-9283

Ohio

Robert Andress, Warrensville Heights High School Planetarium, 4270 Northfield Road, Warrensville Heights, Ohio 44128, (216) 752-8590

Ron Derewecki, Coshocton Public Schools Planetarium, Coshocton Middle School, Seventh Street, Coshocton, Ohio 43812, (614) 622-1058

Bill D. Kobel, Fairview High School Planetarium, 4507 W. 213th Street, Fairview Park, Ohio 44126, (216) 333-4250

Bud Linderman, Midpark Planetarium, 7000 Paula Drive, Middleburg Heights, Ohio 44130, (216) 234-6884

Gary E. Mechler, Cincinnati Museum of Natural History, 1720 Gilbert Avenue, Cincinnati, Ohio 45202, (513) 621-3889

Oklahoma

Jolene Ingram, 2600 N.W. 63rd #85, Oklahoma City, Oklahoma 73116, (405) 755-6777

Ron P. Olowin, Omniplex, Kirkpatrick Planetarium, 2100 N.E. 52nd Street, Oklahoma City, Oklahoma 73111, (405) 424-5561

Oregon

Gary M. Bogner, H.C. Kendall Planetarium, Oregon Museum of Science and Industry, Portland, Oregon 97221, (503) 248-5925

Pennsylvania

Henry D. Dobson, Central Colombia High School Planetarium, 4777 Old Berwick Road, Bloomsburg, Pennsylvnia 17815, (717) 784-2833

Jack Lefkowitz, Interboro Senior High School Planetarium, 16th and Amosland Road, Prospect Park, Pennsylvania 19076, (215) 521-1500

Gerald L. Mallon, Methacton School District Planetarium, Arcola Junior High School, Eagleville Road, Norristown, Pennsylvania 19401, (215) 489-1900

Thomas P. O'Brien, Fels Planetarium, 20th and The Parkway, Philadelphia, Pennsylvania 19103, (215) 448-1292

George Reed, West Chester College Planetarium, West Chester, Pennsylvania 19380, (215) 436-2788

Texas

Barbara Baber, Morgan Jones Planetarium, P.O. Box 981, Abilene, Texas 79604, (915) 673-2751

Jim Clements, St. Mark's Planetarium, 10600 Preston Road, Dallas, Texas 75230, (214) 363-6491

Wynn Godwin, Richardson I.S.D. Planetarium, 447 Crestover Circle, Richardson Texas 75080, (214) 238-8111

John Hicks, Mariam Blakemore Planetarium, Box 5542, Midland, Texas 79701, (915) 683-6441

Lecie Huff, Richardson I.S.D. Planetarium, 447 Crestover Circle, Richardson, Texas 75080, (214) 238-8111

Keith H. Johnson, Poole Planetarium, Odessa College P.O. Box 3752, Odessa, Texas 79760, (915) 337-5381

Eloise Koonce, Richardson I.S.D. Planetarium, 447 Crestover Circle, Richardson, Texas 75080, (214) 238-8111

Bill Lawson, Garland I.S.D. Planetarium, 3505 Hayman Road, Garland, Texas 75043, (214) 271-4152

Sandy Nobles, Richardson I.S.D. Planetarium, 447 Crestover Circle, Richardson, Texas 75080, (214) 238-8111

Jack C. Pemberton, La Porte High School Planetarium, P.O. Box 22, La Porte, Texas 77571, (713) 471-0950

Donna C. Pierce, Dallas Health and Science Museum, P.O. Box 26407, Dallas, Texas 75226, (214) 428-8351

John Pogue, Grand Prairie I.S.D. Planetarium, 301 Warrior Trail, Grand Prairie, Texas 75051, (214) 264-4731

Scott Pohl, Nimitz High School Planetarium, Oakdale at Center Road, Irving, Texas 75060, (214) 259-3621

James Rusk, Mesquite I.S.D. Planetarium, 2501 Memorial Parkway, Mesquite, Texas 55149, (214) 288-7429

Barbara Soder, Dallas Health and Science Museum, P.O. Box 26407, Dallas, Texas 75226, (214) 428-8351

Jane Wallace, Witchita Falls Museum and Art Center Planetarium, 2 Eureka Circle, Witchita Falls, Texas 76308, (817) 692-0923

Utah

Irvin G. Bassett, 191 Eyring Science Center, Brigham Young University, Provo, Utah 84602, (801) 374-1211

William H. Lowry, 220 South 500 W, Apt. #4, Logan, Utah 84321

Virginia

Darrel G. Ardoin, W.T. Woodson High School Planetarium, 9525 Main Street, Fairfax, Virginia 22030, (703) 323-1911

Elvira A. Euler, West Springfield Planetarium, 6100 Rolling Road, Springfield, Virginia 22151, (703) 451-6403

Lee Ann Hennig, Fort Hunt High School Planetarium, 8428 Fort Hunt Road, Alexandria, Virginia 22308, (703) 360-5800

Richard L. Joyce, Penninsula Astronomy Society, 524 J. Clyde Morris Boulevard, Newport News, Virginia 23601, (804) 595-1900

John W. Kritzar, Edison High School Planetarium, 5801 Franconia Road, Alexandria, Virginia 22310, (703) 971-6850

Gina Lynch, Defense Mapping School, Department of Survey, Fort Belvoir, Virginia 22060, (703) 664-4391

Herbert D. Teuscher, Plaza Jr. High School Planetarium, S. Lynnhaven Road, Virginia Beach, Virginia 23452, (804) 486-1971

John W. Trissel, Jr., Rt. 2, Box 281-A, Waynesboro, Virginia 22980, (703) 943-1057 (Augusta County Schools Planetarium)

Chris Vagnos, Hayfield Planetarium, 7630 Telegraph Road, Alexandria, Virginia 22310, (703) 971-8920

Paul D. Wilson, Defense Mapping School, Department of Survey, Fort Belvoir, Virginia 22060, (703) 664-4391

Washington

N.A. Higginbotham, Department of Physics, Eastern Washington University, Cheney, Washington 99004, (509) 359-2874

Dennis Schatz, Pacific Science Center, 200 2nd Avenue, Seattle, Washington 98109, (206) 382-2873

Washington, D.C.

Robert Wehrli, Model Secondary School for the Deaf, Kendall Green, Washington, D.C. 20002, (202) 447-0630

West Virginia

Richard Wonkka, Alderson-Broaddus College Planetarium, Philippi, West Virginia 26416, (304) 457-1700

Wisconsin

Peter Chard, University of Wisconson, Fox Center, 1478 Midway, Menasha, Wisconsin 54952, (414) 734-8731

Paul A. Taylor, Buckstaff Planetarium, University of Wisconsin, Oshkosh, Wisconsin 54901, (414) 424-4429

Appendix C

AN ANNOTATED BIBLIOGRAPHY FOR PLANETARIUM EDUCATORS

An exhaustive bibliography of books and articles of interest to planetarium educators would contain thousands of entries. We have selected several sources in each major category that are likely to be of interest to most readers. Those who wish to go beyond these sources may find it useful to turn to section 9, *Bibliographies and Reviews*, for more comprehensive listings.

The major categories contained in this selected bibliography are as follows:

1. Periodicals Covering Astronomy
2. Books for Observers
3. Books for Elementary Students and Teachers
4. High School and College Texts
5. Collections of Astronomy Activities
6. Articles and Research Relevant to Participatory Planetarium Programming
7. Research in the Classroom Setting
8. Piaget's Theory of Intellectual Development
9. Bibliographies and Reviews

1. Periodicals Covering Astronomy

Astronomy is a beautiful, colorful magazine for the layperson. It's not for those seeking technical information or treatments of the more difficult concepts. Astro Media Corp., 411 E. Mason Street, 6th Floor, Milwaukee, Wisconsin 53202.

Mercury is an excellent, thoughtful journal on popular astronomy that tackles topics like travel near the speed of light and astronomical images in poetry. Critical bibliographies on newsworthy and controversial issues like pseudoscience appear regularly. This magazine is free with a membership in a worldwide astronomical group which also provides many other fine benefits. Astronomical Society of the Pacific, 1290 24th Avenue, San Francisco, California 94122.

Odyssey is the only periodical on astronomy we are aware of that is written expressly for children. It contains activities as well as pictures and short articles. Astro Media Corp., 411 E. Mason Street, 6th Floor, Milwaukee, Wisconson 53202.

Planetarian is published expressly for and by planetarium personnel. Included are articles on programming, finance, technical developments, educational effectiveness studies, cosmic humor, and in short, just about anything you and your planetarium colleagues would like to read about. The journal is free for members of the International Planetarium Society. Write to Walt Tenschert, I.P.S., Membership Chairman, Thomas Jefferson High School, 6560 Braddock Road, Alexandria, VA 22312.

Planetarium Directors' Handbook contains a variety of programs, activities, and technical tips for use in the planetarium. Address inquiries to Planetarium Director's Handbook, Spitz Space Systems, Inc., Chadds Ford, PA 19317.

Science News is easy to read, up-to-date, and informative. If you want to be the first on your block to know what was discovered in the sky last week, this is the magazine for you. Subscriptions Department, 231 West Center Street, Marion, Ohio 43302.

Sky and Telescope is for more technically inclined amateur astronomers and science educators. Very good for people who want to build their own telescopes, or go beyond casual star gazing. Fine photo-essays on observatories, professional and amateur. Sky Publishing Corporation, 49-50-51 Bay State Road, Cambridge, Massachusetts 02138.

2. Books for Observers

Norton, Arthur, *Norton's Star Atlas and Reference Handbook*, 1973, Sky Publishing Corp., 49-50-51 Bay State Road, Cambridge, Massachusetts 02138. This is the standard reference for amateur astronomers, and includes star charts, lists of interesting objects to look at and a capsule report on the state of astronomical knowledge.

Paul, Henry E., *Telescopes for Skygazers*, 1976, American Photographic Book Publishing Co., Garden City, New York. Available from Sky Publishing Corp. (for address see reference to Norton, above.) This is the best book available on selecting a telescope and accessories.

Peltier, Leslie C., *Starlight Nights*, 1965, Harper and Row, New York. Peltier is one of the greatest comet-hunters of all time, and his autobiography is delightful reading. It's the best introduction in writing to the excitement of being an amateur astronomer.

Rey, H.A., *Find the Constellations*, revised, 1976, and *The Stars: A new Way to See Them*, 1975, Houghton Mifflin Co., Boston. These books provide simple line drawings for identifying constellations. Many users find Rey's constructions visually clear and more meaningful than the traditional Greek and Roman constellation outlines. The first book is for young stargazers (grades 3-7) and the second book is for more mature stargazers (grade 8 and above). See the study by Smith in section 6. of this bibliography for an evaluation of the educational effectiveness of Rey's outlines as used in the planetarium.

3. Books for Elementary Students and Teachers

Atkin, J. Myron, and Stanley P. Wyatt, Jr., Co-Directors, *The University of Illinois Astronomy Program*, 1969, Harper & Row, New York. This series of six booklets presents a comprehensive, activity-based course in astronomy. The concepts selected and level of presentation are best suited for high-ability students in upper elementary and junior high schools.

Bergamini, D., *The Universe*, 1969, Life Nature Library, Time Inc., New York. This is a good book not only for elementary school children, but also for older persons with little knowledge of astronomy. Slightly dated.

Elementary Science Study (ESS) Teachers' Guides, *Daytime Astronomy*, 1971, and *Where Is the Moon?*, 1968, McGraw Hill Book Company, Webster Divison, New York. Here are a number of participatory astronomy activities which can be done during the day, and as homework.

Jobb, Jamie, *The Night Sky Book*, illustrated by Linda Bennett, 1977, a Brown Paper School Book, Little, Brown, & Company, Boston. Attractive illustrations, photos, and suggestions for things to make and do will draw many readers into astronomy. Teachers and parents should be aware, however, that although the book is intended for 5th grade and above, the reading level is too difficult for most children at this age; consequently, *The Night Sky Book* would probably be most effective for junior high students.

MacBean, J.C., A. Stecher, D.F. Wentworth, and J.K. Couchman, Examining Your Environment: *Astronomy*, 1973, Winston Press, Minneapolis. This classroom set has many nice astronomy activities, but doesn't cover any subject in depth.

Moché, Dinah, *What's Up There?*, 1975, Scholastic Book Services, 904 Sylvan Avenue, Englewood Cliffs, New Jersey. This is an excellent and inexpensive "first" book on astronomy for young children.

4. High School and College Texts

In this section we have listed only a few of the more than 50 astronomy textbooks that are now on the market. For an overview of these textbooks, see the two articles by Andrew Fraknoi, cited below.

Abell, George O., *Exploration of the Universe, 3rd Edition*, 1975, Holt, Rinehart, and Winston, New York. Abell is a classic text on astronomy, covering all aspects. The math level is first year algebra.

Fraknoi, Andrew, "An Analysis of Introductory Textbooks in Astronomy," *Physics Teacher*, May, 1978, p. 309.

Fraknoi, Andrew, "Textbooks," *Mercury*, January/February, 1979, p. 20. This article updates Fraknoi's 1978 analysis of astronomy textbooks.

Holton, Gerald, F.J. Rutherford, and F.G.Watson, directors, *Project Physics*, 1970, Holt, Rinehart, and Winston, New York. The *Unit II Text* and *Reader* provide an excellent high school level treatment of the concepts and historical development of astronomy. Laboratory exercises which accompany the program have students plot orbits, measure the height of mountains on the moon, measure the diameter of the earth, and perform other activities.

Jastrow, Robert, and Malcolm H. Thompson, *Astronomy: Fundamentals and Frontiers*, 3rd Edition, 1977, John Wiley, New York. This college level text is one of the best books for a fundamental understanding of astronomy--all without math. It does not cover in depth the motions that can be observed in the sky.

Reed, George, *Naked i Astronomy*, and *The Astronomy of One Constellation*, 1976, Kendall Hunt Publishing Co., Dubuque, Iowa. Designed as a two semester course for secondary or college students, the first volume includes information and activities related to what the students can observe with the naked eye. The second volume covers modern astronomy, relying on examples from the constellation Orion.

5. Collections of Astronomy Activities

American Astronomical Society, *AAS Resource Packet for Teachers*, AAS Education Office, c/o Harry Shipman, Sharp Laboratory, University of Delaware, Newark, Delaware 19711. This packet is a sampling of classroom activities and other resources for middle school teachers.

Knappenberger, Paul H. Jr., editor, *Astronomy Activities for Secondary Schools*, 1976, Science Museum of Virginia, 2500 W. Broad Street, Richmond, Virginia 23220. This set of activities has been distilled from a large number of activities developed by teachers to present astronomy in grades 7-12. The activities have been tested for accuracy of information presented and for workability in the classroom.

Lawrence Hall of Science, Astronomy Education Program, *Sky Challenger--Games for Star Gazers*, 1979, available from Discovery Corner, Lawrence Hall of Science, University of California, Berkeley, CA 94720. This series of interchangeable "sky wheels" provides several naked-eye and binocular observing activities for age 10 to adult.

Middle Atlantic Planetarium Society and the University of Maryland, *Under Roof, Dome, and Sky*, 1973, available from Lee Ann Hennig, 3911 Sonora Place, Alexandria, Virginia 22309 ($8.00). Forty-five activities are described which can be performed in the planetarium. These were designed for use with the new curriculum projects.

6. Articles and Research Relevant to Participatory Planetarium Programming

Bishop, Jeanne, "The Development and Testing of a Participatory Planetarium Unit, Emphasizing Projective Astronomy Concepts and Utilizing the Karplus Learning Cycle, Student Manipulation, and Student Drawing," 1980, unpublished doctoral dissertation, University of Akron, Akron, Ohio. A unit on astronomy was developed to enable students to learn the relationship between two perspectives (on earth and from space) of common astronomical phenomena. The unit was presented to one group using a traditional method of instruction and to another group using the Karplus Learning Cycle, a specific "participatory" approach. Both groups performed better on an immediate post-test than did a no-treatment control group, but there was no significant difference between groups exposed to the two instructional methods. A delayed post-test, however, revealed that the students exposed to the participatory approach retained significantly more of what they had learned than did students exposed to the traditional approach.

Curtin, John T., "An Analysis of Planetarium Program Content and the Classification of Demonstrator's Questions," 1967, unpublished doctoral dissertation, Wayne State University. Curtin analysed 38 recording tapes and 35 questionnaires of planetarium programs presented to school children. "According to Bloom's criteria, all but 9 of 413 questions were in the knowledge class." Seven questions were in translation. One was in analysis of relationships, and one was in extrapolation.

Fletcher, Jack, "An Experimental Comparison of the Effectiveness of a Traditional Type Planetarium Program and a Participatory Type Planetarium Program," 1977, unpublished doctoral dissertation, University of Virginia at Charlottsville. Fifteen planetarium instructors presented participatory and traditional versions of a program on Stonehenge and how it relates to the annual rising and setting points of the sun. Since discussion was permitted during the "traditional" programs, the only difference between the two presentations was the physical activities. When data from all of the instructors were combined, both methods were found to be educationally effective, but no significant difference was found between them. However, the students of six of the instructors learned significantly more from the participatory program than from the traditional program,, and a significant difference in the opposite direction was found for two instructors. This finding led Fletcher to conclude that the instructor was a more important factor in student achievement than the method of instruction.

Friedman, Alan J., "Alternative Approaches to Planetarium Programs", 1973, *Mercury*, v.2, Jan/Dec, pp. 12,18. Presents two alternative approaches to planetarium programming: 1) actively involving the visitors in activities during the program; and 2) presenting astronomy concepts within their cultural context.

Friedman, Alan J., "Interactive Public Planetarium Programs", *Proceedings of the 1974 Conference of ISPE*, International Society of Planetarium Educators, Special Report #6, Atlanta, GA, pp. 52-55. Describes interactive programs at the Holt Planetarium. A variable star observing activity is offered as an example of how visitors can interact with materials and the instructor during the program.

Friedman, Alan J., "Participatory Planetarium Shows", *Planetarium Director's Handbook*, 1975, no. 32, Spitz Space Systems, Chadds Ford, PA. Presents six activities that can be used during planetarium programs to enable the visitors to learn about the concepts and process of astronomy.

Friedman, Alan J., Dennis L. Schatz, and Cary I. Sneider, "Audience Participation and the Future of the Small Planetarium", 1976, *Planetarian*, December, pp. 3-8. This article offers a more precise definition of "participatory" programs, and extends the rationale for this approach to include economic considerations and research in the fields of education and psychology.

Mallon, Gerald, "A Pilot Study: Tape vs. Live Teaching," 1974, *Science Activities*, vol. 11, no. 5, pp. 10-11. Mallon performed a carefully controlled experiment to see if the physical presence of a planetarium instructor makes a difference in learning by the visitors. The same program was presented by automated tape and by an instructor. The group who had the live presentation performed significantly better than the group who had the taped presentation.

Mallon, Gerald, "Student Achievement and Attitudes in Astronomy: An Experimental Study of the Effectiveness of a Traditional *Star Show Planetarium Program* and a *Participatory-Oriented Planetarium Program*," 1980, unpublished doctoral dissertation, Temple University, Philadelphia, Pennsylvania. The study found that the participatory program was more effective than the traditional star show in promoting concept learning and attitude change. The major study, which involved 324 students in Pennsylvania, was complemented by four smaller studies at widely separated regions in the US.

Schafer, Sheldon, "An Experiment in Participatory Planetarium Programming," 1977, *Planetarian*, vol.6, no. 2, pp. 10-21. Planetarium audiences were polled at the conclusion of various programs. The primary results showed that 48 percent preferred the participatory show, 21 percent preferred the theatrical multimedia show, and 31 percent had no preference and enjoyed both shows.

Shafer, Sheldon, "A Brief Negative Encounter With Participatory Shows," 1977, *Planetarian*, vol. 6, no. 3. The author reports the results of a post-visit survey of school groups that experienced participatory planetarium programs. Although students claimed to prefer participatory shows, teachers expressed the following reservations: 1) there was too much questioning and answering, 2) the show was not as visually interesting as conventional shows, 3) only the brightest students tended to participate, and 4) the teachers believed that the students enjoyed the conventional show more.

Schatz, Dennis, Greg Swanson, and Dave Taylor, "Cerebral Participatory Programs: Their Role in the Planetarium", 1978, Pacific Science Center, Seattle, Washington (paper presented at IPS Convention in Washington, D.C.) Describes a study which compared two types of interactive programs: a program which involves the visitors in physical manipulation of star maps, and a program in which a slide was substituted for the actual maps and verbal discussion was substituted for the actual performance of the star map activity. Both groups performed equally well on paper-and-pencil tests of the visitors' abilities to use star maps. Cerebral participation seems especially suited to large planetariums in which some types of physical activities are difficult to arrange.

Smith, Theodore V., "The Effectiveness of Constellation Figures," 1974, *Planetarian*, vol. 3, no. 3&4, pp. 74-83. This research report on methods for teaching constellation recognition describes previous studies and critically reviews their weaknesses. The central focus of the article is a well-controlled study which showed that constellation figure outlines used during the program do not help visitors recognize the constellations on a test.

7. Research in the Classroom Setting

Dunkin, M. and J. Biddle, *The Study of Teaching*, 1974, Holt, Rinehart, and Winston, New York. This is the most extensive review ever published on classroom research, containing over 1,000 research studies summarized in a coherent and readable format.

Lowery, Lawrence F., *Learning About Learning: Questioning Strategies*, 1973, University of California, Berkeley, CA (for address, see reference to Lowery in Section 8 of this bibliography). This booklet contains personal workshops that instructors in all disciplines can use to improve their own questioning strategies. Also included is a bibliography on the use of questions in the classroom.

Moriber, George, "Wait-Time in College Science Classes," *Science Education*, 1971, vol. 55, no. 3, pp. 321-328. Describes research on wait-time following teachers' questions at the college level.

Rowe, Mary Budd, "Science, Silence, and Sanctions," 1969, *Science and Children*, March, pp. 11-13. Very readable description of research and wait-time following teachers' questions and the use of rewards and punishments with elementary school science students.

8. Piaget's Theory of Intellectual Development

Bishop, Jeanne, "Planetarium Methods Based on the Research of Jean Piaget," 1976, *Science and Children*, May, pp. 5-8. In this article, Biship relates Piaget's stages of intellectual development to concepts that are frequently taught in the planetarium. Relevant for teaching preschool through adult.

Charles, C.M., *Teacher's Petit Piaget*, 1974, Fearon Press, Belmont, California. Possibly the best brief and inexpensive ($2.00) introduction to Piaget's work and its implications for education.

Cowan, P.A., *Piaget With Feeling*, 1978, Holt, Rinehart, and Winston, New York. A general summary of Piaget's work and theory for those working directly with children. It offers an excellent section on the motivational and affective consequents and correlates of Piaget's cognitive stages.

Elkind, David, "Piaget and Science Education," 1972, *Science and Children*, November, pp. 9-12. This is one of the best articles concerning the implications of Piaget's theory for science education.

Lowery, Lawrence F., the *Learning About Learning* series includes the following booklets on Piagetian theory and research: *Classification Abilities*, 1973, *Conservation Abilities*, 1974, and *Propositional Abilities*, 1974, University of California. Available for $3.00 per booklet plus tax and handling, from the author, 4531 Tolman Hall, University of California, Berkeley, CA 94720. Each booklet is a self-contained personal workshop in how to interview students to assess their level of intellectual development. Summaries of the relevant research studies are also included to help the reader relate the results of these interviews to the work of others.

Piaget, Jean, *The Child's Conception of the World*, 1929, Harcourt, Brace, Jovanovich, New York.

Piaget, Jean, *The Child's Conception of Physical Causality*, 1970, Kegan Paul, London.

Piaget, Jean, and Barbel Inhelder, *The Child's Conception of Space*, 1956, Routledge and Kegan Paul, London.

Piaget, Jean, and Barbel Inhelder, *The Growth of Logical Thinking from Childhood to Adolescence*, 1958, Basic Books, Inc., New York.

Piaget, Jean and Barbel Inhelder, *The Child's Conception of Geometry*, 1960, Basic Books, Inc., New York.

Piaget, Jean and Barbel Inhelder, *The Early Growth of Logic in the Child*, 1964, Harper and Row, New York.

Schatz, Dennis, and Anton E. Lawson, "Effective Astronomy Teaching: Intellectual Development and Its Implications," 1976, *Mercury*, July-August, pp. 6-13. This article applies Piagetian theory to astronomy concepts commonly taught at the high school and college levels.

Schatz, Dennis, A. Fraknoi, R. Robbins, and C. Smith, *Effective Astronomy Teaching and Student Reasoning Ability: A Self-paced Workbook*, 1978, Lawrence Hall of Science. This 200-page paperback is available for $8.00 plus postage and handling from the Astronomical Society of the Pacific, 1290 24th Avenue, San Francisco, California 94122. First presented at a meeting of the American Astronomical Society, this workbook is a self-contained program for improving astronomy teaching at the high school and college levels. It includes an introduction to Jean Piaget's theory of intellectual development and its implications for science teaching, as well as sections for analyzing reading materials, laboratory activities, and films. Comprehensive appendices list resources for use in astronomy courses.

Wadsworth, B., *Piaget for the Classroom Teacher*, 1978, Longman, New York. An excellent background to Piaget's theory and research together with applications for education. It also contains excellent chapters on Piaget's theory as applied to science education and evaluation.

9. Bibliographies and Reviews

Berendzen, Richard and David DeVorkin, "Resource Letter EMAA-1: Educational Materials in Astronomy and Astrophysics," June, 1973, and "Resource Letter EMAA-2: Laboratory Experiences for Elementary Astronomy" by Haym Kruglak, September, 1976, *American Journal of Physics*. The *Journal* can be found in most libraries, or reprints can be ordered from the American Association of Physics Teachers, Graduate Physics Building, SUNY at Stony Brook, Stony Brook, New York 11794.

Bishop, Jeanne E., "United States Astronomy Education: Past, Present, and Future," 1977, *Science Education*, vol. 61, no. 3. This comprehensive review of activities in astronomy education sketches the changes in public policy, curricula, professional organizations, and the role of astronomy in the schools from 17th century Colonial America to the present.

Fraknoi, Andrew, *Resource Book for the Teaching of Astronomy*, 1977, W.H. Freeman, San Francisco. This guide was written to accompany Ivan King's introductory college text, *The Universe Unfolding*, but teachers at all levels from junior high up will find it invaluable, regardless of the text being used. Fraknoi summarizes the crucial ideas of each topic in astronomy, and recommends films, articles, slides, discussion ideas, and even quiz questions.

Reed, George, *A Bibliography for Planetarium Educators, Parts I and II*, contained in ISPE Special Report #2, 1972, and #4, 1974, International Society of Planetarium Educators. Reprints are available from the International Planetarium Society. Write to: Walt Tenschert, I.P.S. Membership Chairman, Thomas Jefferson High School, 6560 Braddock Road, Alexandria, VA 22312. This is the most comprehensive listing of research available, although the bibliography is not limited to research. Each study is annotated in detail.

Sunal, Dennis W., Cynthia S. Sunal, and Sarah H. Cowan, "Resources for Teaching Astronomy," 1979, *Science Activities*, vol. 16, no. 1, pp. 31-39. This bibliography contains a large number of articles for teaching astronomy; relevant for primary grades through college.

Sunal, Dennis, "Analysis of Research on the Educational Uses of a Planetarium," 1977, *Journal of Research in Science Teaching*, vol. 13, no. 4, pp. 345-349. Since Sunal rejected all studies which did not provide data on visitor learning, he was left with nine studies to review. Perhaps the most important finding of this review was that research does not support the traditional one-visit planetarium unit--more can be done in a classroom.

Wall, Charles A., "A Review of Research Related to Astronomy Education," 1973, *School Science and Mathematics*, vol. 73, no. 8 (November), pp. 653-669. This article describes a number of interesting studies which are neglected in other reviews, since studies outside of the planetarium setting are included.

Warneking, Glenn E., "Planetarium Education in the 1970's-- A Time for Assessment," 1970, *Science Teacher*, vol. 37 (October), pp. 14-15. This is the earliest review of research studies, and raises a number of points which should be considered in planetarium research.

Appendix D

CONSTELLATIONS TONIGHT

A Program From the William K. Holt Planetarium
Lawrence Hall of Science
University of California, Berkeley, CA 94720

CONSTELLATIONS TONIGHT
A PROGRAM FROM THE HOLT PLANETARIUM

Table of Contents

Preface

Constellations Tonight was designed for public audiences and for school children in grades four and above. With simpler star maps and other slight modifications, it could be presented to somewhat younger audiences as well.

The program begins by inviting the visitors to locate a familiar constellation, the Big Dipper. Then a brief discussion brings out the many possible functions of constellations for the people who invented them. An optional activity for younger school groups helps the children understand the origin of constellation figures by creating their own.

The major activity teaches the visitors how to use a star map for finding specific constellations in the planetarium sky. Visitors then take turns pointing out their constellations to the entire audience. As each constellation is identified, the instructor may project artists' conceptions of the constellation outlines, tell a short version of the relevant star myth, and/or show telescope views of star clusters, nebulae, or galaxies that can be found in the constellation.

We would be very grateful to hear from you about how you used this program, what modifications you made, what worked well and what didn't work well.

Objectives

After attending this planetarium program, the visitors will be able to:

1. Explain that constellation figures are created by people in many societies. Although there are many different possible constellation figures for a given pattern of stars, everyone in a given culture generally agrees on a single figure for each star pattern that is thought to be important.
2. Describe at least two functions that constellations serve for the people who share them;
3. Use a star map to find constellations in the planetarium sky, and ultimately in the real night sky; and
4. Realize that they can use the star map they take home, and feel that it is fun and satisfying to find constellations in the sky.

Acknowledgements

The particular versions of the Dipper mentioned on pages 124-125 come from the following sources (referenced fully on page 126):

Greek myth and "Bear and the Oak Tree" myth from Staal's *Patterns in the Sky*.

"Five Wolf Brothers" myth from Clark's *Indian Legends of the Pacific Northwest.*

Materials

The following special materials are required to present this program in your planetarium:

1) **A one-page star map** for the current season for each participant to use and to take home. Copies of the maps we use are attached to this program. You may wish to develop your own, or you can obtain free permission to reproduce ours by writing to us. Gerald Mallon, of the Methacton School District Planetarium in Norristown, Pennsylvania, suggests using an overhead transparency of the map to explain how to use it. Sheldon Schafer of the Lakeview Museum Planetarium of Peoria, Illinois, prefers the "Formée Cross" style map, developed by R.K. Marshall.

2) **A battery-operated light pointer.** These are available from photographic stores. They may be used as is. We modify ours in the following ways to increase battery life: a) replace the slide switch with a momentary contact push button; b) add a silicon power diode in series with the batteries to drop the voltage; and c) use rechargeable ni-cad batteries.

Optional:

3) **Reading lights for the participants.** We have 7-watt night-light orange bulbs under the cove, with shades so they shine down on the audience. This is very convenient, because visitors can examine their star charts and look back up at the sky freely. The program can also be done by turning up the daylight for people to study their charts, and then turning it down for sky examination.

4) **Constellation outline projectors.** We use the inexpensive "brute force" units from Charles Walker, 33 Beatrice Avenue, Bloomfield, Connecticut 06002. Another optional component of this program is a set of outlines of other versions of Ursa Major--a dipper, a plow, and a group

of figures from a Native American legend. 35 mm Kodalith slides, intended for "orange-juice can brute force projectors" are available from us at cost. See page 97.

5) **Slides** of interesting objects (nebulae, galaxies, planets) in the current sky. We select three or four slides, usually from the Hale Observatories' series or from the Hansen Planetarium set by Charles Capen (15 South State Street, Salt Lake City, Utah 84111). The latter more closely approximate the view in small telescopes.

Script

We don't expect the script which follows to be memorized (as an actor might memorize a part) but to be used as a guide in learning, rehearsing, and improving presentations. We recommend that you read the script once or twice, then work with it in the planetarium, practicing the projector controls, slides, special effects, and music. You should be able to imagine yourself presenting information, asking questions, and responding to participants. For your first few presentations, you can have the script on hand, using major headings as reminders of what to do next.

The script is organized in blocks or sections. The purpose of these separations is only to help you learn and remember what comes next. Once you have begun a section, the slides or special effects and your own train of thought will keep you on track. When beginning a new section, make the transition logically and smoothly.

Directions for the instructor are printed in *italics*, the instructor's narrative is printed in regular type, and directions and questions to which the audience is expected to respond are printed in CAPITAL LETTERS. There is no point in memorizing narration word-for-word since what you need to say will depend upon the participants. The language you use and the number and kinds of questions you ask will depend on how old the participants are, how willing they are to respond, and how easily they seem to understand what is going on.

We believe the most important elements of the program are the questions and the activities since these involve the audience in active learning. If you must shorten your presentation, we recommend that you borrow time from the narration.

The following checklist is suggested as a guide in preparing for each presentation:

1. Latitude: Home.
2. Precession: Current.
3. Time: About 9:00 p.m.
4. Set sun for today's date.
5. Turn off sun, moon, planets, NESW lights.
6. Check constellation outline alignments.
7. Set slide projector on first slide.
8. Turn on daylight, stars and music.
9. Be sure to have a current star map on hand for each member of the audience.
10. Check operation of battery-operated light pointer.

INTRODUCTION

Gradually turn down daylight and music. (Stars will appear.)

Welcome. My name is ---------- and I would like to welcome you to the --------------- Planetarium. Today, you can learn how to use a star map to find the constellations and some of the brightest stars.

The stars which you see now are just as they will appear tonight from our area around nine or ten p.m., if the sky is clear. Let's see if you can find one constellation without any help from me. LOOK AROUND THE PLANETARIUM SKY AND SEE IF YOU CAN FIND A GROUP OF STARS THAT LOOKS LIKE A BIG DIPPER. HOLD UP YOUR HAND WHEN YOU FIND IT.

Wait until most of the participants indicate that they have found it, then give one person the pointer to show everyone else the location. Ask him or her to slowly point out the "handle" of the Big Dipper and the "part that holds the soup." If your person found "another" dipper shape, be positive. Note that there are many dipper-like shapes, all good, but we want the most familiar one. Then ask for another dipper shape to be found.

Every civilization, all over the earth, has names and stories about the stars. Usually, these stories are about a group or "constellation" of stars that seem to form a pattern or shape in the sky. People who lived at different times, in different places, often chose the same groups of stars as constellations, but imagined them to look like the particular animals or gods that were important in their own culture. What we call the Big Dipper, for instance, was called Ursa Major, or the Big Bear, by the ancient Romans. *(Point out parts of bear.)* WHY DO YOU THINK THAT PEOPLE LIKE THE ROMANS, WHO LIVED THOUSANDS OF YEARS AGO, MADE UP NAMES AND STORIES ABOUT THE STARS?

Accept all answers equally, then list the participants' ideas before going on.

One of the reasons for identifying constellations is still important today--finding directions. Sailors, flyers, and even astronauts tell directions by the stars. If you are lost in the woods, but you know that there is a city to the South, you can use the Big Dipper to find Polaris, the North Star. Since Polaris is always in the direction of North, we can use it as a compass in the dark. DOES ANYONE KNOW A GOOD WAY TO FIND POLARIS? *(Usually someone does. In any event, use your pointer to show the pointer stars, Polaris, and the northern horizon and the other direction.)* In fact, Polaris indicates North with more accuracy than a simple magnetic compass. *(Turn on NESW lights.)*

Astronomers today use constellations as convenient direction markers to help name and locate interesting objects, like "the galaxy in Andromeda." We shall use constellations this way in today's program.

MAKING UP CONSTELLATIONS

THIS SECTION IS OPTIONAL. IT IS ESPECIALLY USEFUL FOR ELEMENTARY SCHOOL CHILDREN.

TAKE A LOOK AROUND THE SKY AND SEE IF YOU CAN FIND A GROUP OF STARS THAT LOOKS LIKE SOME KIND OF ANIMAL, PERSON, OR THING. RAISE YOUR HAND IF YOU HAVE AN IDEA THAT YOU WANT TO TELL US ABOUT.

(Allow three or four students to point out their constellations and describe them to the group--try to help everyone see what the inventor of the constellation sees.)

If you had lived thousands of years ago, you might have spent time making up constellations like this, just as you spend time watching TV today.

SKY MAP ACTIVITY

Turn up orange seat lights (or daylight).

Pass out one map to each participant. In some planetariums, it may be more convenient to have done this as people entered. Introduce the activity as follows:

These are maps of the sky which we will use to identify some of the major constellations that can easily be seen this month. After you have some experience using these maps right here in the planetarium, your map will be yours to take home so that you can identify constellations from your own backyard.

(After maps have been passed out, continue.)

These maps represent the sky for ----------- and ---------- months around nine and ten p.m. The whole sky is compressed on these charts to fit within a circle. If you hold the map over your head, and turn the words "Northern Horizon" to the direction of North, the map will show you how the stars in the sky look. The dots on the map represent stars--the bigger the dot, the brighter the star will be. Only the brightest 50 or so stars are marked on the map.

WHAT DO YOU THINK THE BIG CIRCLE ON THE MAP REPRESENTS? The big circle on the maps is intended to represent the "horizon"--where the sky seems to meet the earth, and what you see when you look straight out horizontally. *(Point out, indicating the planetarium horizon.)* If a star on the map is near the words "Northern Horizon," it will be in the northern part of the real sky. *(Point out.)* If the star on the map is near the words "Eastern Horizon," it will be in the eastern part of the sky. *(Point out.)*

The closer to the center of the map a star is, the higher in the sky it will be. WHERE WOULD THE VERY CENTER OF THE MAP BE IN OUR SKY? A star at the very center of the map would be directly overhead in the sky (the point directly overhead is called the "zenith").

As an example, let's see how to use the map to find the Little Dipper, called by its Roman name, Ursa Minor. WHEN YOU FIND URSA MINOR ON THE MAP, RAISE YOUR HAND. IF YOU HAVE TROUBLE, ASK YOUR NEIGHBOR FOR HELP.

When the visitors indicate they have found it, go on.

WHAT DIRECTION SHOULD YOU FACE TO FIND IT?

"North" (or a little east or west of North, depending on the time of year.)

IS URSA MINOR NEAR THE HORIZON OR HIGH UP IN THE SKY?

(Make sure that everyone agrees before going on.)

Now watch me as I use the map to find Ursa Minor in the sky. On the map, Ursa Minor is closest to the "Northern Horizon," so I know I should face North and hold the map over me, with the words "Northern Horizon" forward. When I look at the sky, about this high, I should see the same pattern of stars that appears on the map, and there it is! *(Point out.)* If I were looking for a constellation in the South, I would have turned myself to face South, so that the words "Southern Horizon" were in front of me, and looked that way. *(Demonstrate.)*

Remember, when using your map:

1) First locate the constellation on the map.

2) Determine what direction you must face.

3) Decide if the constellation is high in the sky or near the horizon.

4) Hold the map over you and compare the map with the stars you see in the sky.

It will be easier to locate the brightest stars in your constellation first.

Assign groups to locate constellations. Be certain each group can see its constellation from their own position in the planetarium. Encourage the group members to help each other, to stand up and move around if they need to, and to use the hand pointers to help discuss which stars are which.

Leave reading lights on continuously. Fully dark skies are too full of stars, and all the constellations on these maps can be found in a "light-polluted" planetarium sky.

Offer to help individual groups one at a time, but don't rush them. Don't point out stars for anyone, but talk through the procedure for using the star map step-by-step for their constellations until they are looking in the correct direction. If some groups finish quickly, ask them to find neighboring constellations in the sky. Check to see that all groups have found their constellations before going on.

Is everybody ready? Let me pass around a flashlight-pointer so that one member of each group can show us which stars in the sky you think make up your constellation. Let's begin with the constellation------------ *(appropriate constellation for the season).*

Have one person in each group name the constellation his or her group has been assigned, and then ask everyone to find that one on their maps, and to approximate what part of the sky it should be in. Then have the same person point out where they decided the constellation was, star by star. If they mis-identify it, be positive and encouraging, pointing out how close the resemblance is, and ask them (or others) to try again.

OPTIONAL

As each constellation is identified, you may wish to:

1) Project an outline of the mythological figure, and present a brief summary of the mythology.

2) Show a slide of an interesting object (nebula, cluster, double star, galaxy, etc.) that appears in the constellation. If possible, show a slide of the binocular appearance, as well as one of the appearance in a large telescope.

3) Point out the location of the interesting object in the constellation, and invite the visitors to mark that position on their maps, and look for the object themselves, using binoculars, the next time they are out under dark skies. Mention that these objects are not physically "in" the constellations, but may be very far beyond the stars we can see (like the Andromeda galaxy). The stars of the constellations merely provide convenient direction markers, or frames.

Constellation outlines are a useful way to introduce a brief narrative on the mythological origin of each constellation.

MOTION OF THE STARS

In Spring and Summer, when the Dipper is already overhead, advance diurnal motion only until the Dipper is aligned with the constellation outlines you have prepared, then go directly to "Versions of the Big Dipper." Next return to this section, followed by the "Conclusion." In Winter and Fall, follow the normal order: "Motion of the Stars," followed by "Versions of the Big Dipper," followed by the "Conclusion." If you present the Dipper first, make appropriate minor changes in the following paragraphs.

So we have found each of the major constellations in tonight's sky. IF WE KEPT WATCHING TONIGHT, WOULD THE STARS REMAIN LIKE THIS? WHAT WOULD HAPPEN? WHY? *(Accept ideas from the audience, amplifying and correcting as necessary, in a positive fashion.)* So we can judge that the earth is turning on its axis. Let's go through the entire night, speeded up so that we will come to tomorrow morning in just three minutes. Please keep track of your constellation to see what happens to it during the course of the night. ALSO, PLEASE WATCH THIS STAR, WHICH WE SAID WAS POLARIS. WHAT IS SPECIAL ABOUT ITS BEHAVIOR?

Fade in music, gradually dim orange lights (or daylight), and begin diurnal motion. In Fall and Winter, stop when the "Dipper" is aligned with your constellation outline for the following section (if used).

It is now about two a.m. CAN YOU STILL SEE YOUR CONSTELLATION? WHAT HAS HAPPENED TO IT?

WHAT HAS HAPPENED TO THE BIG DIPPER?

WHAT HAS HAPPENED TO POLARIS, THE NORTH STAR?

Allow time for responses and discussion after each question. Encourage general observations such as "stars seem to rise and set like the sun," or "the North Star always stays still."

VERSIONS OF THE BIG DIPPER (OPTIONAL)

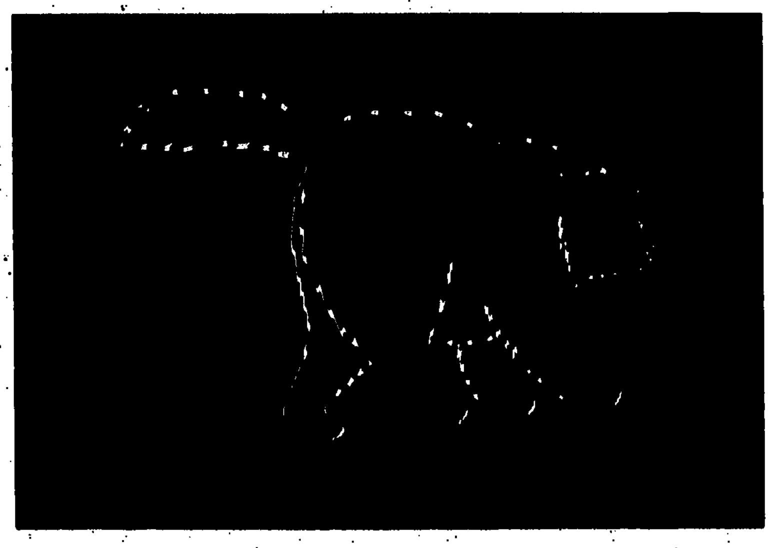
Turn on diurnal motion until "Dipper" mark on projector equator is reached.

Now, to me, the Big Dipper is just that, a big dipper; and indeed, to some people in southern France, this group of stars was the Casserole, or sauce pan.

1) *CASSEROLE OUTLINE*

But to the Romans, the Dipper was just part of a larger constellation, Ursa Major, which means the great bear. TRY TO IMAGINE A BEAR. WHERE IS HIS NOSE; WHERE ARE HIS LEGS? *(etc.)*

2) *BEAR OUTLINE*



Tell the story (page 126) in one minute or less. For example: "Once the king of the gods, Jupiter, fell in love with Callisto, a beautiful young girl. But Juno, the queen of the gods, was very jealous, so she turned poor Callisto into a bear. Jupiter felt sorry for Callisto, so to protect her from hunters, he placed her up in the sky where we can see her every night if we look."

To many Native American tribes, the Dipper was also a bear. It is remarkable that many cultures, so very far apart, came up with the same unlikely image for these stars. But the Native Americans did not draw their bear exactly this same way. Many of you have seen bears in the zoo. WHAT IS WRONG WITH THIS ROMAN VERSION OF THE BEAR? *(Accept ideas from audience.)* So we can see that what's wrong with this bear is its long tail.

If you have lots of time, take another minute to tell the story of the oak tree (page 126).

To the early people in England, the Dipper was neither a dipper nor a bear, but was a plough, drawn by oxen. WHY DO YOU THINK THEY THOUGHT OF THIS CONSTELLATION, WHICH IS HIGH IN THE SKY LIKE THIS IN THE SPRINGTIME, AS A PLOUGH?

3) *PLOUGH OUTLINE*

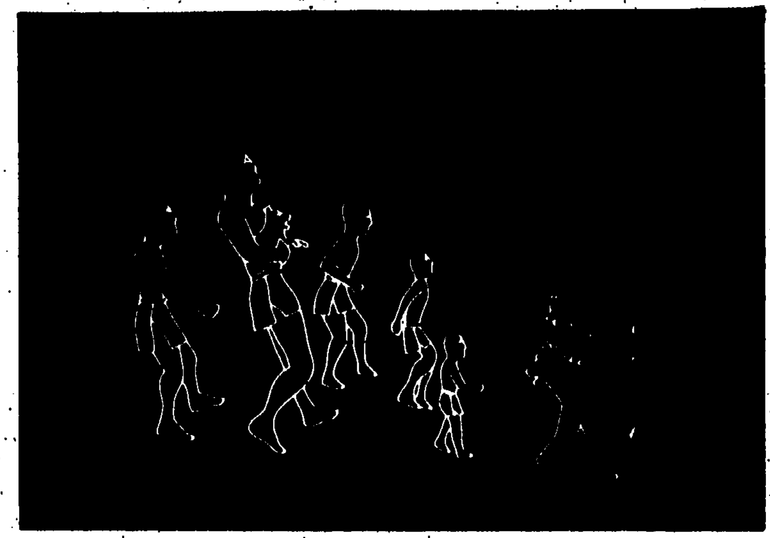
Responses might include "it is time to plant," "it goes round and round like a farmer ploughing his field," etc. Accept all answers.

Finally, I'd like to tell you one last story that is a favorite of mine. It is a Native American story, one from the Wasco Indians of the Pacific Northwest, the area we call Oregon and Washington.

Tell the story of the five wolf brothers (page 126). It would be especially appropriate to use a story from Native American culture of your own planetarium's region.

4) *WOLF BROTHERS*

AND BEAR OUTLINE



There is no "best" or "correct" story, of course. I hope each of you will make up your own story about the Big Dipper and the other constellations. Stars belong to everyone, so your own imagination is just as valid as the ancient Romans' or anyone else's.

CONCLUSION

Now we'll speed up the motion of the earth again and watch what happens.

Gradually fade in music, turn on sun, and begin diurnal motion. After ten or fifteen seconds, gradually turn on red sunrise. As sun disk appears on horizon, slowly turn on daylight and fade out music.

It is now eight o'clock in the morning--time for school and work. Please take your star map with you so you can locate the constellations in the real sky on the next clear night. Thank you for visiting with us in the planetarium. Happy star hunting!

VERSIONS OF THE BIG DIPPER

Recommended Sky Mythology Source Books

Richard H. Allen, *Star Names, Their Lore and Meaning*, 1963, Dover.

Ella Clark, *Indian Legends of the Pacific Northwest*; 1953, University of California Press.

Edith Hamilton, *Mythology*, 1971, New American Library.

Julius D.W. Staal, *Patterns in the Sky*, 1972, Econi-Co Press (available from Fernbank Science Center, 156 Heaton Park Drive, N.E., Atlanta, Georgia 30307.)

The first two versions below are based on Staal, and the third is based on Clark.

The Roman Version: The Great Bear

Jupiter, the King of the gods, often fell in love with mortal women of earth, so his wife Juno was often jealous. When Juno found out that Jupiter was favoring a young maiden named Callisto, Juno got so furious that she changed Callisto into a big shaggy bear. Years later, Callisto's son Arcas was hunting in the forest when his mother, now in the form of a bear, saw him. She got so excited, she forgot she was a bear and she rushed forward to embrace him. Of course, Arcas did not recognize his mother and he leveled an arrow in his bow to kill her. In the last instant, Jupiter intervened by changing Arcas into a bear as well, and then grasping both Callisto and Arcas by their tails, flung them into the sky--where Callisto is now the Great Bear and Arcas the Little Bear.

Juno, still not satisfied with her revenge, persuaded Poseidon to forbid the two bears from cooling their feet in the waters of the oceans. This is why Ursa Major and Ursa Minor never sink below the horizon.

Native American Version: The Bear in the Oak Tree Forest

Long ago there was a great oak forest that was enchanted and magical, because every night at midnight the trees in this forest would move around and visit each other. One day a bear wandered into this forest and got so lost, he couldn't find his way out. He became frightened, and when midnight came, he was terrified to find the trees moving about. The poor bear started racing madly all over and bumping into trees right and left. The trees did not appreciate this intruder at all and one tree was so upset that it started chasing the bear. Because bears generally are faster than trees, this chase lasted almost till dawn. The tree knew that he and all the other trees had to go back to their original places by dawn or the sun would notice that they had moved. So the tree, just at twilight, made one last grasp at the bear with its longest branch and just barely caught the bear by the tail. Then the tree thrust the bear up into the sky where we see him now. Now you can well imagine why his tail is so long.

Wasco Indian Version: The Five Wolf Brothers

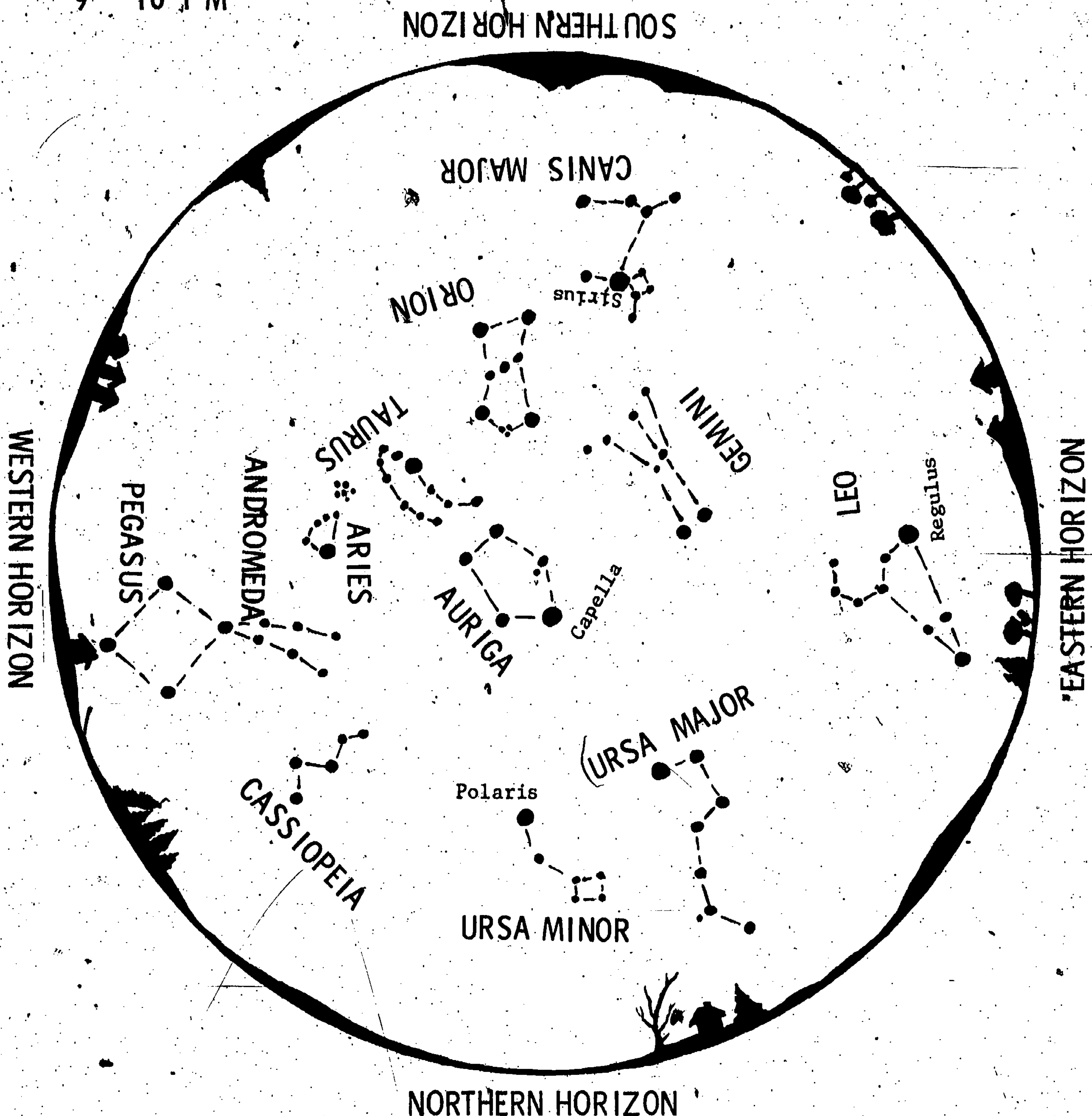
Once upon a time there were five brothers named the Wolf brothers who made their living by hunting deer. Every night they would make a camp fire, cook some meat and eat together. They shared their food with another man named Coyote (a mythical god-like character). After eating, the brothers would relax and gaze into the sky in a certain area and look puzzled. One night Coyote asked the oldest brother, "What are you looking at?" The oldest brother said, "I won't tell you-- you would think I was foolish." But on later nights Coyote questioned the other brothers until one night they answered, "We can see two animals moving in the sky but they are so high up we cannot tell what kind of animals they are." Coyote replied, "Wouldn't you like to get a closer look at them to see what they are?" To which the brothers replied, "Oh, yes, but none can travel into the sky." Said Coyote, "Nonsense, it is easy," and proceeded to collect three quivers full of arrows. Then he took an arrow and shot it straight towards the place in the sky where the brothers said they saw the two animals. The arrow went all the way to the sky and stuck there. Then Coyote shot a second arrow so that its tip stuck into the end of the first arrow. By the time Coyote finished shooting all the arrows, which took all night, there was a string of arrows reaching all the way from the sky to the earth. At dawn the five brothers and Coyote began climbing the arrow ladder. The youngest brothers went first, and Coyote and the oldest brother, carrying their little dog, went last.

After climbing almost all day, they reached the sky and found that the two animals were grizzly bears. The oldest brother shouted, "Stay away! They might tear you to pieces." But the younger brothers, who didn't want to appear afraid, crept closer and closer to the bears. The other brothers followed behind. Finally, the grizzly bears looked up and noticed the five Wolf brothers, but the bears did not attack, for they had never seen people before, and were curious. The bears just stood there looking at the brothers and the brothers stood very still looking back at the bears.

Coyote thought, "What a funny picture these bears and the Wolf brothers make just staring at one another. I would like for everyone to be able to see this," and he proceeded to climb down the arrow ladder, taking out the arrows as he went, leaving the picture in the sky for everyone to see.

Evening Star Map for January - February

9 - 10 PM



to use map:

Hold this sheet in front of you. Turn the map so the direction you are facing is on the bottom. The constellations in the sky will match the constellations on the map.

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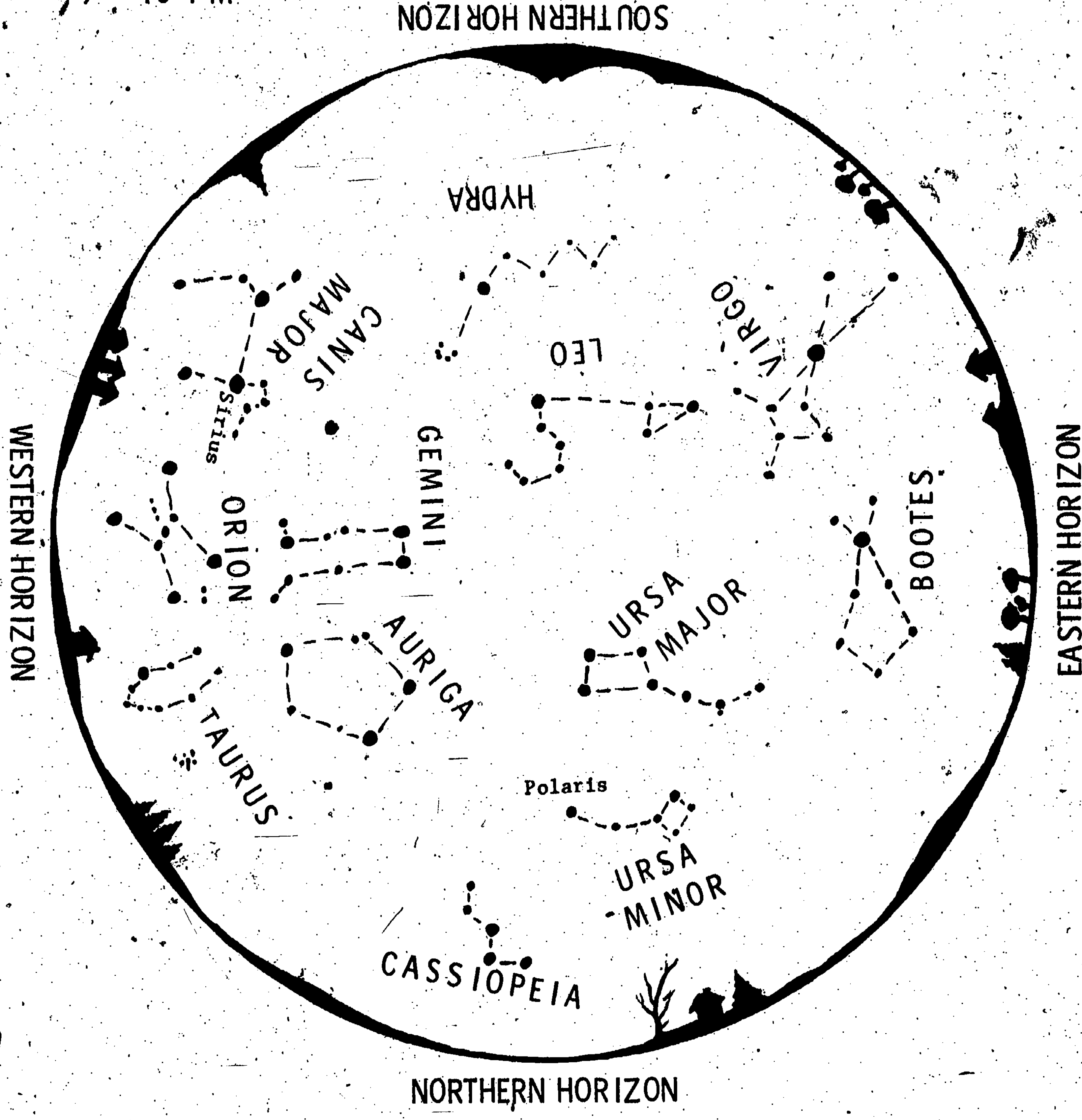
Evening Star Map for March - April

9 - 10 PM

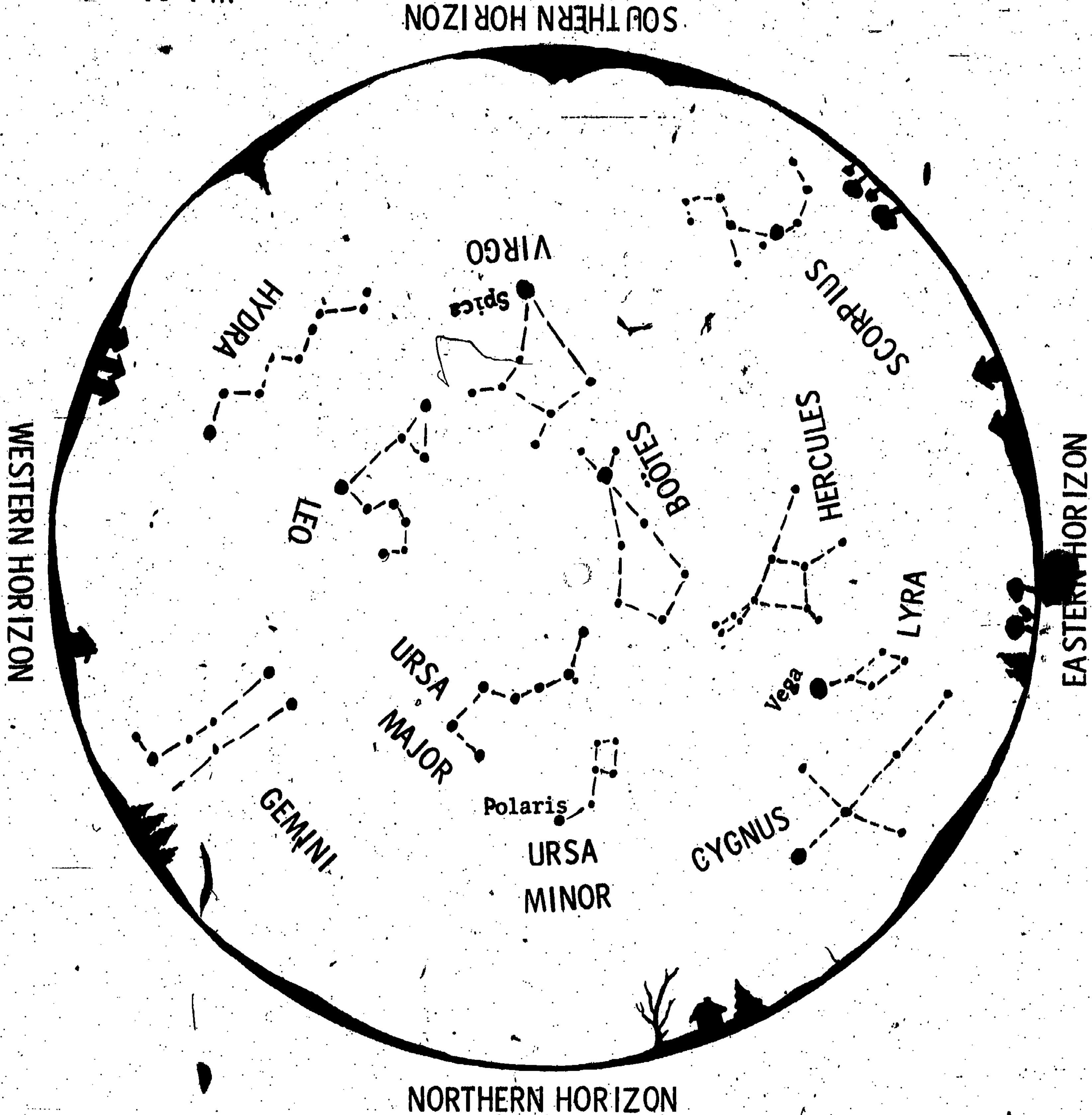


to use map:

Hold this sheet in front of you. Turn the map so the direction you are facing is on the bottom. The constellations in the sky will match the constellations on the map.

Evening Star Map for May - June

9 - 10 PM



to use map:

Hold this sheet in front of you. Turn the map so the direction you are facing is on the bottom. The constellations in the sky will match the constellations on the map.

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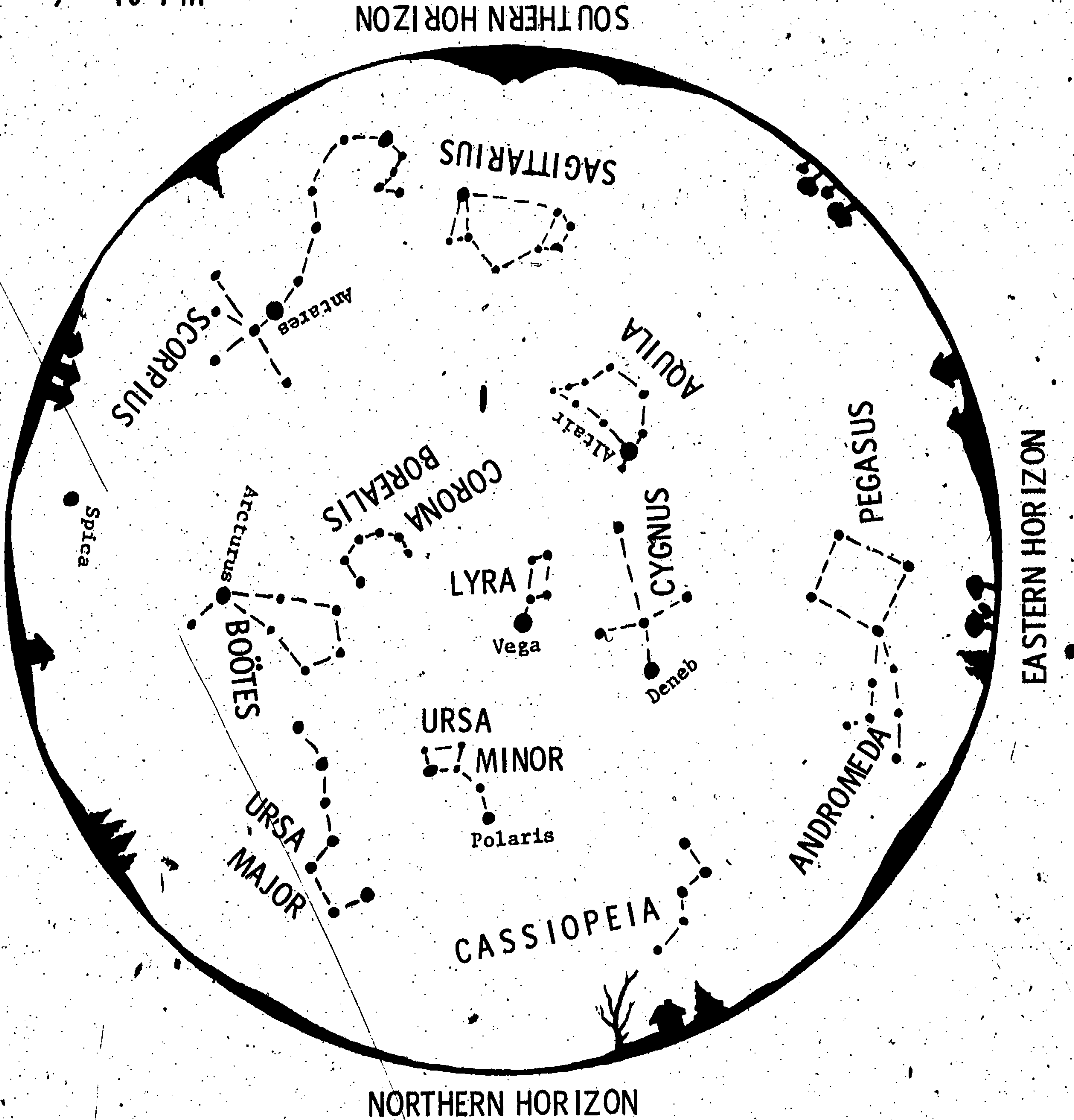
Evening Star Map for July - August
9 - 10 PM



to use map:

Hold this sheet in front of you. Turn the map so the direction you are facing is on the bottom. The constellations in the sky will match the constellations on the map.

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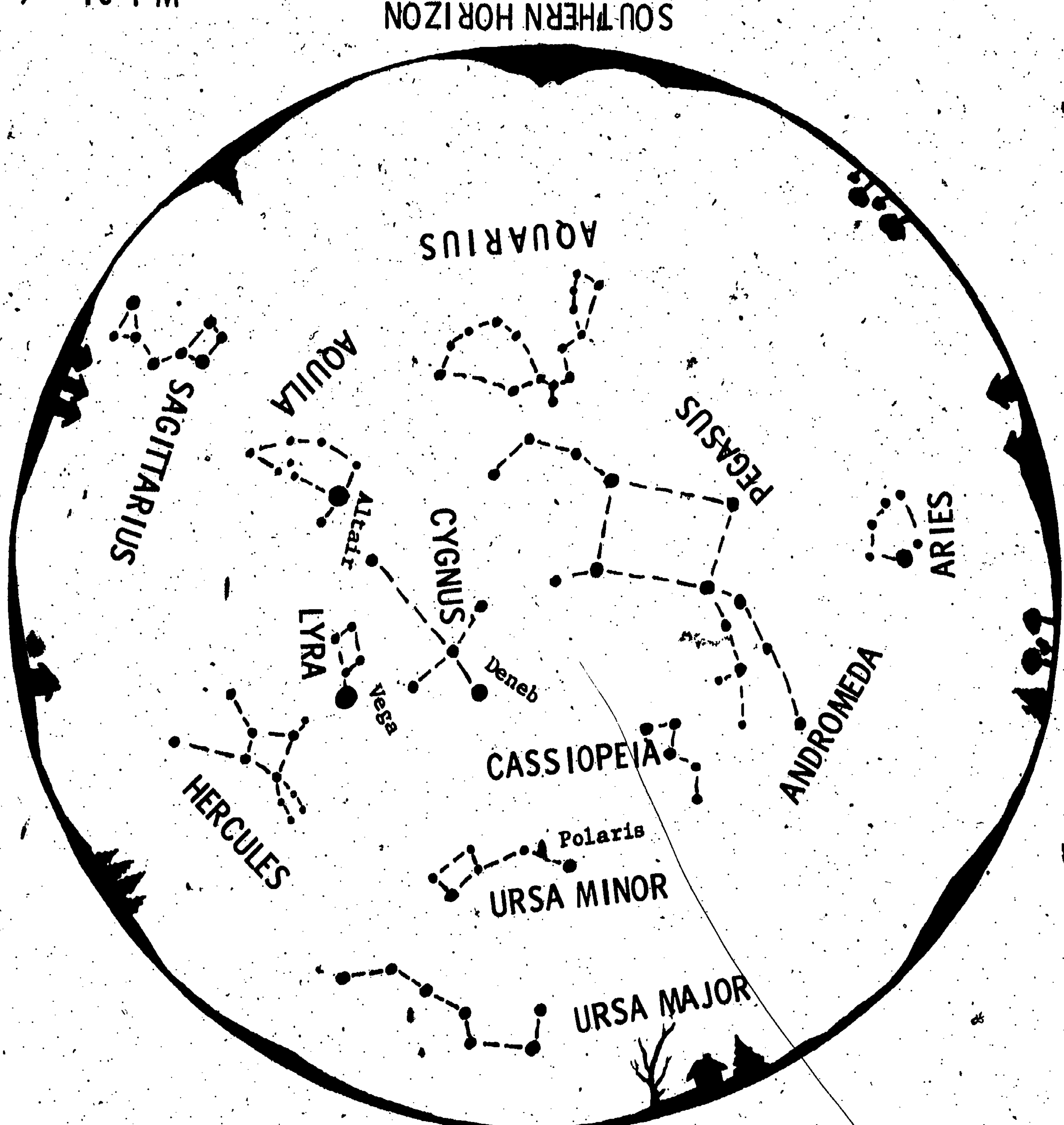
Evening Star Map for September - October

9 - 10 PM



to use map:

Hold this sheet in front of you. Turn the map so the direction you are facing is on the bottom. The constellations in the sky will match the constellations on the map.

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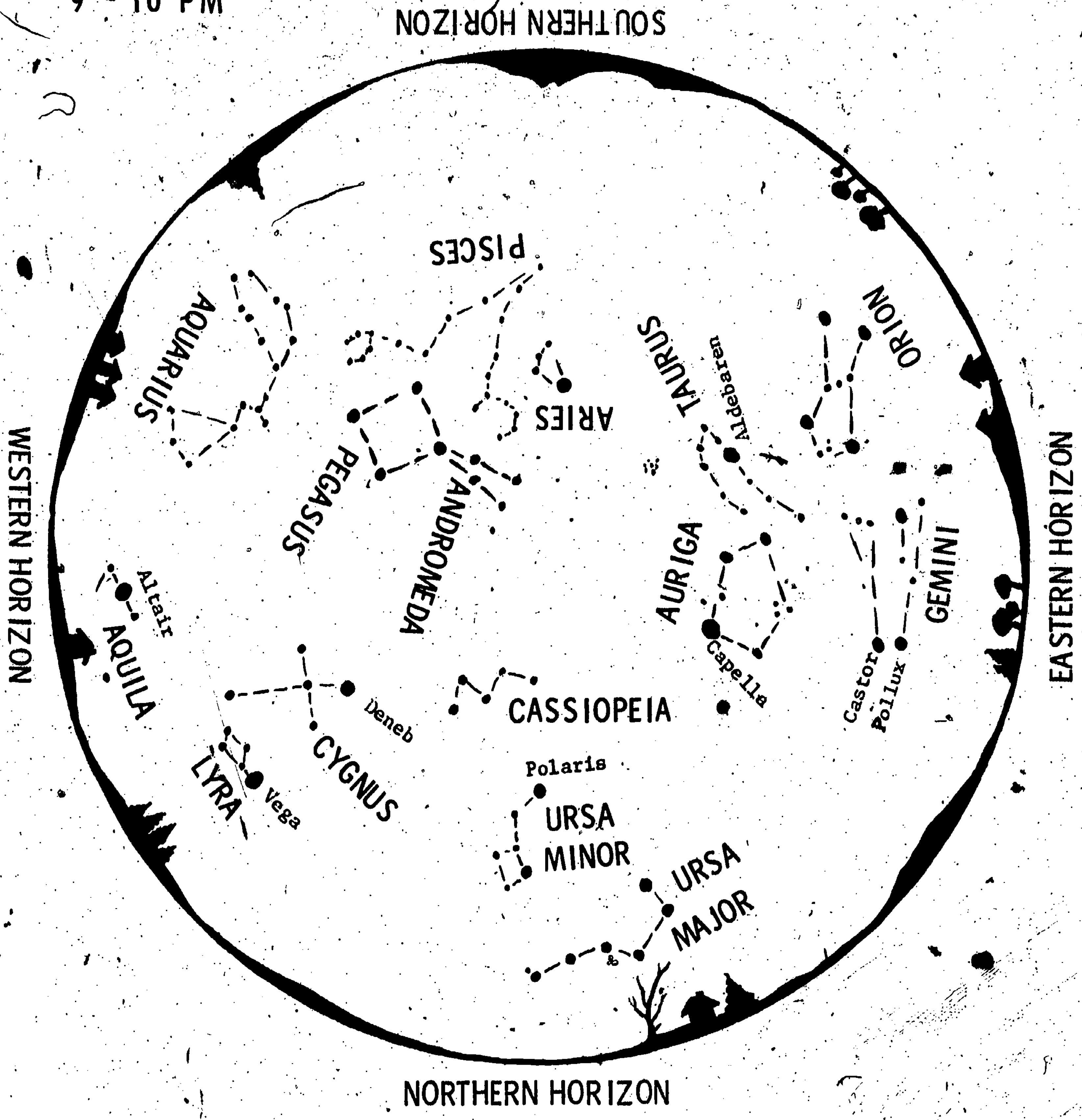
Evening Star Map for November - December
9 - 10 PM



to use map:

Hold this sheet in front of you. Turn the map so the direction you are facing is on the bottom. The constellations in the sky will match the constellations on the map.

(Handout)

Discover More About CONSTELLATIONS

STAR MAPS

Star Paths--Star and Planet Chart, Edmund Scientific Company, Barrington, New Jersey. An inexpensive adjustable star wheel that can be set to show how the sky appears at any time.

Sky Challenger, a unique set of six interchangeable star wheels, provides many activities in star gazing, including "Binocular Treasure Hunt," "Native American Constellations," and "Test Your Eyes/Test Your Skies." Discovery Corner, Lawrence Hall of Science, Berkeley, California 94720.

Arthur P. Norton, *Norton's Star Atlas*, Sky Publishing Company, Cambridge, Massachusetts (new edition every few years). A set of detailed star charts and good lists of interesting objects for telescope observing (star clusters, nebulae, galaxies, double stars, etc.)

R.M.S. Inglis, *A Popular Star Atlas*, Gall and Inglis, London, 1972. A much shorter and less expensive version of Norton's atlas.

CURRENT PHENOMENA

Astronomy is a beautiful, colorful magazine devoted to astronomy. It's not for those seeking technical information or treatments of the more difficult concepts. Astro Media Corp., 411 E. Mason Street, 6th Floor, Milwaukee, Wisconsin 53202.

Sky and Telescope is for those more technically inclined. Very good for people who want to build their own telescopes, or go beyond casual star gazing. Fine photo-essays on observatories, professional and amateur. Sky Publishing Corporation, 49-50-51 Bay State Road, Cambridge, Massachusetts 02138.

Sky Calendar, by Robert C. Victor, Abrams Planetarium, Michigan State University, E. Lansing, Michigan 48823. This monthly calendar gives a day-to-day guide to interesting events in the sky.

MYTHOLOGY

Julius D.W. Staal, *Patterns in the Sky*, Econi-Co Press, Atlanta, 1972. An excellent compilation of the Greek and Roman myths, this book is available from Fernbank Science Center, 156 Heaton Park Drive, N.E., Atlanta, Georgia 30307.

Ellas Clark, *Indian Legends of the Pacific Northwest*, University of California Press, Berkeley, California, 1953. American Indian stories about the star patterns that we call Orion, Cassiopeia, the Seven Sisters, the Big Dipper, and others.

Richard H. Allen, *Star Names: Their Lore and Their Meaning*, Dover Publications, Inc., New York, New York, 1963. This book has the origin of star names and constellations from various cultures.

Look in library card catalogues and you will find many titles that start out *Myths and Legends of*... on almost every culture.

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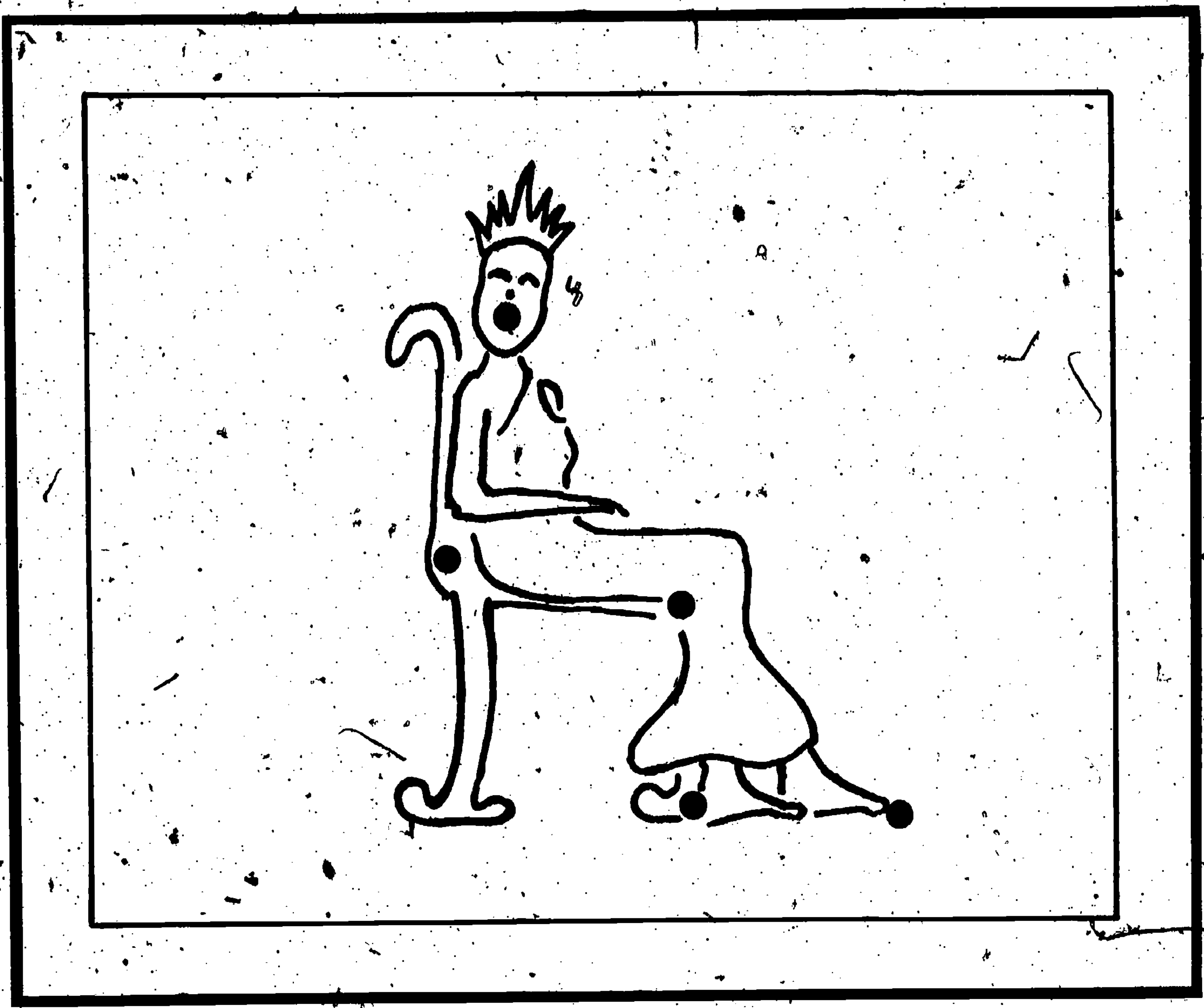
CREATING CONSTELLATIONS



A Classroom Activity to Supplement
"Constellations Tonight" Planetarium Program

William K. Holt Planetarium, Lawrence Hall of Science
University of California, Berkeley CA 94720

CREATING CONSTELLATIONS

A Classroom Activity to Supplement "Constellations Tonight" Planetarium Program

This science activity is designed for students in grades three through eight. It can be presented by teachers with no special preparation in science. CREATING CONSTELLATIONS is keyed to some of the concepts in the planetarium program, "Constellations Tonight," so it will probably be most effective if presented just before or just after visiting the planetarium. Each teacher may wish to adapt the language and pace of the activity to his or her particular class.

Objectives

This activity involves the stage of scientific thinking in which many different ideas, or hypotheses, are generated. It focuses on the type of problems that have many equally good solutions (like naming a new animal) in contrast to problems that have only one right answer (like finding the North Star). After the lesson, the students will be able to:

1) Recognize that several different ideas may be equally good solutions to the same problem.

2) Recognize when they need to "break set"--that is, to find a new approach to the problem. (Set breaking can be thought of as "getting out of a mental rut.")

3) Recognize that the constellations which they invent can be just as useful as the ancient Greek and Roman constellations.

Before the Class

1) Duplicate one copy of the Circle Puzzle, Dots Puzzle, and Create a Constellation for each student. Prepare large sheets of paper and crayons.

2) Have board space and tape ready to display the students' work.

3) On a different section of the blackboard draw three or four circles, about 18-20 inches in diameter.

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Part A. Circle Puzzle

Here is a puzzle that has many equally good answers. Please follow the directions on the worksheet. Don't forget to make each circle into a DIFFERENT picture, and to NAME what each picture shows.

Hand out the Circle Puzzle. Read the directions with the students if necessary. Then allow about ten minutes for them to work.

Who would like to come to the board to show one of their ideas?

Three or four students draw in the prepared circles on the blackboard.

Share your papers with your neighbors to see how many different ideas you can count. How many did you find? How many different possibilities do you think there are?

How many of you thought of a few different ideas for the circles, and then just couldn't think of any more? What are some different things you could try at that point, to think of a different idea?

Let the students share strategies for generating new ideas that THEY find useful. Examples of strategies are: to look around the room for round objects, to imagine my room at home, to share ideas with someone else, and so on.

Part B. Dots Puzzle*

Directions for this last puzzle are very similar to the Circle Puzzle. Only this time you have to invent and name just four pictures.

Hand out one copy of Dots to each student. Give them about five minutes to work.

Now compare your drawings with your neighbors' drawings. Did any of you have the same idea? How many different ideas can you count?

Let the students discuss their ideas with their neighbors for a minute or two. Then, hand out the last sheet, entitled "Create A Constellation."

On this sheet you will probably recognize the same pattern of dots that you saw in the Dots Puzzle. This is actually a pattern of stars visible in the sky. Ancient Greek astronomers, who lived about 2000 years ago, saw the Queen of Ethiopia, called Cassiopeia (pronounce: Kasio-PEE-ah) in this pattern of stars.

Cassiopeia is an especially easy constellation to find just about any time of the year.

A picture and name that ANYONE imagines when he or she looks at a pattern of stars is called a "constellation." In the box at the bottom of the page, draw the idea which YOU like best and name it. This is YOUR OWN CONSTELLATION which you can find in the night sky. When you are working by yourself, your own constellation invention is just as useful, perhaps even better, than the "classic" ones.

Would it sometimes be better for us all to agree on a single constellation for everybody to use? How would that be useful?

Possible answers to this question might be: "To tell someone else where to find certain stars, or directions in the sky."

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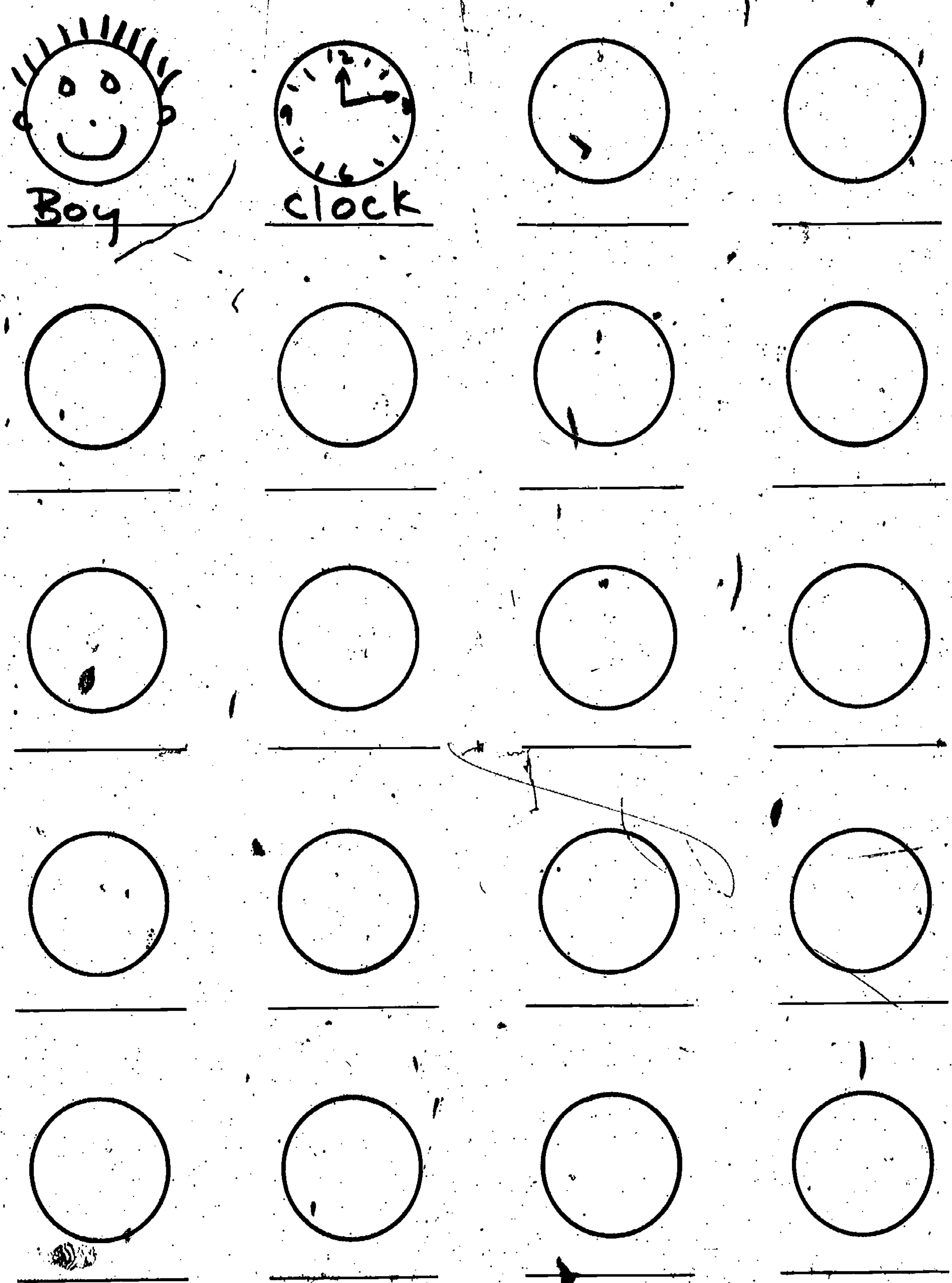
* The activities described in Part B have been adapted from "An Introduction to Constellation Study (or Isn't that Big Bird in the Sky?)" by Gerald L. Mallon, Arcola Junior High School, Eagleville Road, Norristown, Pennsylvania 19401. Published in *Science and Children*, November/December 1976, Volume 14, No. 3, pp. 22-25.

CIRCLE PUZZLE

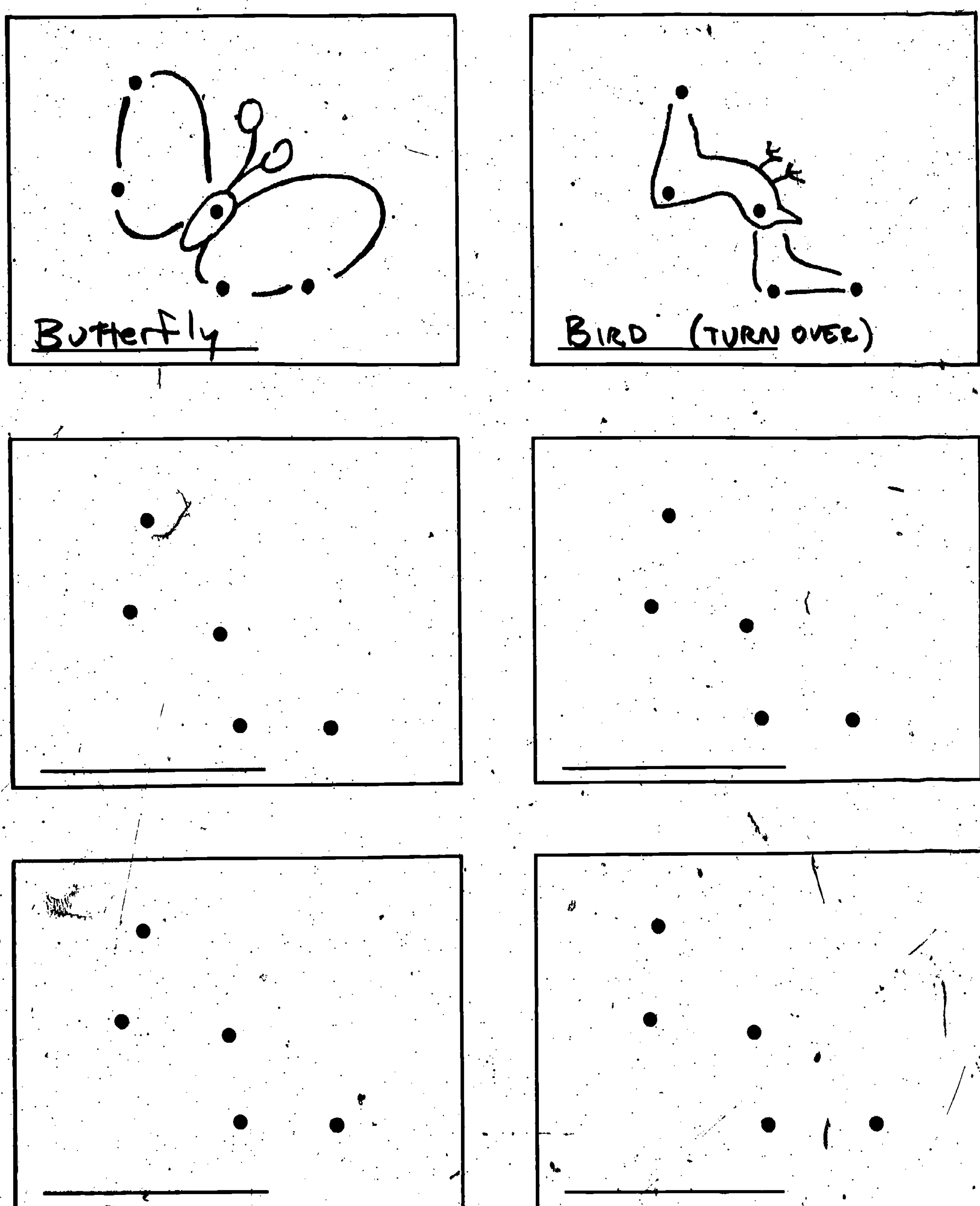
Make each circle into a picture of something and write a name for what you draw underneath. The first two circles are completed as examples. Notice that each one is DIFFERENT and each one has a name.



DOTS PUZZLE

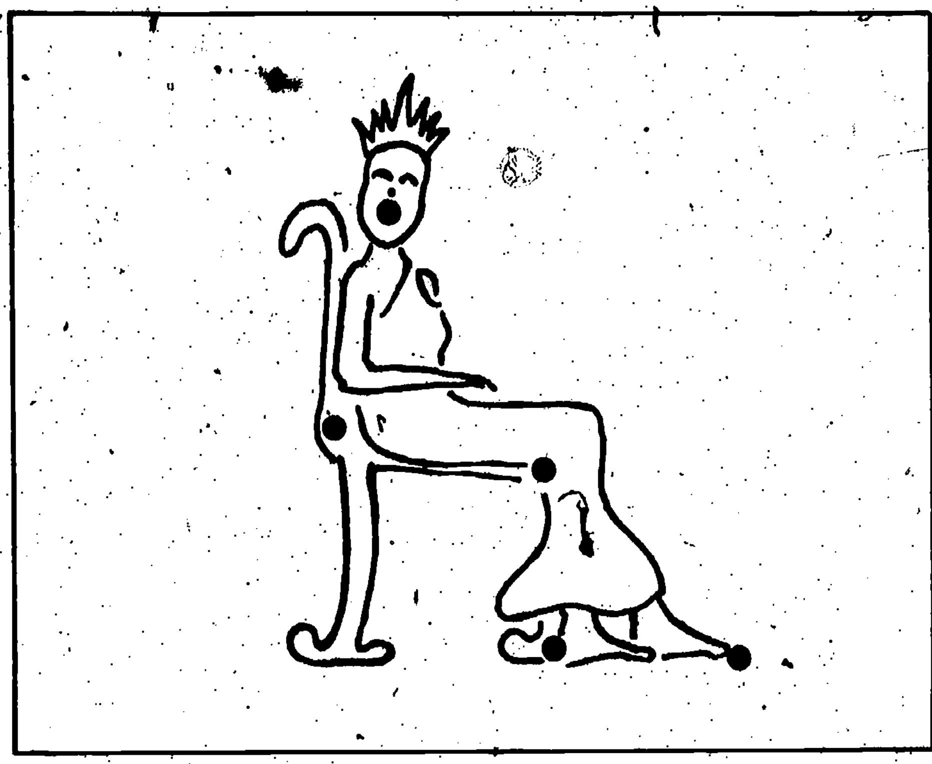
These six pictures all show the same pattern of dots. In the first two pictures, people have drawn something which the dots make them think of. They labeled their pictures with a name that tells what the drawing is supposed to be. INVENT FOUR COMPLETELY DIFFERENT THINGS BASED ON THE SAME PATTERN OF DOTS.

Draw your ideas in the last four boxes and label each one to tell what it is supposed to be a picture of.



CREATE A CONSTELLATION

The pattern of dots from the "Dots Puzzle" is really a pattern of stars that you can find in the sky. The Ancient Greeks saw this pattern as a beautiful queen, Cassiopeia, sitting on a throne.



The Queen Cassiopeia Sitting On Her Throne

In this box, create your own constellation for the same pattern of stars.

Follow-Up Activities

1) Have the students invent myths which tell the story of their constellations. This activity might be preceded by having them read ancient Greek, Roman, or Native American star myths which appear in many anthologies for children.

2) Have the students draw or paint more detailed pictures of the constellation figures they have created to illustrate their stories. Instruct them to show where the stars appear in the pictures.

3) Sheldon Schafer of the Lakeview Museum in Peoria, Illinois recommends the following activity, best done just after the circle puzzle, to demonstrate the value of using constellation figures.

a) Draw a random assortment of dots on the board.

b) Ask the students to memorize the arrangement. Allow a minute or two. No notes should be taken.

c) Cover the dots with paper.

d) Ask for a volunteer to recreate the pattern on the board or have all students do so on a piece of paper.

e) Compare the results with the original.

f) Draw a new pattern of dots on the board, this time connected into some kind of figure.

g) Repeat steps b-f.

h) Compare the results of the first trial with those of the second. Usually there will be an easily noticeable difference between the two.

4) The quiz on pages 153-155 may be used as an activity, and may also tell you something about how well your students understand the concepts in this program, either before or after they have experienced the program. Please note that some questions refer to "Creating Constellations," while others refer to "Using A Star Map" or CONSTELLATIONS TONIGHT. You should revise this test as needed to fit your particular classroom situation.

USING STAR MAPS

A Classroom Activity to Supplement
"Constellations Tonight" Planetarium Program

William K. Holt Planetarium, Lawrence Hall of Science
University of California, Berkeley, CA 94720

USING STAR MAPS

A Classroom Activity to Supplement

"Constellations Tonight" Planetarium Program

This science activity is designed for students in grades five through eight. It can be presented by teachers with no special preparation in science. USING STAR MAPS is keyed to some of the concepts in the planetarium program, "Constellations Tonight," so it will probably be most effective if presented just before or after visiting the planetarium. Each teacher may wish to adapt the language and pace of the activity to his or her particular class.

Objectives

The primary objective of this activity is to increase the students' abilities to use maps. Following the lesson, the students will be able to:

1) Use "direction" and "distance" to find locations in the classroom.

2) Draw a map of the classroom.

3) Use a star map to locate the positions of constellations in the sky by noting the direction and distance from the zenith (point overhead).

4) Use a star map to visualize the orientation of constellations in the sky.

Before the Lesson

1) Gather the following materials for each student: a pencil, and one copy of Worksheets #1, #2, and #3. (If necessary, make a new version of sheet #1 to match the shape of your room.) Assemble for the class: one large poster of a Star Map with a cardboard "Star Window." This poster is available from the Lawrence Hall of Science. See page 97. This write-up uses September-October skies, and shows the poster for September-October evening sky only. Star maps are available from many sources for all seasons. You may wish to draw your own poster and make other changes appropriate for other seasons.

2) Label the four walls of your classroom with paper signs marked with the four primary compass directions. These need not correspond to the actual compass directions. However, a person facing "North" should be able to see "East" to the right, "West" to the left, and "South" to the rear.

3) As an example of how to draw a map of the classroom, draw a rectangle on the blackboard, and label the four directions (as on sheet #1). Draw in the teacher's desk or some other prominent object so the students can see how to proceed.

Part A. The Directions Game

We will begin today's lesson about Star Maps by playing the Directions Game. Notice the four signs on the walls that indicate the primary compass directions: North, South, East, and

William K. Holt Planetarium, Lawrence Hall of Science
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West. What direction would I look to see Northeast? Southeast?

Point to the four direction markers. Question the students to see if they understand the system of compass directions.

Now we are ready to play. Who will be our first volunteer? Okay, Jennifer, please stand in the center of the classroom and face AWAY from the blackboard. I will write the name of some object in our classroom so that everyone but Jennifer will know what I have in mind.

Write the name of an object that is within Jennifer's line of sight--say "George's Desk"--on the blackboard. Let everyone read it, then erase it.

Now I would like someone to give directions to Jennifer so she can find the object, just by looking around. Do this by giving the DIRECTION she should turn, and HOW FAR she must look. For example, you might say, "Look Northeast, about half-way to the wall." Who wants to give Jennifer directions first?

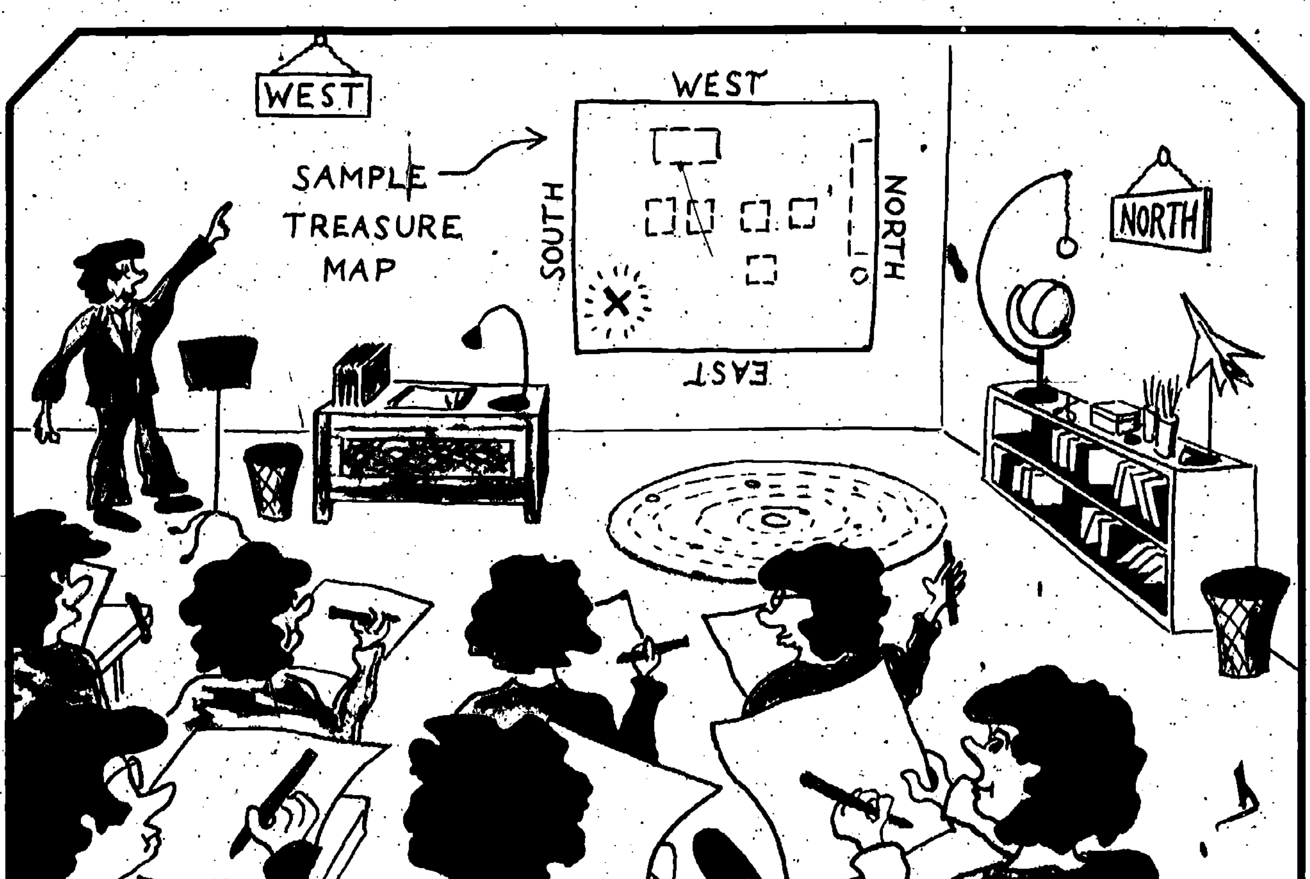
If Jennifer fails to find the object on the first try, encourage the students to give clues, but not to name the object. Let the students use whatever strategies they can think of (like giving the size, shape, or color of the object.)

Good! Now that Jennifer has found the object, who would like to try the next one?

Part B. Treasure Map of the Classroom

On the blackboard I have started to draw a map of our classroom. Notice that I have labeled the four primary directions and I have drawn the location of my desk.

Point to the example on the blackboard.



If a stranger who has never before been to our classroom saw this map, how would he or she use it to find my desk?

If the students are not able to transfer learning from the "Directions Game," help them by drawing an arrow from the center of the map to the location of the desk, and ask what the stranger would do if he or she stood in the center of the room.

Now that you understand how to use direction and distance to locate things on a map, I want you to complete the map of our classroom. On this paper, show all of the things that rest on the floor--chairs, tables, desks, and anything else you think is important. Make sure the directions on your maps correspond to the directions in the classroom, and that the distances are about right.

Hand-out Sheet #1.

Help students as they request it. Allow them to look at each others' papers to get ideas and to criticize.

When you are finished, plant a "treasure" somewhere in the room, and mark the spot with an "X" on your map. Exchange treasure maps with one other person to see if you can find each others' treasures.

The same exercise can be done with older students using the entire schoolgrounds rather than just the classroom.

Part C. Reading Star Maps

This star map shows how the stars will appear tonight at about 9 or 10 o'clock. The center of the circle shows the point directly overhead, called the "Zenith." The rim of the circle shows the "horizon," which is what we call the line where the sky meets the earth.

Let students inspect the star map on Sheet #2.

I would like another volunteer to stand in the center of the room. *Sam volunteers and takes his position.*

Pretend the walls and ceiling of our classroom is the sky. Where would you look, Sam, to see the zenith? How about the Northern Horizon? The Southwestern Horizon?

If Sam has difficulty, other students can help. Thank Sam and ask him to be seated.

Now locate Orion on your maps. What direction is Orion in? How far between the zenith and the horizon is Orion? Who would like to take our volunteer's place and show us where Orion would appear in the sky?

Do this with several constellations, having students answer by taking the position in the center of the room and indicating where on the walls or ceiling the constellation would appear. Then, hand out Sheet #3.

When you use these maps to find constellations in the real sky, you must turn them around so the direction you are looking in is at the BOTTOM. Do this for the Northern Horizon. Notice on Sheet #3 how the Northern Horizon stars would appear in the sky. Check the next two "windows" to see how you have to turn the map to see stars overhead and in the Southwest. Any questions?

Illustrate the first two pictures on Sheet #3 by using the Star Map poster and "sky window." Turn the poster so the direction you are looking is down, and place the "sky window" over the part of the sky specified. This operation is illustrated on the bottom of this page.

Now try to fill in the stars you would see in the next two boxes on Sheet #3. Then, we will use our Star Window so you can see if you were right.

While the students are working, draw two boxes on the blackboard labeled like the next two boxes on Sheet #3.

Who would like to come to the board and draw the stars as they are on your paper?

After a student comes to the board and tries one of the windows, use the Star Window and poster to box in the correct part of the sky.

Let's compare this answer with the Star Map. What do you think? Is this what you would see in the sky if you looked in this direction tonight?

Now test yourself by filling in the last two boxes on Sheet #3.

Illustrate the last two answers by using the Star Window and poster.

If you understand how the Star Map works, you can go outside tonight and find any of these constellations that you wish. Good Luck!

Sheet #1 Map of My Classroom

SOUTH

EAST

WEST

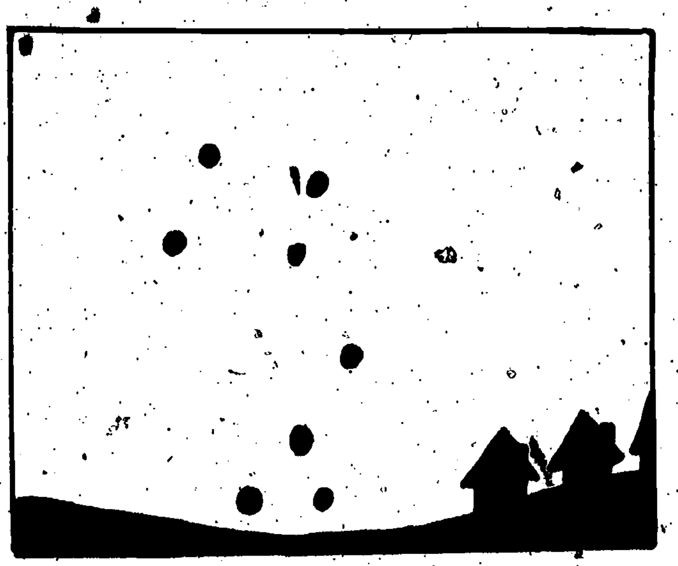
NORTH

In order to get to my own desk from the center of the classroom, in what direction must I go?____________________

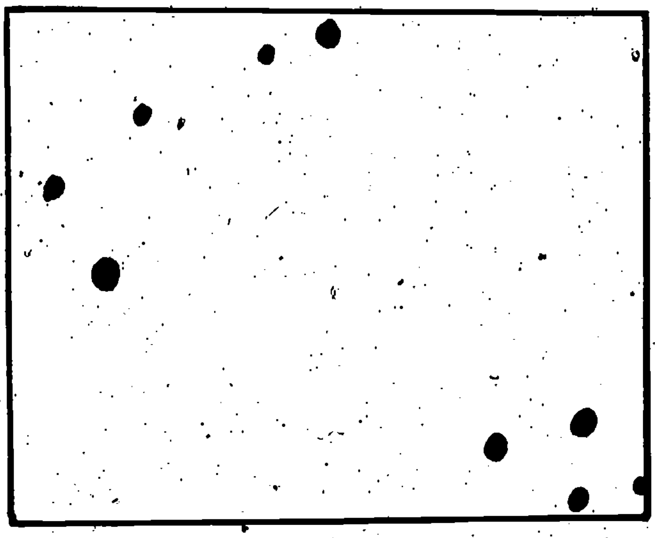
How far towards the wall must I walk?____________________

Sheet #2 Star Map for September-October

Sheet #3 Sky Windows



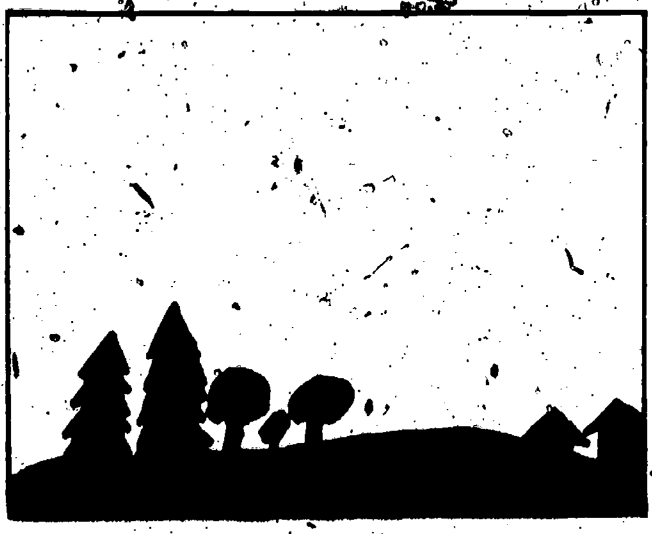
Southwestern Horizon



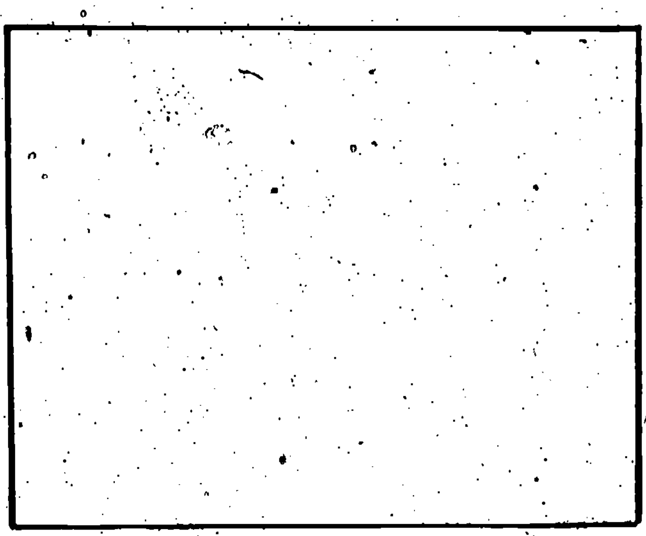
Zenith (overhead)

Northern Horizon

Western Horizon



Eastern Horizon



Half-way between Zenith and Northern Horizon

Follow-Up Activities

1) Have the students locate the constellations in the sky at night and draw in more stars for each constellation they can find.

2) Have the students draw the SHAPE and POSITION of the moon on their star maps each night for a period of two weeks. Instruct them to show where the moon is located in comparison to the stars and constellations. Ask your local planetarium director when the crescent moon will start to appear so the students can begin their observations.

3) Use this unit as an introduction to social studies activities using maps. The *Elementary Science Study* (ESS) unit on "mapping" provides a large number of different activities.

4) Gerald Mallon of the Methacton School District Planetarium recommends further activities in *Igniting Creative Potential* by Project Implode, Bella Vista Elementary School, Salt Lake City, Utah, 84121

5) Jeanne Bishop at the Westlake Public Schools Planetarium recommends additional activities in the *Science Curriculum Improvement Study* (SCIS) unit "Relative Position and Motion," published by Rand McNally & Company or American Science and Engineering Company.

6) The quiz which follows may be used as an activity, and may also tell you something about how well your students understand the concepts in this program, either before or after they have experienced the program. Please note that some questions refer to "Creating Constellations," while others refer to "Using a Star Map" or CONSTELLATIONS TONIGHT. You should revise this test as needed to fit your particular classroom situation.

Answers to the Astronomy Quiz CONSTELLATIONS

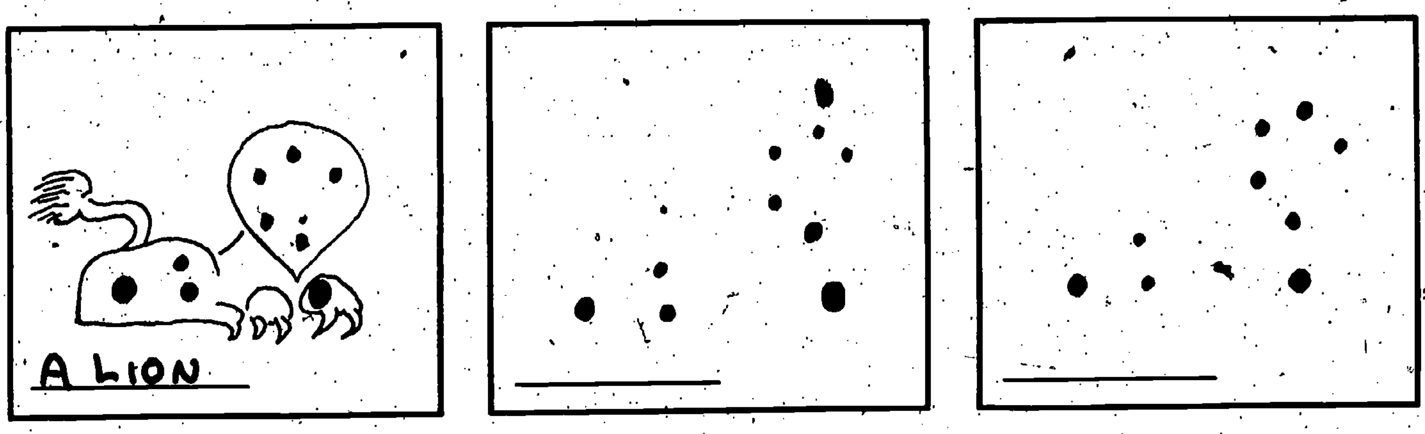
1-True, 2-True, 3-True, 4-(look for two different constellations that make use of the dots), 5-D, 6-(depends on class discussion, but answers might include time-telling, calendars, navigation, or just because it was fun), 7-(depends on class discussion, but answers might include the same as above, plus space navigation, locating deep-space objects for telescopes, studying the history of stars and ancient cultures), 8-C, 9-(circle touching near the words "EASTERN HORIZON"), 10-(X in the center of the star map circle), 11-(line ending at the horizon circle near the words "NORTHERN HORIZON."

Astronomy Quiz
CONSTELLATIONS

Circle the best answer.

1.	Constellations can be used to find directions on Earth.	True	False	Don't Know
2.	If you see a dim star next to a bright star, you will always find it next to the same bright star.	True	False	Don't Know
3.	A star map is used to find constellations.	True	False	Don't Know

These three pictures show the same pattern of stars. Picture A shows a constellation that was invented a long time ago.



A B C

4. Invent two different constellations and draw them in Pictures B and C. Label each constellation with a name that fits your drawing.

5. Ancient people in America, Europe, and China saw different constellations in the same set of stars. Why do you think this was so? (Circle the best answer.)
   A) People in different countries saw different stars.
   B) In those days people did not have telescopes.
   C) The atmosphere blurred the view of the sky.
   D) People in different countries saw things important to them.
   E) They spoke different languages.

List as many answers as you can for questions 6 and 7.

6. Long ago people probably invented constellations because: ______________________

____

____

____

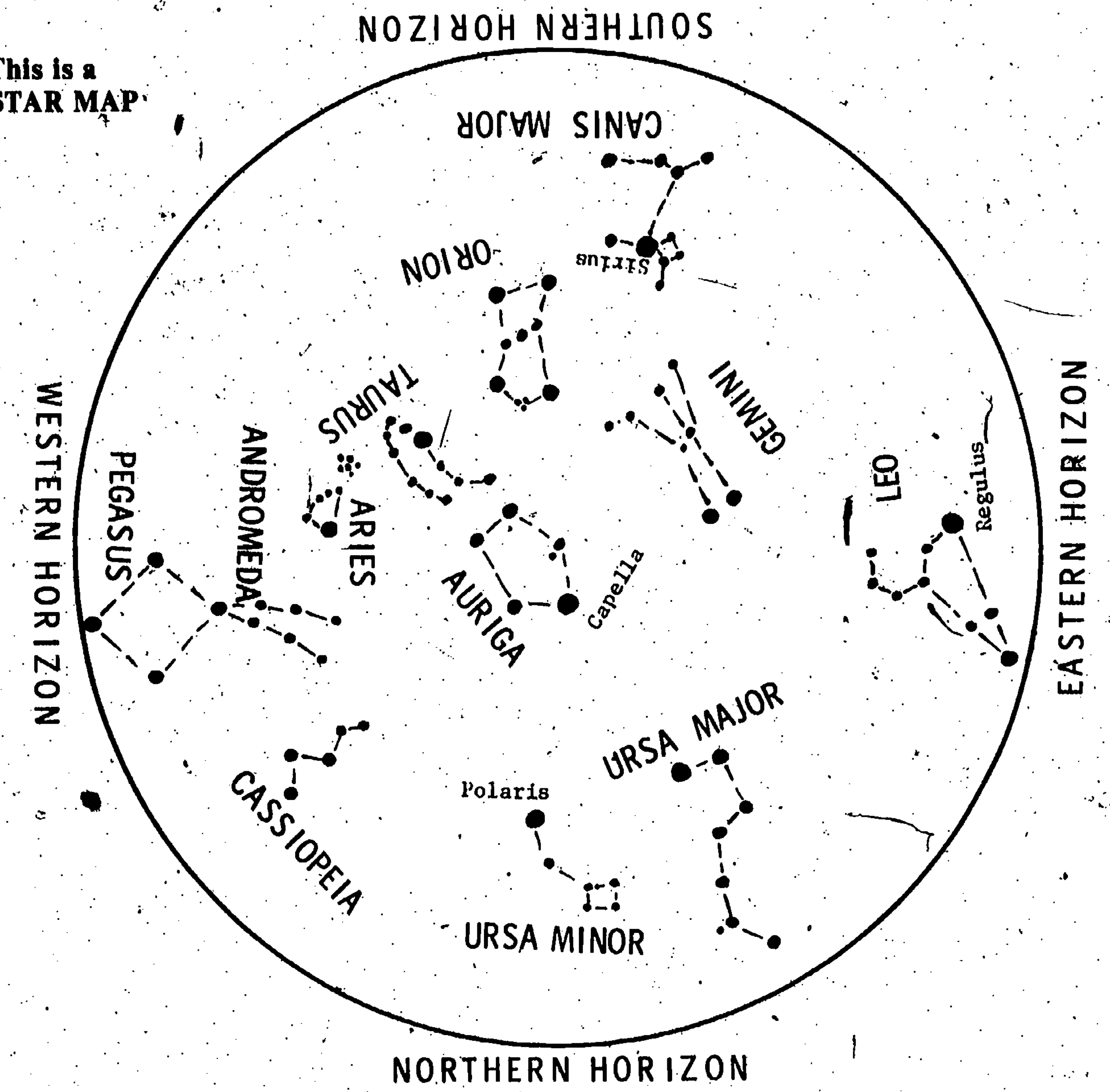
7. Today constellations are still useful for: ____

____

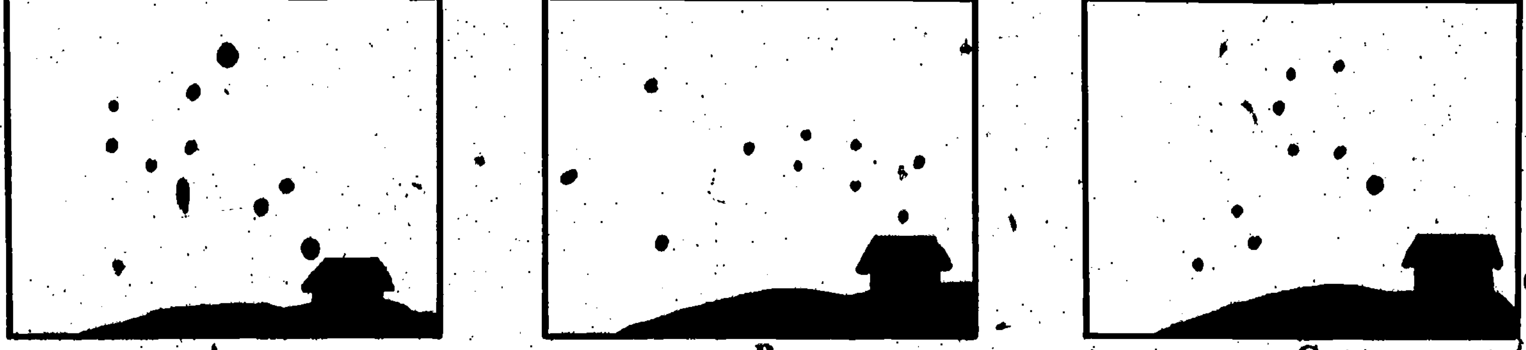
____

____

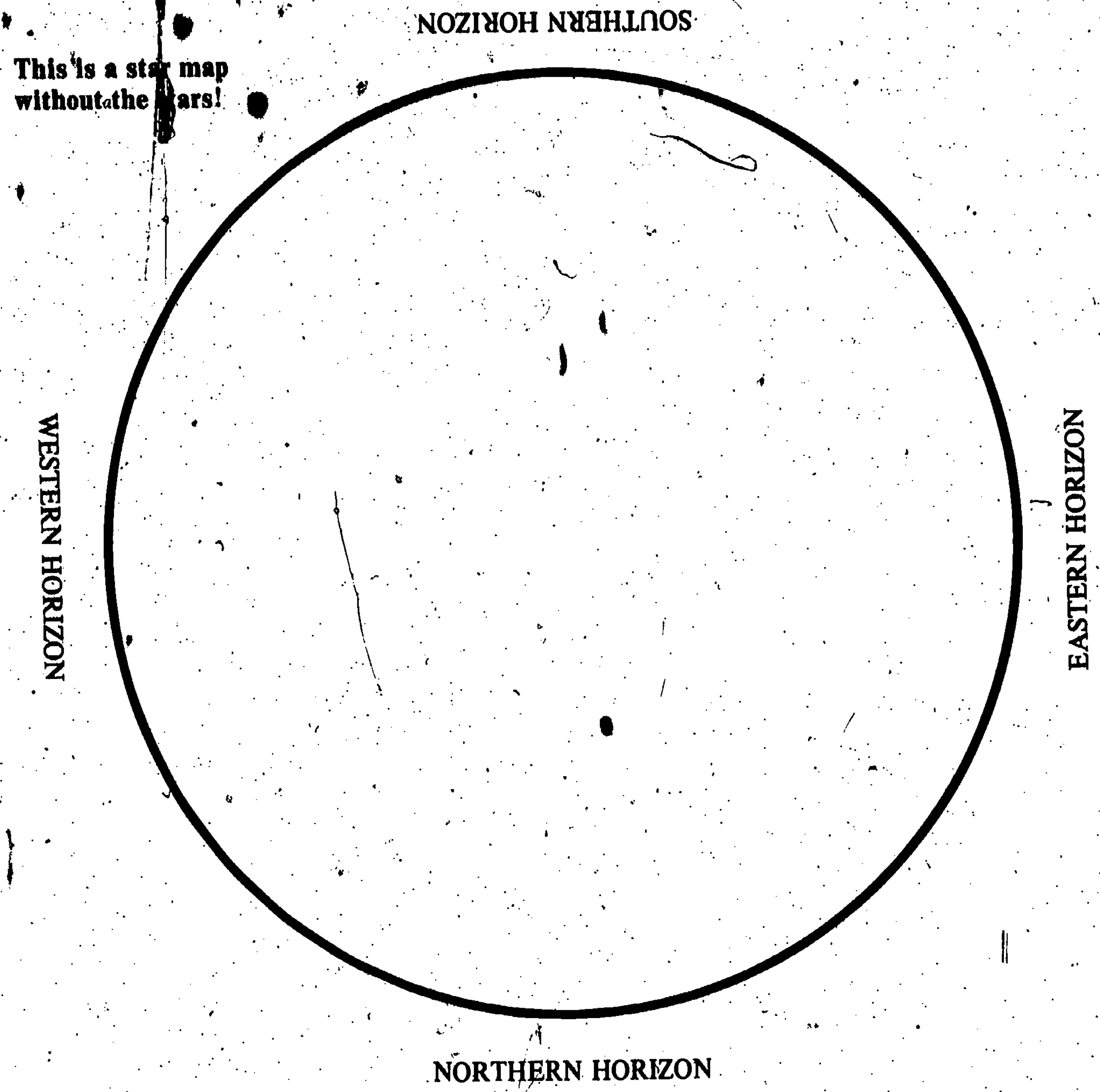
This is a
STAR MAP



8. Circle the letter of the picture that shows what you would see if you looked towards the Eastern Horizon tonight, according to the above star map.



A B C



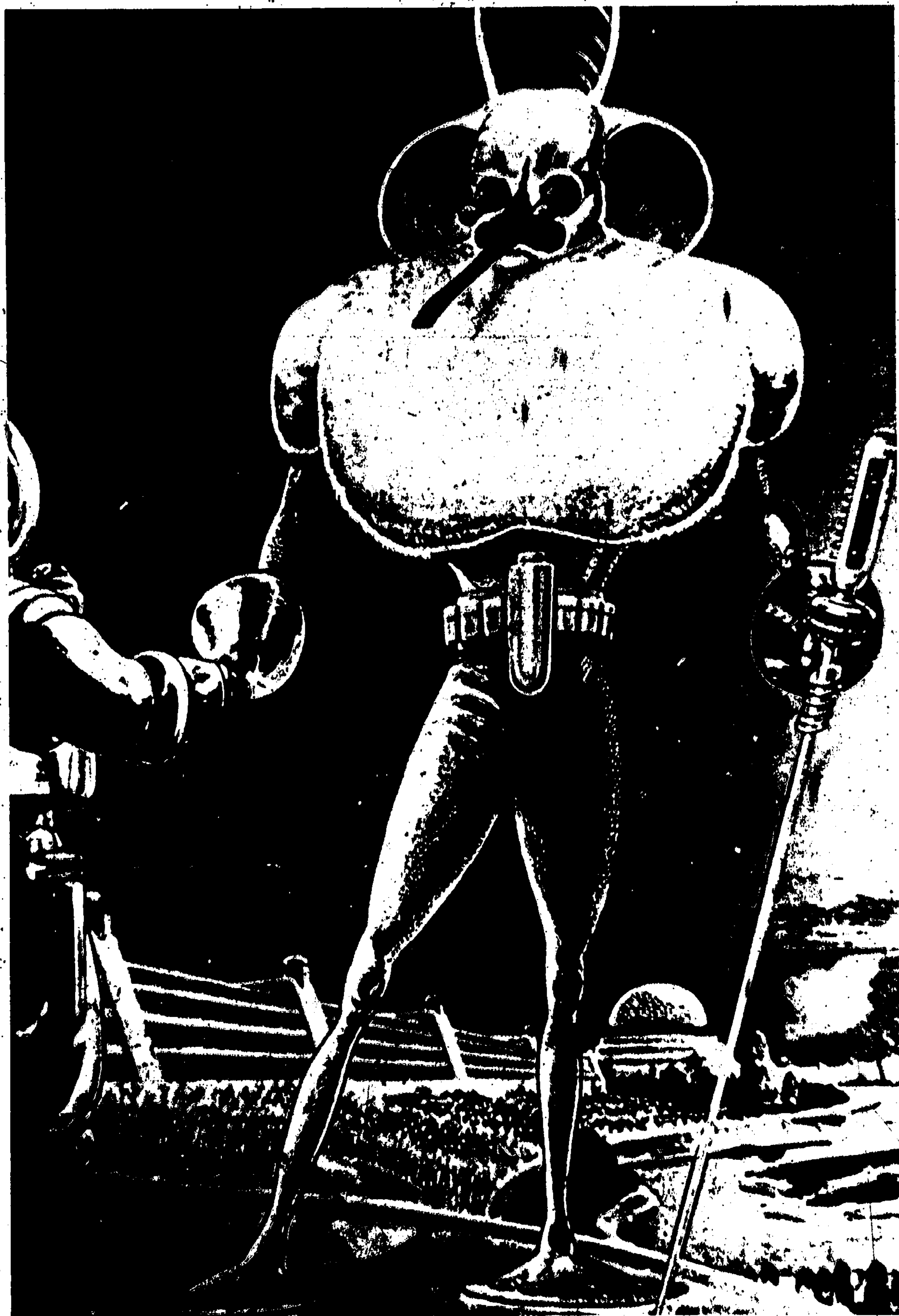
This is a star map, just like on the last page, but without any stars on it. Please mark your answers to the following questions directly on the map.

9. The moon is just rising on the Eastern Horizon. Show the moon on the map as a little circle.

10. Pretend you just saw a UFO (or "flying saucer") just overhead. Draw an "X" on the map showing where it would appear in the sky.

11. Pretend you saw the UFO fly in a straight line and zoom out of sight over the Northern Horizon. Draw a line showing the path of the UFO.

RED PLANET MARS



A Program From The William K. Holt Planetarium

Lawrence Hall of Science, University of California, Berkeley, CA 94720

RED PLANET MARS
A PROGRAM FROM THE HOLT PLANETARIUM

Table of Contents

Preface

Red Planet Mars was designed for public audiences and for school children in grades four and above. With some adaptation, it could be presented to slightly younger groups as well.

The purpose of the program is not to tell the visitors all about Mars, but to enable them to make their *own* discoveries about the red planet. Through a series of activities the visitors learn about planets in general, and about how astronomers investigate them.

In the first activity, the visitors identify Mars as the ancient Greek astronomers did, by observing its motion from night to night as it wanders among the "fixed" stars. Next, slides are used to show how Mars looks through a telescope. As a special effect projector simulates the changing, distorted view caused by the Earth's atmosphere, the visitors are invited to sketch a map of Mars. The visitors' discussion of their own maps provides a jumping-off point for the instructor to discuss the Great Canal Debate which astronomers waged during the first half of the twentieth century.

The science of "exobiology," still very much alive today, provides the rationale for the next activity: inventing a creature which might have evolved on a Mars-like planet. The program concludes with the modern space scientists' view of Mars through photographs taken by Mariner and Viking.

We would be very grateful to hear from you about how you used this program, what modifications you made, what worked well and what didn't work well.

Objectives

After attending this program, the visitors will be able to explain that:

1. Planets and stars look similar at first glance with the unaided eye;
2. Some stars are reddish, as is Mars;
3. Planets can be detected by noting their motion against the background stars;
4. Atmospheric interference blurs the view through a telescope;
5. Several different observers may report conflicting aspects of a phenomenon poorly observed, and yet all may be reporting useful information;
6. Exobiologists imagine forms of life adapted in specific detail to the planets other than Earth;
7. The Viking spacecraft have vastly increased our knowledge of Mars, but have not found clear signs of life.

Acknowledgements

We wish to thank Sheldon Schafer of the Lakeview Center Planetarium, Peoria, Illinois, who conceived and developed the "Fuzzy Mars" observatory activity; the National Air and Space Museum of the Smithsonian Institution, for permission to reproduce illustrations of Bonnie Dalzell's extraterrestrial creations (copyright, 1974); Ultimate Publishing Company, for permission to reproduce Frank Paul's Martian (copyright, 1939); the Lowell Observatory, for permission to reproduce one of Percival Lowell's drawings of Mars; the Hansen Planetarium,

for supplying slides of Charles Capen's drawing of Mars (copyright, 1974, Charles Capen); the Hale Observatories, for their photograph of Mars (copyright, 1965, Hale Observatories); and the Astronomical Society of the Pacific for supplying NASA photography of Mars. Permission to use the copyrighted materials has been obtained for this particular program only, and no other reproduction or use has been authorized.

Materials

1) **Slides** for this program have been assembled from several different sources, listed in the acknowledgments. We have obtained permission to reproduce for planetariums those slides not commercially available, but only for use in this program. Copies of all the slides may be obtained ~~from us~~ at ~~cost~~. See page 97. No other use or reproduction has been authorized.

2) **One Special Effect Device** is used in this program, a "Mars-under-poor-seeing-conditions" single slide projector devised by Sheldon Schafer of Lakeview Center Planetarium, Peoria, Illinois. This inexpensive device may be easily assembled and consists of nothing more than a slowly rotating transparent plastic disk placed in the projected image beam of any slide projector. The disk is thinly smeared with vaseline, with some areas wiped clean to produce moments of clarity. We use a disk 20 cm. in diameter glued to a 2 r.p.m. motor. (Similar motors and disks are available from Edmund Scientific Company, Barrington, New Jersey 08807 for under $20--motor 60,734 ~~and wheel~~ 71,242.) We project a slide of a drawing of Mars made by Charles Capen, available commercially from the Hansen Planetarium, 15 South State Street, Salt Lake City, Utah 84111. The effect is quite accurate. (see diagram)

3) **A Naked-eye Mars Projector** is needed for the first activity. It must be moveable, and similar in diameter and hue to other red stars in the planetarium sky. Many planetarium projectors already include a good Mars projector that can be adjusted by hand. However, if your projector, like ours, produces planets much greater in diameter than the stars, you can use a single slide projector instead for Mars. We use a simple black Kodalith slide with a small orange dot which projects a star similar to the other first magnitude stars in the planetarium sky. The single slide projector is moved by hand to produce the two or three relative motions that occur (during the "days") in the program. You'll need to make your own "dot" slide.

4) **An Activity Sheet** for each member of the audience provides space for them to draw their version of Mars, and for their extraterrestrial creations. You can devise your own sheet or use ours (page 174). We also provide a clipboard with attached pencil for each participant.

optional:

5) **An Opaque Projector** allows participants to have their own drawings projected onto the dome for discussion. We use a $15 opaque projector (a "Brumberger #290 Project-o-scope" or a "Rainbow Crafts M100"), sold in art supply stores. This produces quite an adequate image two feet in diameter in our dome. Edmund Scientific sells better projectors for $90 and up. An alternative would be to show slides of drawings by previous audiences.

6) **A Battery-operated Light Pointer.** These are available from photographic stores for about $10, and may be used as is. We modify ours as follows to increase battery life: a) replace the slide switch with a momentary contact push button; b) add a silicon power diode in series with the batteries to drop the voltage; and c) use rechargeable ni-cad batteries.

Script

We don't expect the script that follows to be memorized (as an actor might memorize a part) but to be used as a guide in learning, rehearsing, and improving presentations. We recommend that you read the script once or twice, then work with it in the planetarium, practicing the projector controls, slides, special effects, and music. You should be able to imagine yourself presenting information, asking questions, and responding to participants. For your first few presentations, you can have the script on hand, using major headings as reminders of what to do next.

The script is organized in blocks or sections. The purpose of these separations is only to help you learn and remember what comes next. Once you have begun a section, the slides or special effects and your own train of thought will keep you on track. When beginning a new section, make the transition logically and smoothly.

Directions for the instructor are printed in *italics*, the instructor's narrative is printed in regular type, and directions and questions to which the audience is expected to respond are printed in CAPITAL LETTERS. There is no point in memorizing narration word-for-word since what you need to say will depend upon the participants. The language you use and the number and kinds of questions you ask will depend on how old the participants are, how willing they are to respond, and how easily they seem to understand what is going on.

We believe the most important elements of the program are the questions and the activities since these involve the audience in active learning. If you must shorten your presentation, we recommend that you borrow time from the narration.

The following checklist is suggested as a guide in preparing for each presentation:

1. Latitude: Home.
2. Precession: Current.
3. Diurnal set so Castor & Pollux are 10 degrees above western horizon.
4. Mars set a few degrees to the left of Regulus in Leo.
5. No other planets visible.
6. ~~Sun and~~ Moon off.
7. Slide projectors set for Mars show.
8. NESW lights on.
9. Activity sheet, clipboard and pencil for each member of the audience.
10. "Mars-under-poor-seeing-conditions" effect.
11. Opaque projector. (Optional)
12. Battery-operated light pointer. (Optional)
13. Title and Credit slides on (Slides 1 and 2).

INTRODUCTION

My name is ________, and I'd like to welcome you to the ______________ Planetarium. One of the most exciting things about science is the chance to discover something new. Today, in the planetarium, you will have the chance to experience for yourself some of the excitement of discovering new things about the Red Planet Mars. Mars has been "discovered" several times: thousands of years ago, when people first realized that Mars was different from the stars; 300 years ago, when people first looked at Mars through a telescope; and recently we got our first close-up look at the surface of the planet. You will be able to make each of these discoveries yourself, today, in our participatory planetarium program, "The Red Planet Mars."

It is now evening, and as your eyes grow accustomed to the darkness, you will see the sky as it looked during the summer of 1976. We have gone back a bit, because Mars was easily visible at that time, and as we shall see, the summer of 1976 is when the greatest advance in our knowledge about Mars was made.

FIND RED STARS ACTIVITY

Can we discover Mars, right now?

EVERYBODY, PLEASE LOOK ALL AROUND THE SKY TONIGHT, AND LET'S SEE HOW MANY YELLOWISH-RED POINTS OF LIGHT WE CAN FIND. PLEASE LET ME KNOW WHEN YOU HAVE FOUND A YELLOW TO RED POINT OF LIGHT, SO WE CAN POINT IT OUT TO EVERYBODY. *Turn up reading lights partially; when people find something, let them show it with portable pointers. Keep asking until Mars and two other yellow-red objects are found.*

We now have three candidates--yellow to red points of light that might be Mars. *One* of them has been designated by every society on Earth as being special. Mars, we call it. But which one of these is Mars?.

IS ONE OF THESE DIFFERENT FROM THE REST? HOW? *Each may have some unique quality, but we need an overwhelming difference. They are different through a telescope, but the ancients didn't have telescopes and still knew which one was Mars.*

FIND THE PLANET ACTIVITY

Could one of these points of light do something different? We have been watching for many minutes now, and we know all the points of light in the sky appear to turn very slowly throughout the night. But there isn't much happening so far, and no one star stands out yet.

Maybe we should go ahead several nights to see if anything has changed.

Assign each object to a section of the audience to watch.

NOW STUDY YOUR OBJECT CAREFULLY: LOOK AT ITS POSITION COMPARED WITH THE STARS AROUND IT, SO YOU WILL BE ABLE TO TELL IF IT HAS MOVED.

Turn up daylight, turn down stars and planets. Advance Mars about 10 degrees East.

When the lights dim again, we will be four weeks in the future, and see the stars when they are back in their same positions. But ~~will~~ any of our yellow, orange or red objects be different?

Turn up stars and planets; turn down daylight.

WHAT HAPPENED TO YOUR POINT OF LIGHT? *Go from group to group. Nearly everybody will say theirs moved a little bit.*

Well, most of the objects may have moved a little bit. Maybe we need to go ahead another four weeks. Watch your star again.

Turn up daylight, dim stars and planets, advance Mars another 10 degrees, etc.

WHAT HAPPENED TO YOUR POINT OF LIGHT NOW, EIGHT WEEKS AFTER WE STARTED? *Now a few will have decided theirs didn't move, but the Mars group will be sure theirs did move.*

We are not sure about some of the objects, but have ruled out some, and one group thinks this one *(Mars)* definitely did move. LET'S ALL WATCH THIS ONE VERY CAREFULLY THIS TIME, AND SEE IF IT IS INDEED MARS.

Repeat sequence a final time.

WHAT HAPPENED TO THIS ONE? *It moved!*

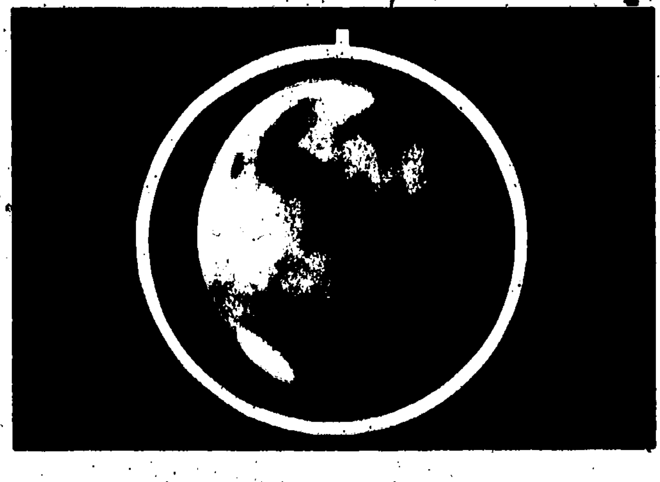
So we *have* found the planet Mars--by its motion. In fact, our word "planet" comes from the Greek "planetes," meaning "wanderer." As the earth turns, all the stars and planets appear to move slowly every night, together. The planets, however, turn a little faster or a little slower than the rest. There are other differences, but we can't tell them without a telescope. Other celestial objects are just as red--in fact, the name of this star *(point out)* "Antares" means "rival of Mars."

We have found it. That red dot of light is the planet Mars, as mankind had seen it from the beginning.

TELESCOPE VIEWS

We have discovered Mars just as it was first discovered: using our unaided eyes. Just 300 years ago, Galileo discovered a new way to look at Mars: through a telescope.

Turn on Slide 3: Telescope Eyepiece Frame Then add slide 4: Mars



This red circle represents the eyepiece of a telescope, and we are going to look at one of the clearest photographs of Mars ever taken through a large telescope on the Earth.

WHAT FEATURES DO YOU SEE IN THIS PHOTOGRAPH? *Color, dark shapes, white pole cap.*

The features - light and dark areas - are not very sharp. In fact, they are kind of blurry. WHY DO YOU THINK THIS PICTURE LOOKS SO BLURRY? *Atmospheric turbulence on Earth.*

Now we are going to see Mars as it would look live, through a large telescope.

Slide 5: Mars Effect on; then Slide 4 off for smooth fade.

There it is. See how *our* atmosphere is changing, blurring the image. But every once in a while, the atmosphere will stabilize, and Mars will become clear for an instant. This is a very accurate simulation of the "live" view of Mars through a very large telescope.

Any photograph we take through any telescope on Earth must also look through this constantly changing atmosphere of the Earth. The turbulent air makes the stars twinkle, and the planets look blurry. Every minute or so on very clear nights, the atmosphere directly along our line of sight may happen to be less turbulent than normal, and for a fraction of a second, we might get an unusually clear view. But the camera doesn't know when these moments will occur, and cameras record the picture over several tenths of seconds, so they would photograph the blur along with the clear. So astronomers observing from the Earth even today usually rely on their eyesight and memory, and sketch details by hand.

There is some fine detail on this view of Mars that I can just barely make out. An astronomer would like to establish as much detail as possible by seeing if there are any barely visible features we all agree are real.

TELESCOPE OBSERVING AND SKETCHING ACTIVITY

Turn up daylight, distribute paper, turn on reading lights full.

Here is your chance to pretend you are an astronomer, trying to help decide what the surface features are. Let me give each of you a piece of paper. On the top half are two sketches of your telescope eyepiece, with a blank disk of Mars ready for you to complete.

NOW, TO HELP DETERMINE WHAT SURFACE FEATURES ARE THERE, PLEASE SKETCH IN THE DARK FEATURES ON THE SURFACE OF MARS. WATCH FOR THE BRIEF MOMENTS OF CLARITY, AND THEN GET AS MUCH DETAIL AS YOU CAN. We will observe for just two minutes, and then hold a brief conference to reach our joint conclusions. There is a second blank disk on your paper in case you don't like the way your drawing is coming out, and want to start over.

Turn off daylight. Go through three periods of clarity, then turn up daylight and turn off Mars' special effect.

How much detail were you able to sketch? COMPARE YOUR SKETCH WITH THE PEOPLE SITTING NEXT TO YOU. DID THEY SEE SOME DETAILS YOU DIDN'T?

Walk around the room, select one or two examples and show everybody using the opaque projector. These sketches are all different; although some features show up on most of them.

WHY DO YOU THINK EACH OF US MADE A DIFFERENT SKETCH OF THE SAME VIEW? *Differing skills of observers, different moments of observation, different choices of what to watch.* There are always differing interpretations of what is really there for something new and as difficult as this. We cannot agree perfectly on what is really there, but we can come to some agreements on broad structure.

LOWELL AND CANALS

One of the most persistent Mars observers was Percival Lowell, an American astronomer in the early part of the 20th century. He observed Mars over and over for many years, and he reported some very controversial features that were very hard to see. Let's look at one of his drawings, showing Mars as Lowell saw it.

Slide 6: Globe of Mars by Percival Lowell

Lowell saw and named hundreds of fine lines criss-crossing the planet. He noted they seemed to connect the poles, which had white caps like the arctic regions of Earth, with the rest of the planet. Many astronomers never could see these fine lines, but several others agreed with Lowell that the lines were there.

IF THE LINES ARE REAL, WHAT WOULD YOU SAY THEY MIGHT BE?

Lowell guessed that the lines were canals, irrigating the Martian deserts. And where there are irrigation canals, there must be canal builders. Thus Lowell suggested there was a civilization of intelligent Martians.

EXOBIOLOGY ACTIVITY

The idea of intelligent beings on Mars sounds fantastic to us today, and it was also fantastic 80 years ago when Lowell suggested it. But the idea of intelligent life *somewhere* in the universe besides Earth is a very reasonable one, and an idea that many scientists today think is very possibly true. Beyond our star, the sun, there are billions of other stars, and each of them may have planets, like the earth or like Mars, that might support other forms of life, even intelligent life.

Scientists today who are investigating the possibility of life on other planets are called exobiologists. Exobiologists try to determine what life forms might exist on planets with different conditions from those on Earth. Exobiologists studied the kinds of life that *could* exist on Mars, so that they could design spacecraft like the Viking, that would be able to search for this possible life.

Let's examine some modern exobiology. We are going to see several creatures designed by exobiologist Bonnie Dalzell for an exhibit at the National Air and Space Museum of the Smithsonian Institution in Washington, D.C. These imaginary creatures have special features that have been evolved to help them survive on planets different from Earth.

Slide 7:
Red Hop-Flier

This is a Red Hop-Flier. It's the kind of creature we might expect on a hot planet with low gravity. There, a hopping creature would be able to travel a good ways on a single hop, and assisted by his thin wings, the Red Hop-Flier gets around very nicely.

DOES THE SHAPE OF THE HOP-FLIER'S WINGS LOOK AT ALL FAMILIAR? WHERE HAVE YOU SEEN T[illegible]SHAPE BEFORE? *Hang-gliders on Earth look very similar, since although air is thinner on a [illegible]gravity planet, the laws of aerodynamics are the same, and a delta wing is a good design.* The big wing is good for flying, and the veins help cool his blood on this hot planet.

Slide 8:
Gliding Green Carnivore

By contrast, this creature glides on a high gravity, thick atmosphere planet. He needs less wing surface for his body mass. Even with six legs, however, he does not hop well due to the high gravity.

Slide 9:
Outrigger Ribbon Fish

Here is a huge fish by Ms. Dalzell designed for a planet with lots of ocean and a very high gravity.

WHY WOULD THE LARGEST ANIMALS ON A HIGH-GRAVITY PLANET PROBABLY BE FOUND IN THE OCEAN? *Hint: Where are the largest mammals found on Earth? Whales live in the sea, because the buoyancy of their bodies in the water reduces the great internal strength that's needed to keep such huge creatures from collapsing under gravity's pull.*

Slide 10:
Bandersnatch

Here is a creature designed for the land of a high-gravity planet. WHAT FEATURES DOES THE BANDERSNATCH HAVE TO HELP HIM SURVIVE ON HIS HIGH-GRAVITY PLANET? *Very thick and sturdy neck, ten short and thick legs, large, low mouth to eat plants that grow close to the ground.*

Let's see the kind of imagination necessary to be an exobiologist. Suppose you are trying to decide what possible forms of life might inhabit a planet like Mars. A Mars-like planet is different from the earth in that it has 1) lower gravity, 2) much thinner atmosphere, and 3) much colder weather.

On the bottom of your sheet of paper is a drawing showing some forms of life that have evolved to meet Planet Earth conditions. They might not be suitable for a Mars-like planet. I'd like you to make your own guess about a being that might be adapted specifically to survive on a Mars-like planet. You want to imagine a being with features designed for lower gravity than Earth's, thinner atmosphere than Earth's, and colder temperature than Earth's. PLEASE MAKE A VERY ROUGH SKETCH OF AN IMAGINARY BEING YOU THINK WOULD BE ADAPTED TO LIFE ON A MARS-LIKE PLANET.

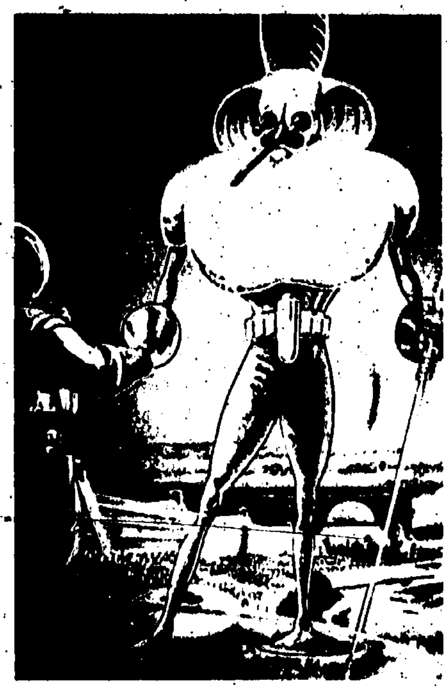
(Note: Adults are often shy about this open-ended activity. Skill on the part of the instructor may be necessary to get adults to give it a try.)

Give people time to draw. Ask people to compare their ideas with their neighbor's. Answer any questions you can. When most people have finished, go around and show a few drawings (using opaque projection if available), asking people to explain what survival features their Martians have. Compliment clever adaptations.

SCIENCE FICTION MARTIAN

Your drawings are good speculation, and, as we will see, modern scientists are working on very similar concepts. WHAT DO YOU THINK OF THIS DRAWING BY AN EARLY EXOBIOLOGIST IN 1939?

Slide 11: Paul's Martian



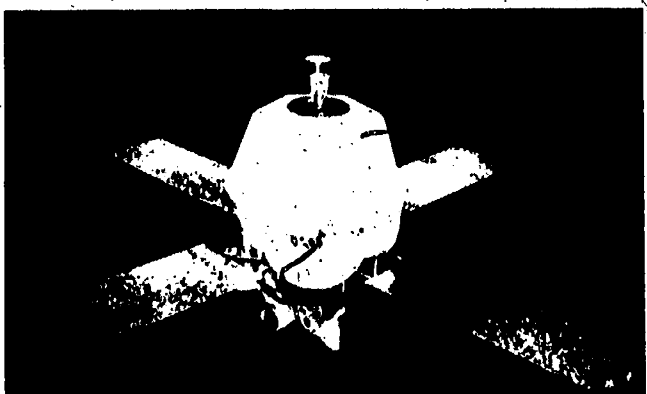
This is what a science fiction artist--Frank Paul, working with astronomers--imagined Martians might look like. WHAT FEATURES DOES THIS BEING HAVE TO HELP HIM SURVIVE ON MARS? *Large ears and lungs for the thin atmosphere; tall and slender due to light gravity; fur and retractable eyes and nose for cold temperatures.*

Are there really Martians like this, who would build canals and farm the planet? Lowell certainly thought so. But you have seen how hard it is to see the details on Mars, and very few other astronomers could see all the canals that Lowell saw. As long as we had to look through the blurry atmosphere of Earth, we could never see Mars clearly enough to be certain. HOW COULD WE BE SURE IF THERE ARE CANAL BUILDERS ON MARS? *Get above Earth's atmosphere, and if possible, get closer to Mars. Then we could get a clear view, and see if the canals really exist.*

Turn off reading lights and daylight.

VIEWING THE MARINER 9 & VIKING MISSIONS

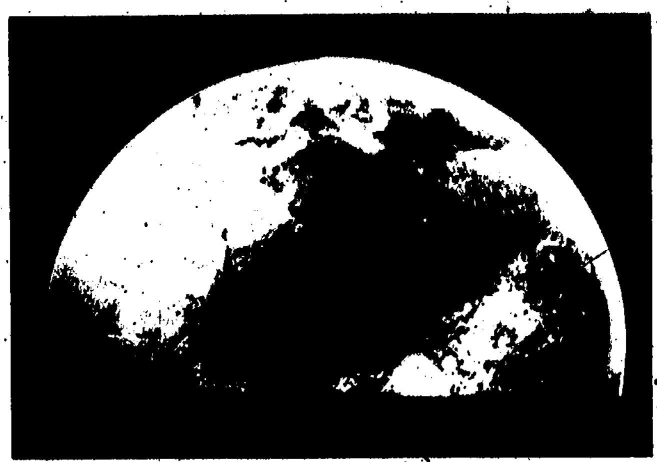
Slide 12: Mariner



SLOWLY rotate diurnal so it looks as if the spacecraft is moving.

This is the Mariner 9 spacecraft that orbited Mars in 1971 and sent back our first closeup pictures of the Martian surface. In 1976, the Viking I and II spacecraft sent back color pictures as they orbited Mars. Once more we see Mars in a new way. Let's watch the television pictures sent from these spacecraft as they approached a few thousand miles above the surface of Mars.

Slide 13:
Mars from Viking II
Half Phase

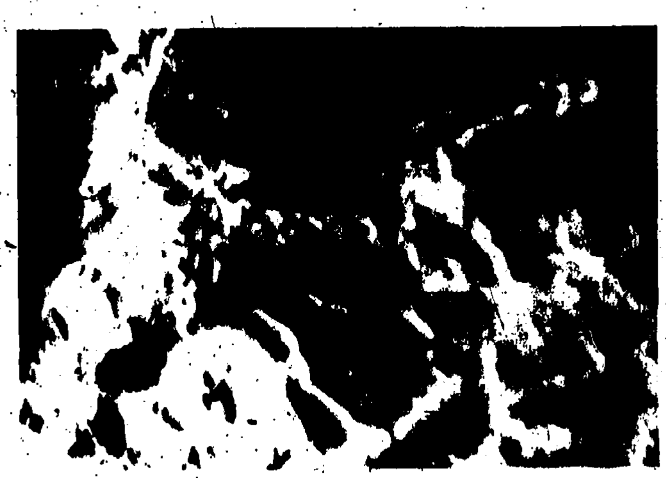


Half of Mars, like the earth, is in night and half is in day, illuminated by the sun. Viking here was just over the part of the planet between night and morning, so we see one-quarter of the surface illuminated. The "grand canyon" of Mars, Vallis Marineris, can be plainly seen. That is one of the few line features in Lowell's canal maps that turns out to be quite real.

Slide 14:
Mars from Viking II
Crescent Phase

Here we see a bit more of the night side. An ice cloud is seen rising off a great volcano, and a frost-covered crater is at the bottom.

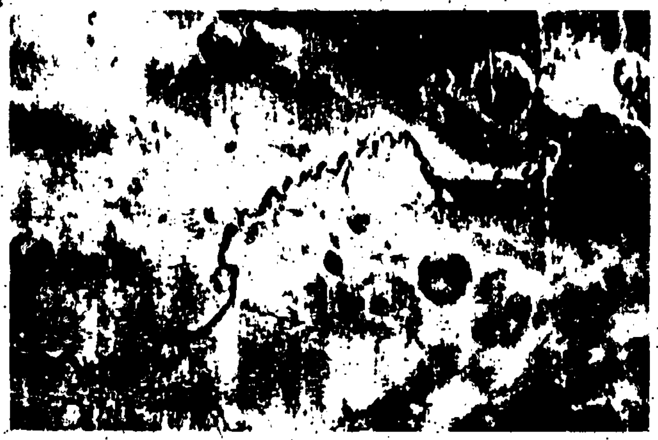
Slide 15:
Mars close-up



As we move in closer, we see an area about 100 kilometers on a side with bright white ice clouds hovering over canyons on Mars.

Slide 16:
Black & White Close-Up

Not far from the south pole, this black and white photograph from the Mariner 9 spacecraft shows another area 100 kilometers on a side, with strange pits and hollows. WHAT DO YOU THINK THEY MIGHT BE? *Possibly the result of ice freezing and thawing underground.*

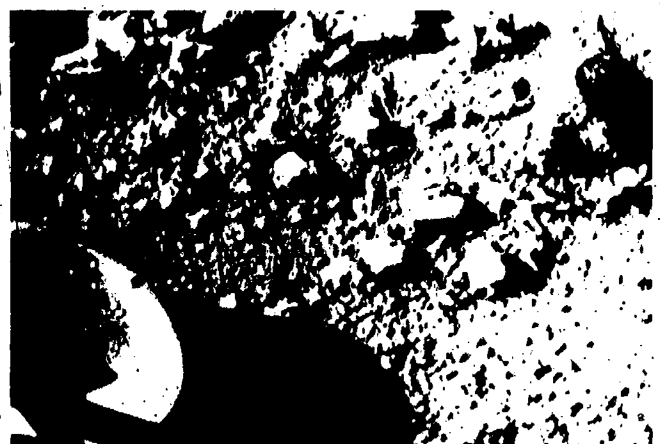


Slide 17:
Mars river valley

Here is a very important picture of an area 400 kilometers wide on Mars. HOW DO YOU INTERPRET THIS PHOTO? It looks like a river valley. The branching tributaries strongly suggest a water-cut valley, but there is no liquid water on the Martian surface now. This creates a fascinating new question: Where did the water come from and where has it gone today?

So these views of Mars pose many further questions about the red planet. But what happened to the canals, the long straight lines carrying water to the Martian farms? Only a half dozen features that we see, such as the "Grand Canyon of Mars," have any correspondence to features on Lowell's canal maps. The rest of the canals do not, in fact never did, exist. You have seen how difficult it was to see surface features through earth-based telescopes. Much of what Lowell did has proved very valuable--he developed the techniques of planetary photography, spectography of the nebulae, and determination of the rotation rates of the planets--and even exobiology -- but his observations of the canals were not correct. Apparently, the human mind "helps" the eye and fills in the details sometimes that the eye partially sees. This is what makes optical illusions work, and in this case, it must have made the rims of craters seem longer, straighter. We now know that the famous canals of Mars never existed.

In the summer of 1976, two Viking spacecraft detached parts of themselves and landed on the surface of Mars. A Viking lander touched down and pointed one of its cameras at its own footpad. As this black and white picture comes on, we will see the first photograph ever taken from the surface of Mars.



Slide 18:
Martian Surface

This remarkably sharp photograph shows the rocks, sand, and dust at our feet as we stand on the surface of the red planet Mars. The rocks are only a few centimeters across.

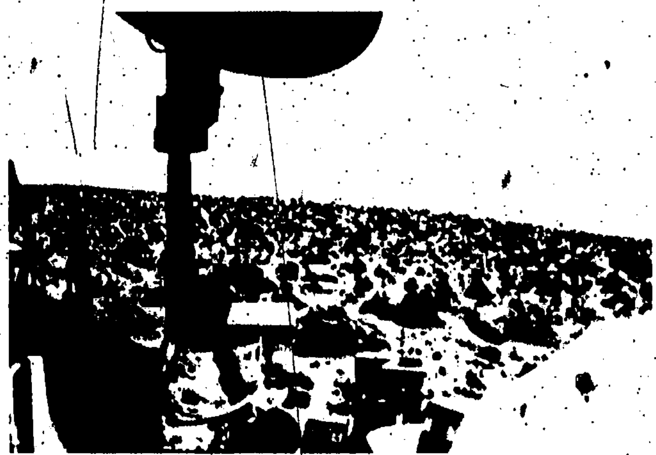
Then Viking II pointed its camera higher, and we will now see a color picture of the horizon. If you stand on Mars and look out horizontally, this is what you will see.

Slide 19:
Martian Horizon

This photo shows part of the spacecraft, including the slender meteorology boom, taking weather data. Mars is even more hostile to life than we had thought based on earth-bound observation. Viking tells us the atmosphere is only 1/100th that of Earth, and the average temperature on a mid-summer afternoon is 30 degrees below zero Celsius. It is *very* dry.

Slide 20:
Viking Digs a Trench

On the ground behind the boom, you can see the trench the spacecraft's "arm" dug for gathering soil samples for more experiments.



Slide 21:
Viking spacecraft with flag

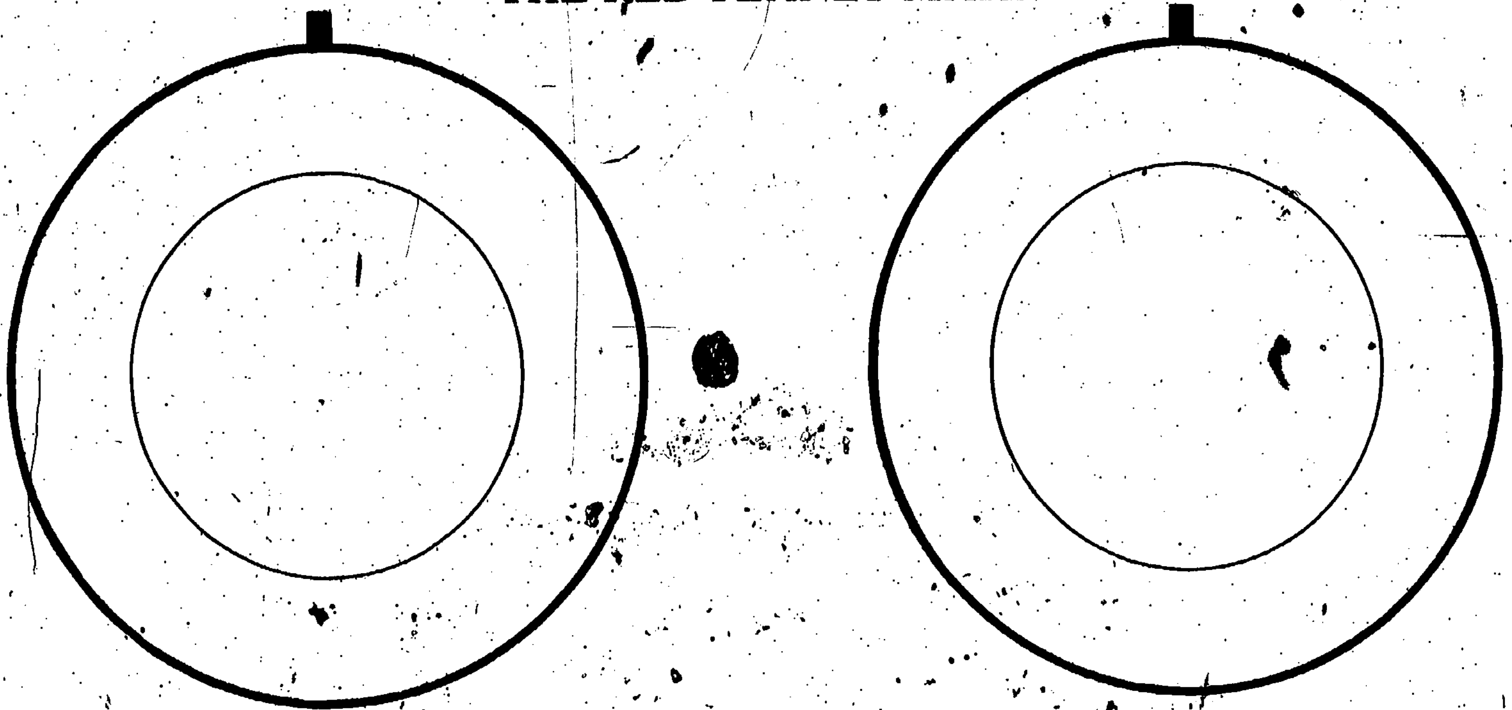
The surface of Mars is like a rocky desert. There is no running water, but only vast, icy polar caps. The surface is cold, the air extremely dry and thin, and the rocks are all covered by a layer of fine, red dust.

Sensitive electronic instruments on the Viking lander searched for microscopic life, but the results are confusing, and there is no clear sign that even microscopic life exists. Viking has conducted a series of interesting science experiments: measuring the weather on Mars, searching for Marsquakes, analyzing the atmosphere and the composition of the soil, and looking for magnetic particles. Maybe we will learn how the river bed we saw was made, and where the water is now.

There still might be some form of life on Mars, and we may not yet know how to look for it, or where it might be. There may yet be more moments when Mars looks new to us. But the intelligent Mars Man, building giant canals to farm the surface, just does not exist. There is no reason for exobiology to stop at Mars, however. There are two hundred billion stars in our galaxy alone, and almost every star, like the sun, may have its own family of planets.

Even if there turns out to be no life at all on Mars, the red planet has taught us more about how planets were formed and how they behave. As we move on to other planets, other suns, we will have learned how to look from our experience on the Red Planet Mars.

THE RED PLANET MARS



Beings from the Planet Earth

Being from a Mars-Like Planet

This Planet Has:
Weaker gravity.
Thinner atmosphere.
Colder weather than Earth.

William K. Holt Planetarium, Lawrence Hall of Science
University of California, Berkeley, California 94720

The Mars Observation Activity was developed by Sheldon Schafer
Lakeview Center Planetarium, Peoria, Illinois.

Discover More About
RED PLANET MARS

H.G. Wells, *War of the Worlds*, 1896. Wells imagined an invasion from Mars, based on the latest theories about the red planet from astronomer Percival Lowell. This fascinating novel started modern science fiction on its way.

William Graves Hoyt, *Lowell and Mars*, University of Arizona Press, 1976. This delightfully illustrated scientific biography of Percival Lowell illuminates the excitement and controversy over Lowell's contributions to planetary astronomy, including his ill-fated speculations about Martians.

James B. Pollack, "Mars," *Scientific American*, September, 1975. Reports the status of our knowledge prior to Viking. Articles in this magazine reporting Viking results appeared in July and November, 1977, and March, 1978.

Science News, June 5 and 12, 1976, and *Astronomy*, July, 1975. Guides to the Viking project and reviews of the history of Mars investigation.

Henry S.F. Cooper, Jr., "Profile: Carl Sagan--A Resonance with Something Alive," *New Yorker*, June 21 & 28, 1976. Superb science reporting sharing the excitement of the search for life elsewhere.

Bevan M. French, *Mars: The Viking Discoveries*, NASA, 1977. A well illustrated, non-technical booklet summarizing the complete Viking project and its major results.

Journal of Geophysical Research, September 30, 1977. Very technical reports from major Viking experiments (about 700 pages). Reprinted as *Scientific Results of the Viking Project* by the American Geophysical Union.

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Slides for The RED PLANET MARS			
Slide #	*Script Page*	*Description*	*Source*
1	162	Title Slide	Lawrence Hall of Science
2	162	Credit Slide	Lawrence Hall of Science
3	164	Eyepiece Circle	Lawrence Hall of Science
4	164	Mars Photograph	Hale Observatories
5	165	Mars Drawing	Charles Capen/Hansen Planetarium
6	167	Lowell's Globe of Mars	Lowell Observatory
7	168	Red Hop-flier	Bonnie Dalzell for the National Air and Space Museum, Smithsonian
8	168	Gliding Green Carnivore	Bonnie Dalzell
9	169	Outrigger Ribbon Fish	Bonnie Dalzell

Slide 3 is intended as a frame for slides 4 and 5. We project slide 3 from a separate single slide projector positioned so that the images on slides 4 and 5 fall within the "eyepiece" frame. This is a nice effect, but is optional.

Slide 5 is used in the "fuzzy Mars" activity, described in the text.

For more information on Bonnie Dalzell's work (slides 7-10), see *Smithsonian*, October 1974, pp. 84-91.

Slides 4 and 5 may be purchased from the Hansen Planetarium, Salt Lake City, Utah 84111. Black and white slides from the National Aeronautics and Space Administration (NASA) may be purchased from PIC, P.O. Box 6699, Burbank, California 91510. Color NASA slides may be purchased from Astronomical Society of the Pacific, 1290 24th Avenue, San Francisco, California 94122.

Slide #	Script Page	Description	Source
10	169	Bandersnatch	Bonnie Dalzell
11	170	Paul's Martian	*Fantastic Adventures, 1939*
12	170	Mariner 9 Spacecraft	NASA
13	171	Mars, 1/2 disc, from Viking	NASA
14	171	Mars, 1/4 disc, from Viking	NASA
15	171	Ice clouds over Martian canyons	NASA
16	171	Pits and hollows near Martian pole	NASA
17	172	Martian river valley	NASA
18	172	Martian surface, B & W closeup	NASA
19	172	Martian horizon	NASA
20	173	Viking digs a trench	NASA
21	173	Viking Spacecraft with flag	NASA

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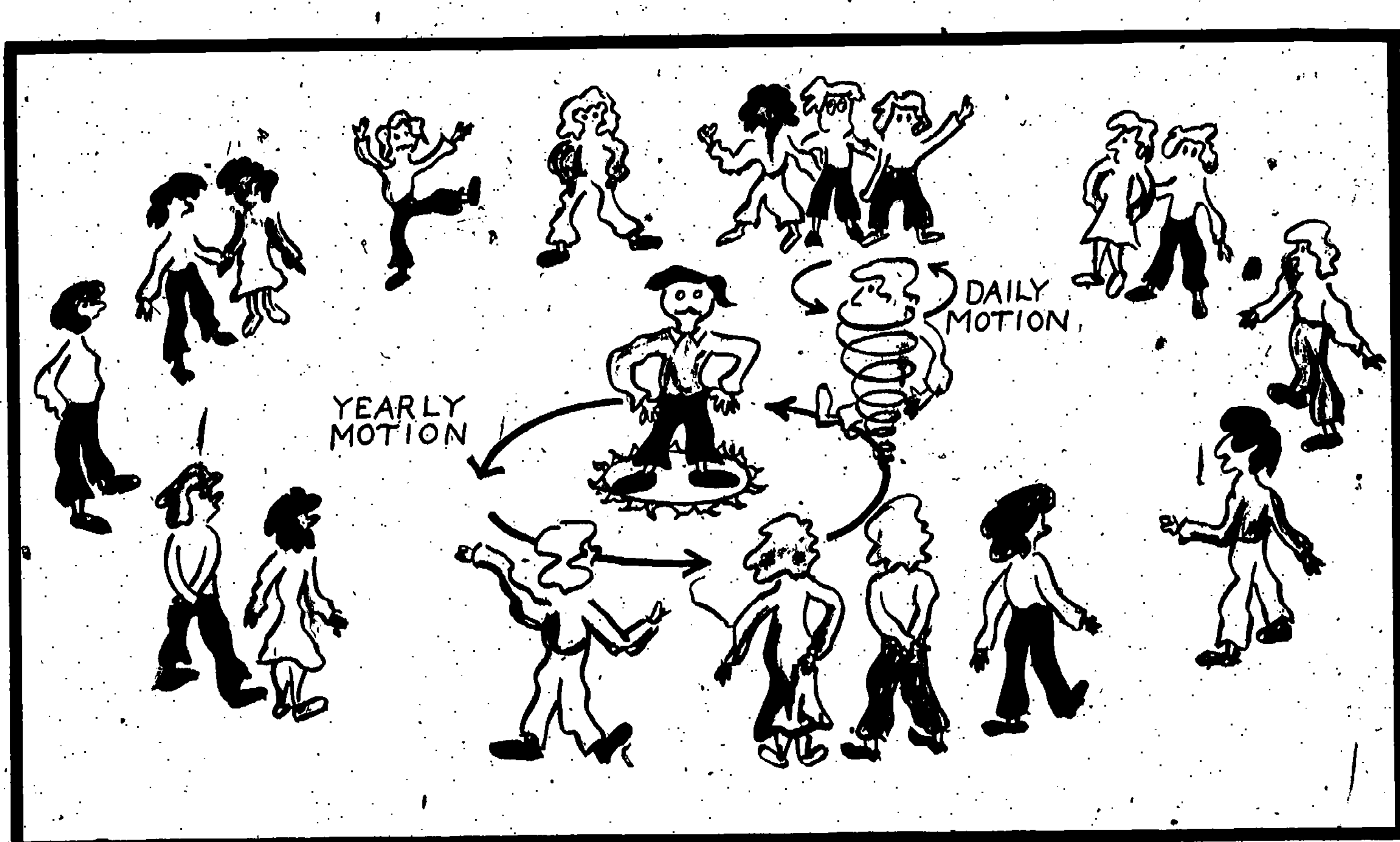
SIMULATING THE SOLAR SYSTEM



A Classroom Activity to Supplement
"The Red Planet Mars" Planetarium Program

William K. Holt Planetarium, Lawrence Hall of Science
University of California, Berkeley, CA 94720

SIMULATING THE SOLAR SYSTEM

A Classroom Activity to Supplement

"The Red Planet Mars" Planetarium Program

This science activity is designed for students in grades five through eight. It can be presented by teachers with no special preparation in science. SIMULATING THE SOLAR SYSTEM is keyed to some of the concepts in the planetarium program, "Red Planet Mars," so it will probably be most effective if presented just before or just after visiting the planetarium. Each teacher may wish to adapt the language and pace of the activities to his or her particular class of students.

Objectives

The primary objective of this activity is to increase the students' understanding of the appearance and movements of the stars and planets. After the lesson, the students will be able to explain or demonstrate:

1) What a planet looks like in the night sky.
2) How to find out if a given point of light in the night sky is really a star or a planet.
3) Why a planet appears to "wander" among the background stars.
4) How to use a model to figure out why the stars and planets appear to move as they do.

Before the Lesson

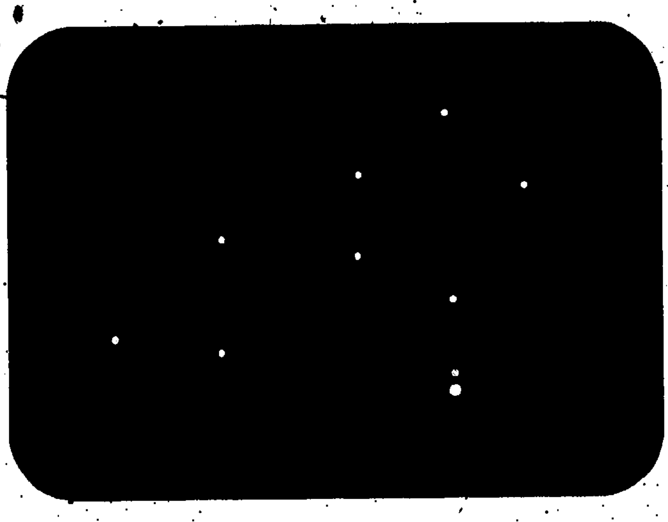
1) Arrange to move outdoors for the last part of the activity.
2) Mount the three posters for this activity on light cardboard.*
3) Stack the three posters together on the chalk tray so Star Pattern #1 is showing, with Patterns #2 and #3 hidden behind it.

Part A. Observing A Planet

Stars and planets both look like points of light in the nighttime sky. Stars are hot balls of gas like the Sun. Planets are cooler balls of material like the Earth. Planets circle around stars in "orbits." It takes the Earth one full year to complete its orbit around the Sun.

Here is a picture of what you would have seen if you had looked up at the sky and seen the planet Saturn among the stars on January 15, 1978. Which one of these points of light do you think is Saturn?

Show poster of Star Pattern #1.



* Posters are available from the Lawrence Hall of Science. See page 97.

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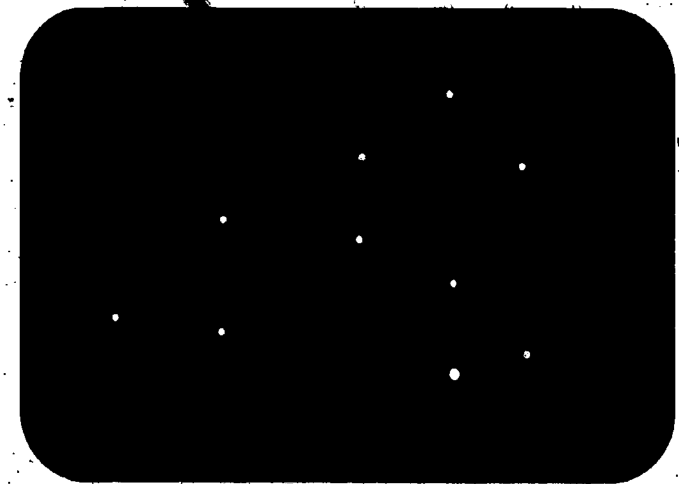
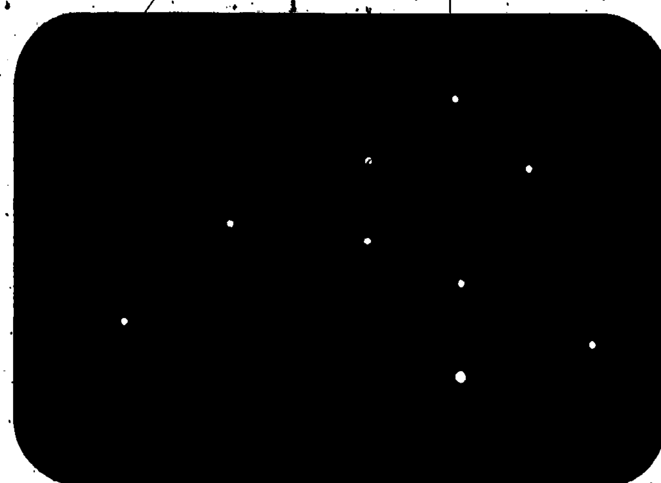
Here is another picture made one month later, on February 15, showing the same part of the sky. Can you see anything different about it? Would you like to take a second guess about which one of these points of light is Saturn? Where do you PREDICT Saturn will appear one month later?

Place Star Pattern #2 next to #1.



Well, let's see if you are right. Here is how this pattern of stars appeared one month later, on March 15, 1978. Who would like to describe how Saturn "wanders" against the background stars?

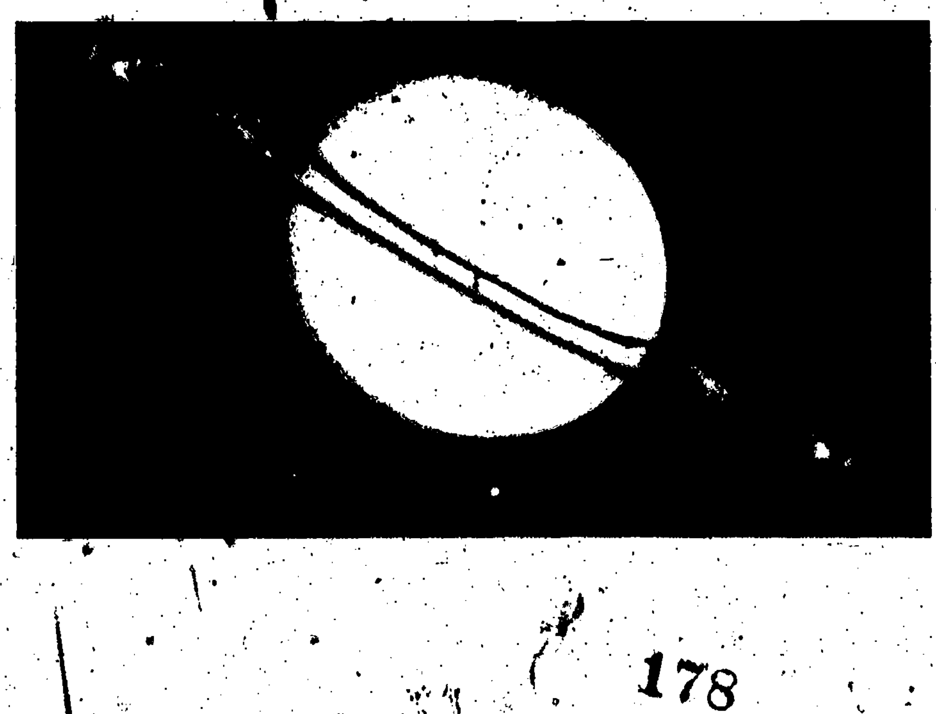
Place Star Patterns #1, #2, and #3 next to each other on the chalk tray.



The planets appear to wander at different rates of speed and in different directions from month-to-month. Teachers who would like to learn more about these motions are encouraged to consult their local planetarium director.

Through a telescope, a star appears very bright, but it is still just a point of light. A planet, however, is much closer to us, so we can see details on it. Let's look at this wandering point of light and see what it looks like through a telescope.

Point to the "star" that has changed its position. Show a poster, slide, or a picture of Saturn.



Part B. Simulation Activity

Have the students go outdoors and stand in a large circle, about 40 feet in diameter (but close enough to hear you).

Now we will do an activity to see why the planets seem to wander among the stars. First, we need two volunteers to stand in the center of our circle to play the parts of the Sun and Earth.

Have the Sun stand in the very center of the circle, and the Earth stand about five feet away.

Imagine that all of you in the circle are stars. Like the real stars, each of you has a name. If you want to appear even more like the stars, space yourselves around the circle so the Earth sees groups, or CONSTELLATIONS of stars.

The students move a little closer or further apart so they are spaced unevenly around the circle.

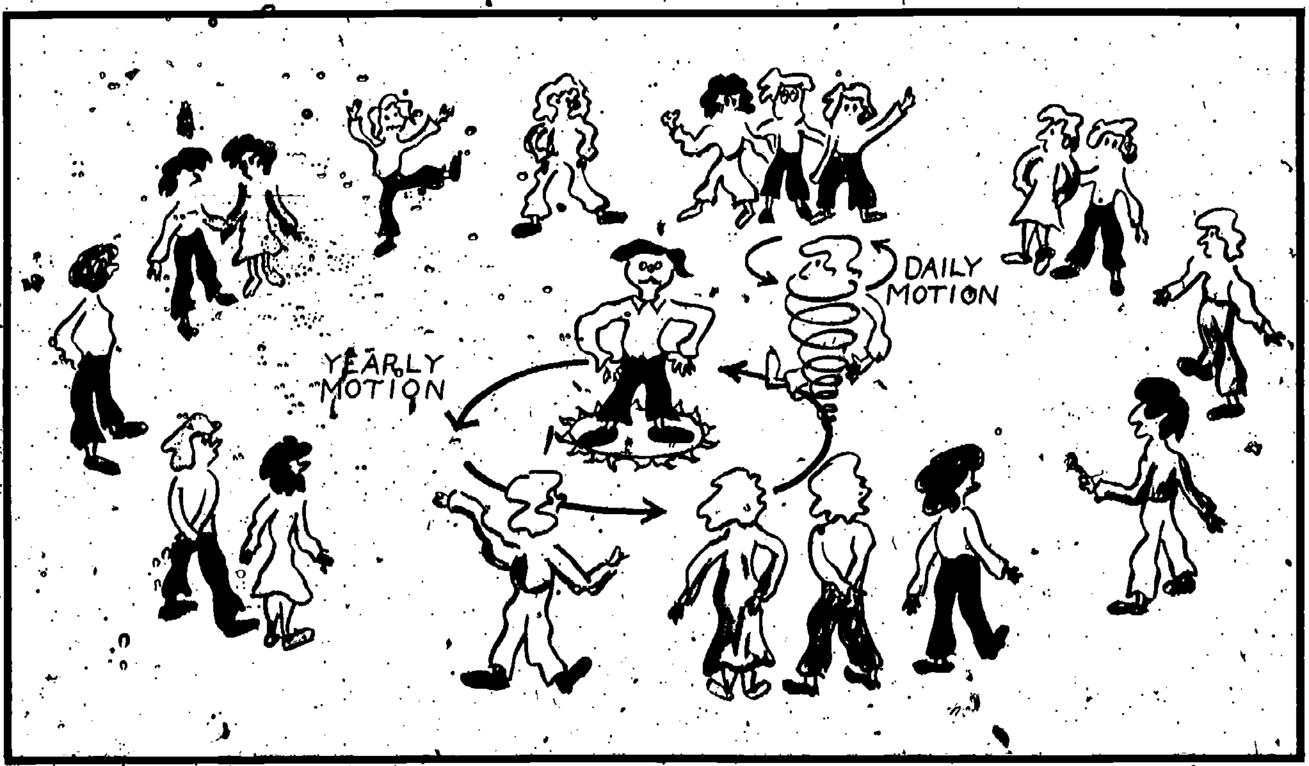
Earth, please turn so you can see the Sun. What time of day is it for your face? *(Noon.)* Now turn so it is night for your face. Please point out some stars whose names you know!

The student playing Earth points to three or four classmates and says their names.

How should the Earth move so that a whole week of time goes by? How should the Earth move so that a whole year goes by?

At least one or two students in the class will probably be able to suggest that in one week the Earth would turn around seven times while standing in the same spot, or moving a bit along in its orbit. To demonstrate a year, the Earth will have to walk around the Sun while at the same time spinning around.

Earth, please demonstrate one year by walking all the way around the Sun in your orbit. If you get dizzy, we'll pretend you turned around 364 times as you walked in one complete circle.



Now I have a problem for you to figure out. I will divide the class into two groups. I want each group to make its own model of the Solar System, with the Earth, Sun, Stars, AND SATURN. You must decide where Saturn should be and how it should move. When we get back together again, I want each group to demonstrate why Saturn appears to "wander" against the stars. Any questions?

Divide the class into two groups and assign areas for them to work in. Let the students choose who will play the Earth, Sun, and Saturn, and discuss how the planets should move. The students may want to know how long Saturn's day is (10 hours) or how long it takes for Saturn to go around the Sun (about 29 Earth years), but this information is not vital for this activity. Allow the teams to work until they have solved the problem (probably five to fifteen minutes.)

Come back and form a large circle again. Who would like to explain why Saturn appears to wander against the stars, while your teammates act out the Solar System?

The students may discover either or both of the following explanations for why the planets appear to wander against the stars: First, the planets are VERY much closer to Earth than are the stars, so a slight change in the Earth's location will make planets appear to move with respect to the stars. Second, the planets are moving in their own orbits as well, so the direction an Earth observer must look to see another planet is always changing. It is not important for the teacher to explain these concepts in detail, but rather to let the students explain and demonstrate their ideas while the other students comment and criticize.

Now it's the second team's turn. Who is the explainer? The Earth? The Sun? . . . .

Follow-Up Activities

1) Have the students extend their simulation of the solar system to include three, four, or even nine planets.

2) Simulate the phases of the moon in a darkened room. Have the "Sun" hold a bare bulb lamp, and the "Moon" hold a white ball. The "Earth" will see the "Moon" go through its phases as the "Moon" walks around the "Earth" (once per month). This arrangement can also be used to demonstrate eclipses of the sun and moon.

3) Have the students make a scale model of the solar system. We suggest the following procedure developed by Bob Risch and Jim Vickery, Co-Directors of the Jeffco Planetarium, Lakewood, Colorado, for their School District's *Curriculum Guide.* First, the students make models by selecting small objects to represent the planets. These can be taped to cards with cellophane tape and labeled. Then, the students can go out to the playground with measuring sticks to illustrate the distance scale of the solar system. They may be surprised at how much "space" there is in space! The scale recommended by the *Jefferson County Curriculum Guide* is printed on page 185 with permission of the developers.

4) Gerald Mallon of the Methacton School District Planetarium suggests a larger scale initially to compare the earth and sun. He constructs a clay marble for the earth, and asks students to guess the size of the sun. The sun is then introduced as a 3-foot-diameter weather balloon! (Available for about $5 from Edmund Scientific Company, Barrington, New Jersey 08007).

SCALE MODEL OF THE SOLAR SYSTEM
(2 inches = 1 million miles)

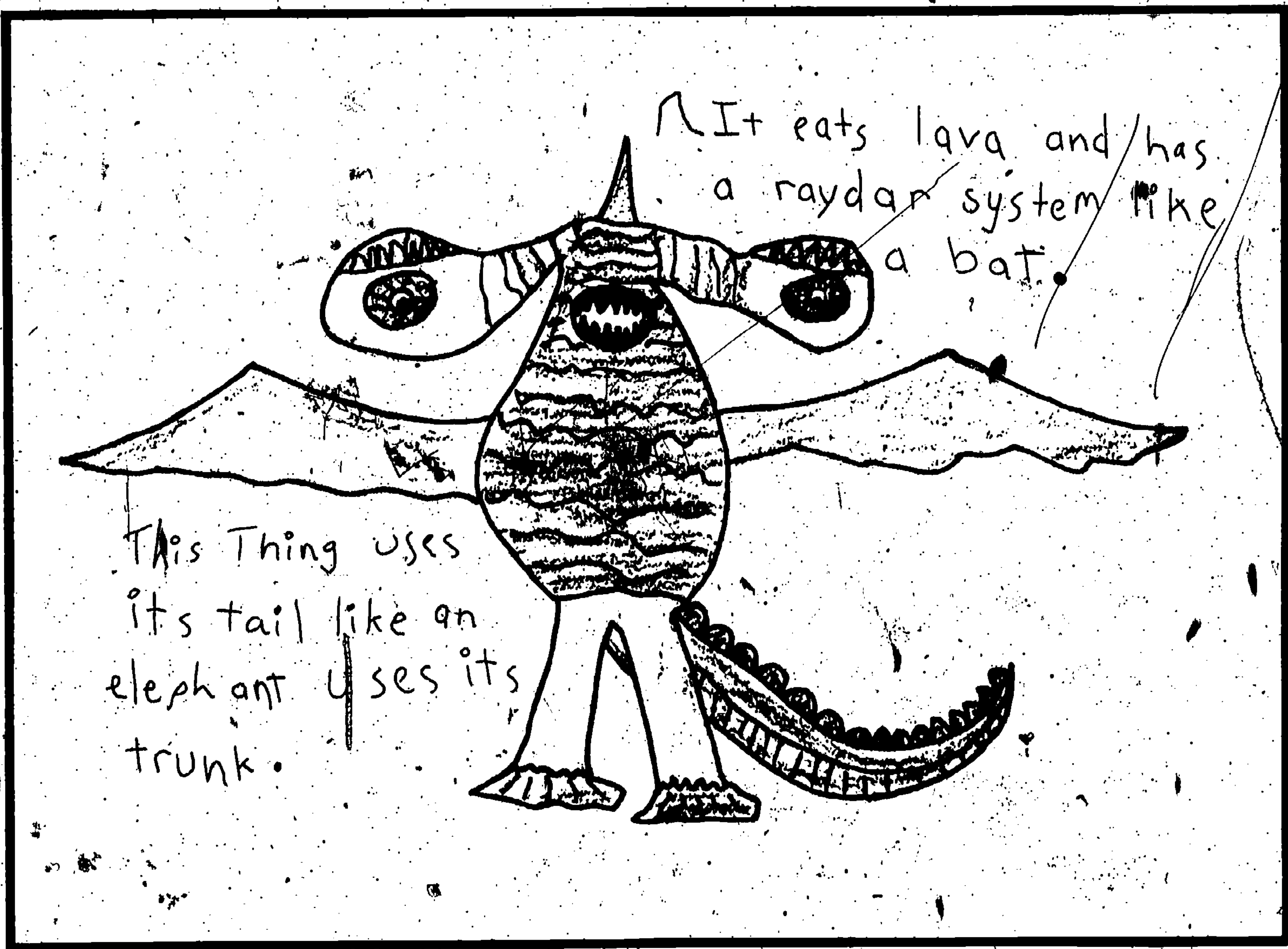
	Size*	In Model	Distance**	In Model***
Sun	864,000	ping pong ball	0	0
Moon	2,000	very tiny grain of sugar	0.25	0.5"
Mercury	3,000	small grain of sugar	36	6' 0"
Venus	7,500	large grain of sugar	67	11' 0"
Earth	8,000	large grain of sugar	93	15' 6"
Mars	4,000	medium grain of sugar	142	23' 6"
Jupiter	89,000	large mustard seed	483	80' 0"
Saturn	75,000	small mustard seed	886	148' 0"
Uranus	29,000	cake decoration	1,783	297' 0"
Neptune	28,000	cake decoration	2,794	466' 0"
Pluto	3,500	medium grain of sugar	3,666	611' 0"
Nearest Star	800,000	ping pong ball	24,000,000	760 miles

* Approximate diameter of the sun and planets in miles.

** Average distance in millions of miles from sun; except for the moon entry which refers to distance from earth.

*** In feet(') and inches(").

INVENTING COSMIC CREATURES



A Classroom Activity to Supplement
"The Red Planet Mars" Planetarium Program

William K. Holt Planetarium, Lawrence Hall of Science
University of California, Berkeley, CA 94720

INVENTING COSMIC CREATURES

A Classroom Activity to Supplement

"The Red Planet Mars" Planetarium Program

This science activity is designed for students in grades four through eight. It can be presented by teachers with no special preparation in science. INVENTING COSMIC CREATURES is keyed to some of the concepts in the planetarium program, "The Red Planet Mars," so it will probably be most effective if presented just before or just after visiting the planetarium. Each teacher may wish to adapt the language and pace of the activity to his or her particular class.

Objectives

The primary objective is for the students to learn how exobiologists work with limited information to imagine what life may be like on other planets. After the lesson, the students will be able to:

1) Invent life forms which are adapted to their environments.

2) Recognize that several observers may notice different aspects of the same object or event.

3) Recognize that hypotheses are ideas which can be tested by further observation.

4) Recognize that scientists make hypotheses based on partial information. Sometimes these turn out to be right, and sometimes they are found to be wrong.

Before the Lesson

1) Assemble the following materials for each student: two large sheets of paper, magic markers or crayons. Assemble for the class: three different Cosmic Creatures posters* and masking tape.

2) Clear three large areas on the blackboard or wall on which to display the students' work.

3) On the blackboard, write:

Omicron has:

[a] Very sandy soil.

[b] Moist, foggy atmosphere.

[c] Very dim light.

4) Prepare three working areas within the room or in adjoining rooms. The students in each area must be able to draw while looking at *only one* of the three posters.

A. Exploring Omicron

Today's activities will help you find out what it is like to be an exobiologist. That is a scientist who studies the possibility of life in the universe beyond Earth.

Each team is to pretend it is exploring the planet Omicron, circling a distant star. Omicron has: a) very sandy soil, b) moist foggy atmosphere, and c) very dim light. What do you think each of these conditions would mean for the creatures of Omicron?

* Posters available from the Lawrence Hall of Science. See page 97.

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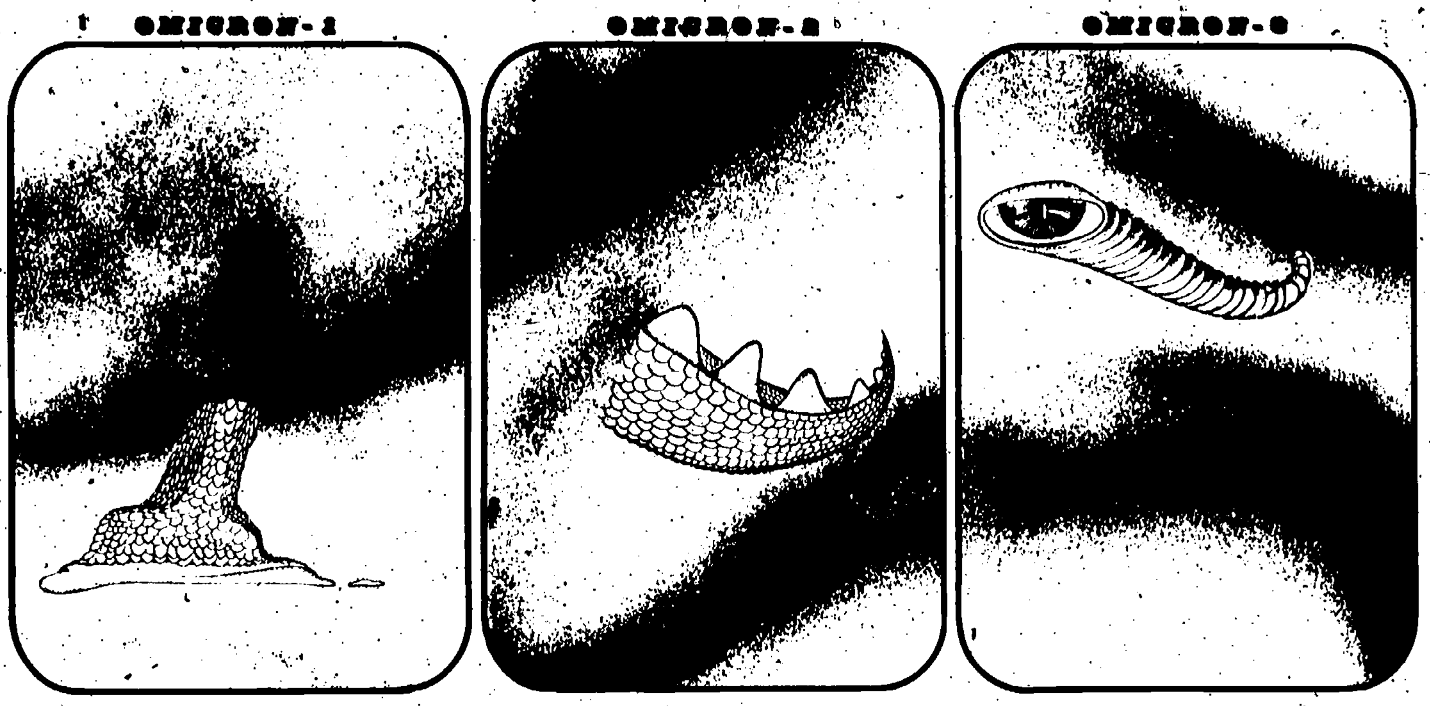
Indicate the list of conditions written on the board. Have the students discuss their own experiences of similar conditions on Earth.

Each team of exobiologists will receive a picture that was taken during the exploration. Since most of the creature was hidden by the fog, your job is to draw what you think the whole creature might look like. Be sure it has specific features to allow it to survive under the conditions of Omicron. Under your drawing, please explain what features your creature has to enable it to survive.

After giving the assignment, distribute paper and crayons or markers. Then, post each of the "Cosmic Creature" posters so each team sees only ONE of them.



Allow five to ten minutes for the students to finish. Have the students post their work on the blackboard or wall next to the work of their teammates. Students should still not have seen the other teams' original posters. When all of the invented creatures are posted in three groups, begin the discussion.

Look at the creatures in the first group. How are they similar? What do you think these exobiologists saw? How are these drawings different from each other? What might explain the differences? Would anyone in the first team like to tell us how your creature is adapted to the conditions of Omicron?

Have the students discuss their answers to these questions. Then, move on to the other groups of drawings and ask the same set of questions. At the end of the discussion, display all three posters. Finally, hand out the second sheet of paper and give the last assignment.

B. How Does Your Creature Survive?

Now that you have more information about the creature, and have heard about some possible adaptations, make one final drawing which shows your best guess as to what the creature looks like. Under your drawings, EXPLAIN THE FEATURES OF YOUR CREATURE THAT HELP IT SURVIVE UNDER ALL THREE CONDITIONS.

Allow five to fifteen minutes for the students to finish. In the meantime, take down their first drawings to make room for the final drawings. As the students finish, they post their new work on the board. (Drawings need not be grouped in teams for this third round.)

Can you see more similarities this time? What are they? Who would like to tell us how your creature is adapted to life on Omicron?

Focus the second discussion on the students' ideas about how their creatures survive under the conditions of Omicron. End with a discussion about how the students' ideas (hypotheses) could be tested on the next expedition on Omicron.

Follow-Up Activities

1) "Inventing Cosmic Creatures" can serve as an introduction to life science activities concerned with adaptations to the environment. For example, the Outdoor Biology Instructional Strategies (OBIS), "Invent An Animal," would be good to do before or after this lesson (available from OBIS, Lawrence Hall of Science, University of California, Berkeley, California 94720).

2) "Inventing Cosmic Creatures" can also serve as the starting point of a language arts activity. The students could write stories about the creatures, describing their means of obtaining food, their houses and social behaviors, the extent of their intelligence and civilizations, interactions with other plants and animals, and so on.

3) In relation to a social science activity, this lesson could lead to a discussion about how different historians report on the same set of events.

4) The quiz which follows may be used as an activity, and may also tell you something about how well your students understand the concepts in this program, either before or after they have experienced the program. Please note that some questions refer to "Simulating the Solar System" while others refer to "Inventing Cosmic Creatures" or THE RED PLANET MARS. You should revise this test as needed to fit your particular classroom situation.

Answers to the Astronomy Quiz

PLANETS

Answers: 1-False, 2-True, 3-False, 4-True, 5-(dot on lower right of Picture C), 6-D, 7-(look for at least one feature designed to help survival under each of the three conditions), 8-C, 9-B, 10-C.

Astronomy Quiz
PLANETS

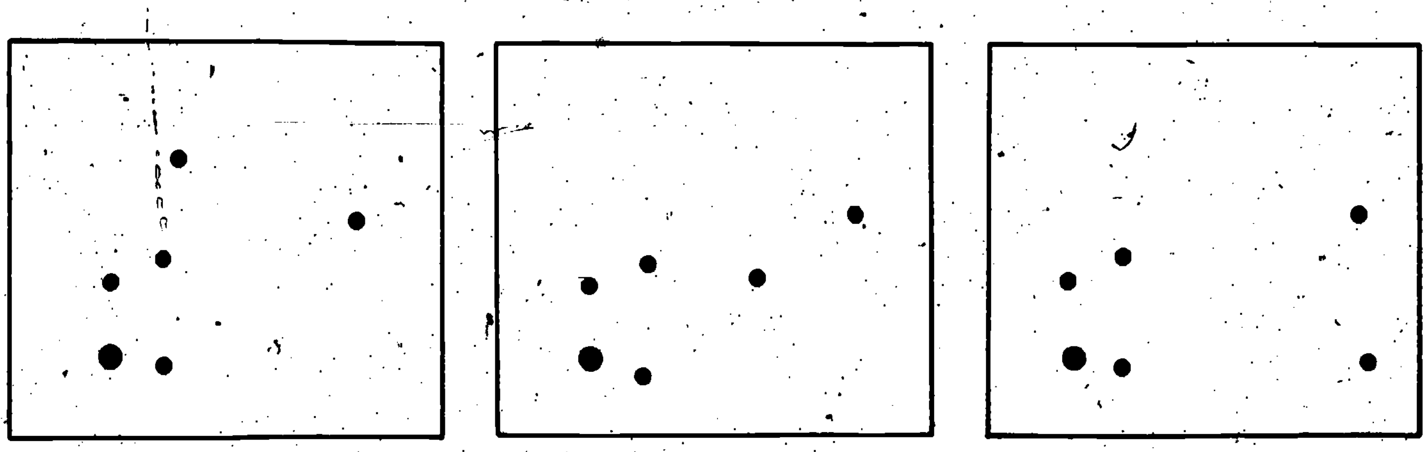
1. "Planet" is just another word for "star." True False Don't Know

2. Without a telescope, a planet looks much like a star. True False Don't Know

3. If you see a planet next to a certain star, you will always find it next to the same star. True False Don't Know

4. If you see a dim star next to a bright star, you will always find it next to the same bright star. True False Don't Know

Here are three views of the night sky seen through the same window but on different nights:



Picture A **First Night** | **Picture B** **One Week Later** | **Picture C** **Two Weeks Later**

5. Circle the PLANET on Picture C. If you think there is more than one planet, then circle each one.

6. Astronomers 70 years ago had a hard time seeing details on Mars. Which of the reasons below could explain this? (Circle the letter which shows the best answer.)

A) Mars was further away then.

B) They did not have telescopes.

C) Their telescopes couldn't see that far.

D) The Earth's atmosphere blurred the view.

E) The Martian atmosphere blurred the view.

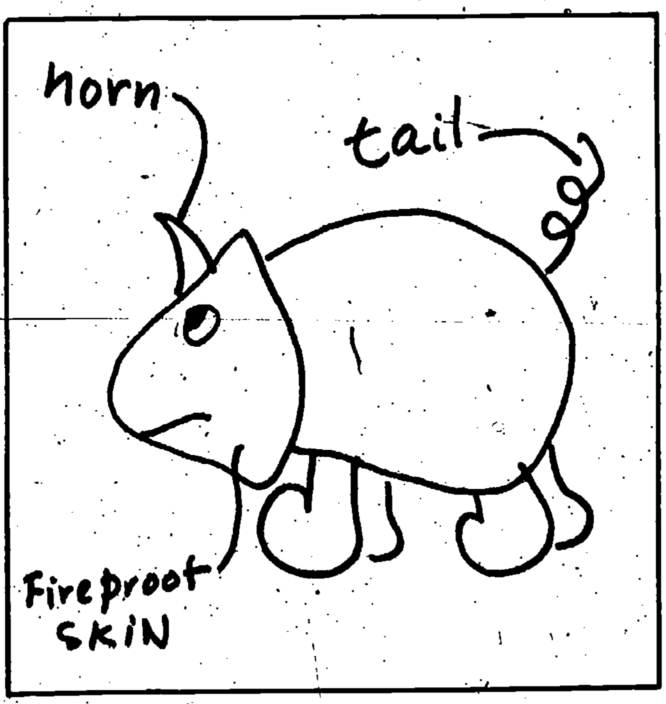
7. Pretend someone called you on the two-way radio and said they discovered a new type of animal living happily on top of Mount Humbug. On top of this mountain: 1) it is very cold; 2) the atmosphere is very thin (not much air); and 3) it is icy and slippery.

In this box, draw a picture of an animal that YOU INVENT which is specifically designed to survive in the conditions on top of Mount Humbug.

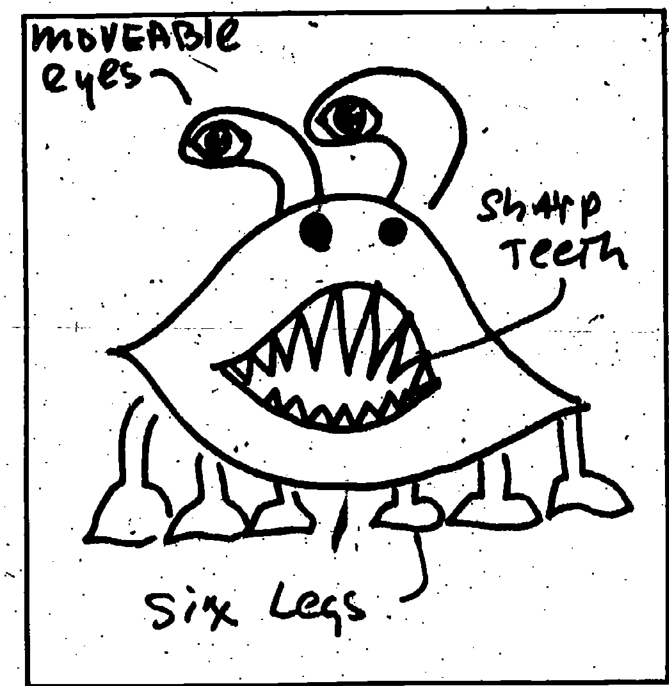
Describe the features of this animal which help it survive under ALL THREE CONDITIONS.

8. Three students drew these pictures of animals that might live in a volcano where: 1) it is very hot; 2) there is very little air; and 3) it is all full of liquid.

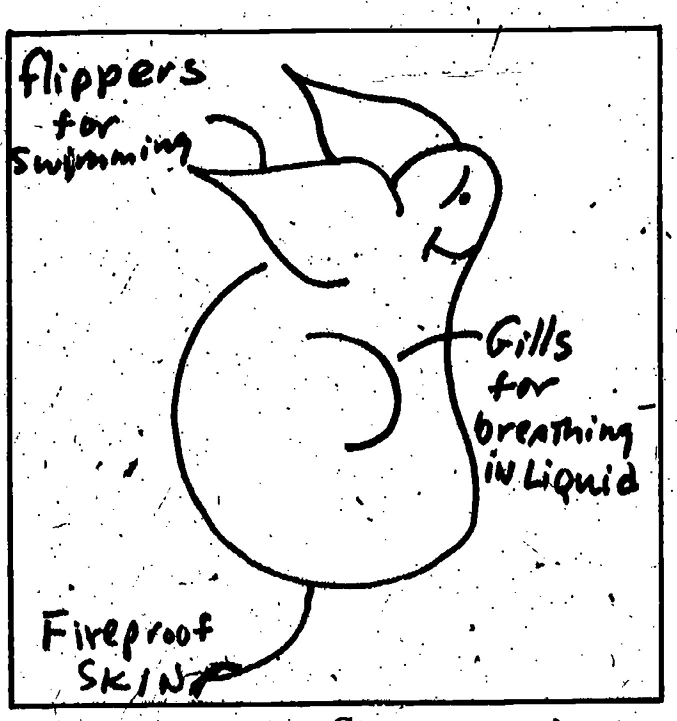
Which of the animals below do you think will survive best in a volcano? (Circle the letter of the best answer.)



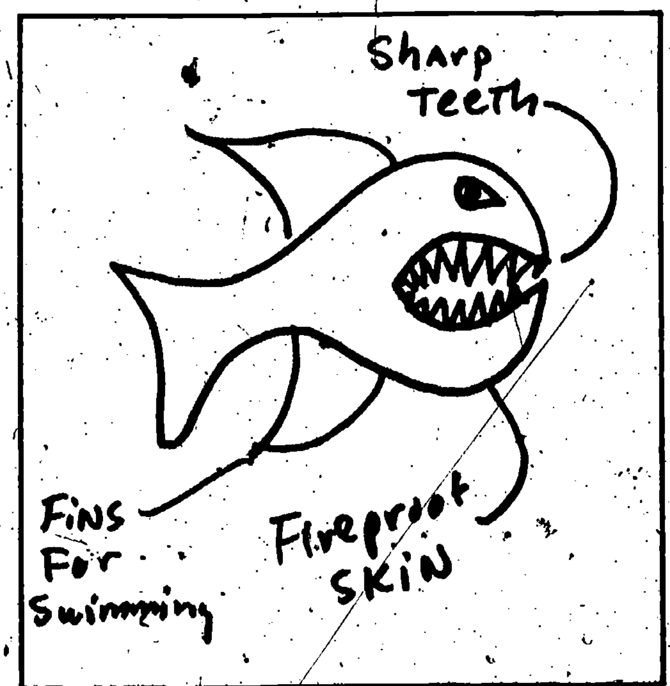
A



B



C



D

9. Three astronomers who worked together used a radio telescope to listen to radio waves from a new star. Without talking about what they heard, the astronomers wrote the following reports:

Astronomer #1 reports hearing buzzing sounds which he thinks may be a warning sent by intelligent beings.
Astronomer #2 reports hearing beeping sounds which she thinks may be a meaningful message in code.
Astronomer #3 reports hearing static which is not sent by intelligent beings.

How can you explain the differences in their reports? (Circle the best answer.)

A) Some of the astronomers had poor hearing.

B) Usually different people don't report exactly the same thing when they find something new.

C) Astronomer #3 didn't believe there could be intelligent life on other planets.

D) Some of the astronomers were tired and not paying attention.

E) Astronomer #1 is older and knows more.

10. The three astronomers mentioned above agree that the signal from this star can be heard every night. Suppose they could not improve their instruments. What should they do to find out which explanation is best? (Circle the best answer.)

A) Ask the chief astronomer to decide.

B) Look and see if they can find the answer in a book.

C) Have more astronomers listen to the same star and then decide.

D) Have the same three astronomers discuss it and take a vote.

E) There is no way to learn which is best.