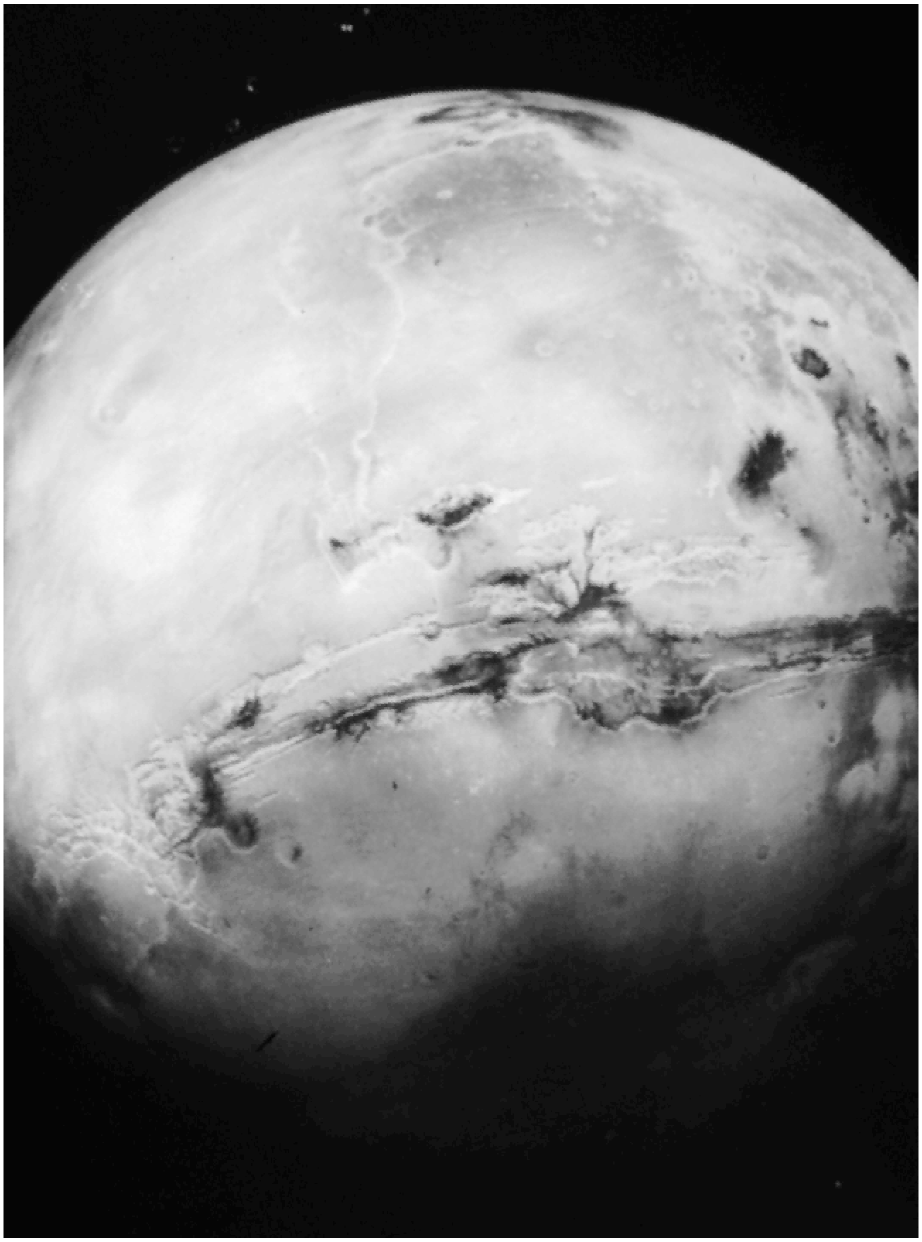
RED PLANET MARS

A PROGRAM FROM THE HOLT PLANETARIUM

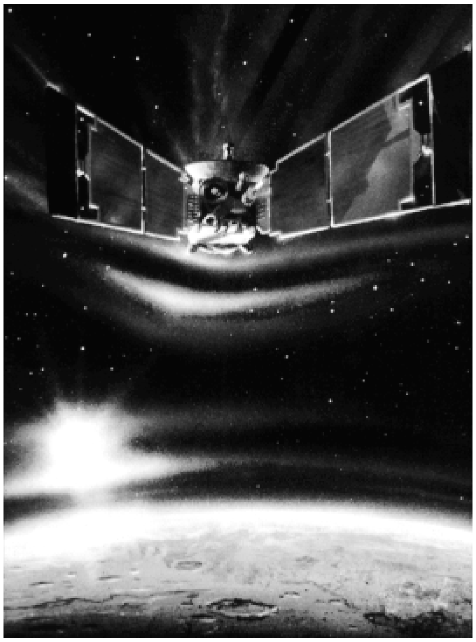


by Alan J. Friedman and Cary I. Sneider

Illustrated by Budd Wentz

Revised by John Hewitt and Alan Gould

Jointly published by the Lawrence Hall of Science, University of California, Berkeley, California and the New York Hall of Science, Flushing Meadows Corona, New York



Mars Climate Orbiter
September, 1999 to December 2004
(NASA Drawing)

Cover and title page photographs of Mars, courtesy of NASA and the United States Geological Survey.

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For latest information, valuable links, and resources relating to the PASS series, visit:

http://www.lhs.berkeley.edu/pass

Additional copies of the *PASS* Volumes may be purchased from:

Learning Technologies, Inc.
40 Cameron Avenue
Somerville, MA 02144
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LHS

Acknowledgements

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Photos & Illustrations

p.ii, NASA, Viking (drawing); p.2, Alan Gould, Telescopic Mars Projector (drawing); p. 5, Budd Wentz, Earthling (drawing); p.9, Lick Observatory, Mars photo; p. 9 Charles Capen, Mars Drawing, p.10, Budd Wentz, Mars Drawing Activity (drawing); p.11, Lowell Observatory, Lowell photo; p.11, Lowell Observatory, Lowell's drawing; pp.12–22, NASA, Mariner Spacecraft, Global Mars View, Mars - Crescent, with Ice Clouds, Mars - 1/2 Disc Showing V. Marineris, Valles Marineris Close-up, Olympus Mons, Olympus Mons Caldera, River Channels, Viking Lander, Viking Digs a Trench, Mars Meteorite, Space Telescope Views of Mars, Pathfinder and Sojourner, Martian Rocks, Mars Climate Orbiter, Mars Polar Lander, Sample-Return Mission, Mars Space Transportation Depot, Geologist on Mars; pp.17-18, Bonnie Dalzell (Smithsonian), Red Hop Flier, Gliding Green Carnivore, Outrigger Ribbon Fish, Bandersnatch; p.13b, Fantastic Adventures, 1939, Paul's Martian; p.23, Alan Gould, Mars in Leo (drawings); p.25, Lick, Saturn photo; p.26, Budd Wentz, Simulating Solar System (drawing); pp.32-36, Cary Sneider, Creatures from Omicron; p.41, Cary Sneider, Quiz Creatures.

Planetarium Activities for Student Success (PASS)

Series Editors: Cary Sneider, Alan Friedman, and Alan Gould

If you have access to a planetarium for teaching about astronomy, space science, and other subjects, this series of books is for you. Designed for both experienced planetarium professionals and teachers who will be using a planetarium for the first time, these volumes provide a wealth of field-tested strategies and practical suggestions for presenting entertaining and educationally effective programs for students.

The first four books provide a general orientation to astronomy and space science education with applications for both the planetarium and classroom settings. Each of the remaining volumes presents a complete planetarium program and related classroom activities. We hope you will find these materials useful in your work with students and teachers, as well as springboards for your own imagination and creativity.

Volume 1: Planetarium Educator's Workshop Guide

Participatory planetarium programs involve students actively in the planetarium environment. The most effective programs are both entertaining **and** educational. This guide introduces the theory and practice of developing effective planetarium programs through a series of thought-provoking activities and discussions.

Volume 2: Planetarium Activities for Schools

This volume provides a wealth of effective planetarium activities for elementary and middle school students, as well as ideas for developing new activities for students of any age.

Volume 3: Resources for Teaching Astronomy & Space Science

There is a wide spectrum of resources for teaching astronomy and space science in elementary and middle schools. This annotated resource guide is a compilation of the best resources that we have found, including school curricula, books, periodicals, films, videos, slides, professional organizations, planetariums, and telescopes.

Volume 4: A Manual for Using Portable Planetariums

Primarily a "how-to" manual for setting up and using a portable planetarium, this guide has many suggestions useful for teaching school programs in **any** planetarium.

Volume 5: Constellations Tonight

In this participatory version of a classic night sky planetarium program, students receive star maps and have an opportunity to use them to find constellations in the planetarium sky. Classroom activities include creating constellations and using star maps.

Volume 6: Red Planet Mars

Students discover Mars three different ways during this planetarium program. First they observe the red planet over a period of several nights as it moves relative to the background stars. Then they view it through a telescope and try to draw a map of its surface. Finally they see Mars via space probes. Classroom activities involve students in modeling the solar system, and creating creatures that might survive under different planetary conditions.

Volume 7: Moons of the Solar System

This program begins with observations of the Earth's Moon and a modeling activity that shows why the Moon goes through phases and eclipses. Then the students look at Jupiter's four major moons on a series of nights and figure out how long it takes each one to circle Jupiter. Finally, the students journey through the Solar System to see many moons through the "eyes" of modern spacecraft. Classroom activities include experiments in crater formation, using moon maps, and designing lunar settlements.

Volume 8: Colors and Space

What can we learn about the stars and planets from their colors? Answering this question requires a fundamental understanding of why we see color. Throughout this program, students deepen their understanding through a series of activities in which they "travel" to an imaginary planet circling a red sun, and experiment with color filters and diffraction gratings. Related classroom activities include making secret messages that can only be decoded with color filters, and then using the same filters to view nebulae and planets.

Volume 9: How Big Is the Universe?

Inspired partly by ideas from the short film *Powers of Ten*, this program surveys distances and sizes of things in the universe. Starting with ordinary things on Earth that students are familiar with, they move to progressively more distant astronomical objects: the Moon, the Sun, the Solar System, nearby stars, the Milky Way galaxy, and clusters of galaxies. Students use various methods to determine distance: parallax, "radar," and comparing brightness of objects. Classroom activities include students writing their complete galactic address, making a parallax/distance finder, and activities about the expanding universe.

Volume 10: Who "Discovered" America?

Students first ponder the meaning of the word *discover* in this program. Can one "discover" a land where people are already living? Students also learn the reasons and methods by which Columbus navigated to the "New World," as well as some of the impacts of his voyages on Native Americans. They also find that certain myths about Columbus are untrue. He was not, for example, alone in believing that the Earth is round. Students also learn about other explorers who "discovered" America long before Columbus's time. Classroom activities include determining the shape and size of the Earth, using quadrants to determine latitude, and modeling lunar eclipses.

Volume 11: Astronomy of the Americas

There are hundreds of Native American cultures, each with distinctive views of the heavens. There are also common threads which run through many of those cultures. In this program students visit five cultures: the Hupa people of Northern California, plains and mountain tribes that have used Medicine Wheel in Northern Wyoming, the Anasazi of Chaco Canyon in New Mexico, the Mayan people in Mexico and Central America, and the Incan people in Peru. Students observe moon cycles and changes in the sunrise and sunset positions on the horizon and learn how solar observations help Native Americans stay in harmony with nature. Classroom activities include the Mayan and Aztec number systems, observing changes in real sunset positions, and learning how Venus can appear as either the "Morning Star" or "Evening Star."

Volume 12: Stonehenge

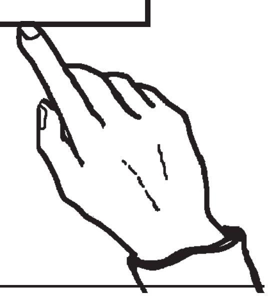
In this program, students learn what Stonehenge is and how it could have been used by its builders as a gigantic astronomical calendar. They also learn how astronomer Gerald Hawkins discovered Stonehenge's probable function, by actively formulating and testing their own hypotheses in the planetarium. Along the way, they learn a lot about apparent solar motion, and the creation of the exciting research field of "archeoastronomy." Classroom activities include making horizon observations of the Sun, constructing a Solar Motion Demonstrator to model the entire yearly cycle of solar motion, and detailed analyses of changes in sunrise and moonrise positions.

Red Planet Mars

Contents

PLANETARIUM PROGRAM

CLASSROOM ACTIVITIES



Red Planet Mars

Planetarium Program

Preface

Red Planet Mars was designed for public audiences and 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 students all about Mars, but to enable them to make their *own* discoveries about the red planet. Through a series of activities the students gain an understanding of planets and how astronomers investigate them.

In the first activity, students 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, students are invited to sketch a map of Mars. Discussion of their own maps provides a jumping-off point for the instructor to introduce 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, images captured by recent NASA missions to Mars, and a look towards the future exploration of Mars by spacecraft and by humans.

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 the program, students 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 may all be reporting useful information;
6. Exobiologists imagine forms of life adapted in specific detail to the planets other than earth;
7. Spacecraft missions have vastly increased our knowledge of Mars, but have found no clear signs of life.

Classroom Activities

The classroom activities, *Simulating the Solar System* and *Creatures from Omicron*, are designed for use before or after the planetarium program. The purpose of these activities is to extend and reinforce the concepts presented in *Red Planet Mars*.

Materials

1. Images for this program are listed on the next page, with sources for the slides on page 4. They have been assembled from several different sources, as noted. With the exception of the Lawrence Hall of Science and NASA images, the photographs are copyrighted. If you have a video system with a laser disc player many of the needed images can be programmed from laserdisc. Optional eyepiece ring, image 2, is intended as a frame for images 1 (in conjunction with the "fuzzy Mars" activity) and image 3. The eyepiece ring is projected from a separate slide projector.

Optional: An extra dimension may be added to the show by adding a few extra videodisc or slide images that compare the orbiter images of Mars with LANDSAT images of Earth. Specific features that are interesting to compare with suitable Earth features are: dunes (image 12), river valley (images 13 & 20), and volcanoes (images 21 & 22). This option may be particularly worthwhile for students who are totally unfamiliar with the appearance of such features in high altitude photos. The added high altitude Earth images may provide a valuable additional experience to enhance their appreciation of the Mars images.

2. Telescopic Mars Projector. This special effect device shows a telescopic view of Mars that shimmers as if due to the Earth's atmosphere. It was devised by Sheldon Schafer of Lakeview Museum Planetarium, Peoria, Illinois. It consists of a slowly rotating transparent plastic disk placed in the projected beam of any slide projector (see diagram). The disk is thinly smeared with Duco cement or Vaseline, with some areas kept clean to produce moments of clarity. The effect is quite accurate. We use a disk 20 cm. in diameter glued to a 2 r.p.m. motor. As a simpler alternative, the disc can be mounted on an arm attached to the slide projector and moved by hand. We project a slide drawing of Mars made by Charles Capen, available commercially from the Hansen Planetarium, 15 South State Street, Salt Lake City, Utah, 84111.

3. A Naked-eye Mars Projector is needed for the first activity. The starlike image of Mars must be moveable and similar in diameter and hue to the 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 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 versions of Mars, and for their extraterrestrial creatures. You can devise your own sheet or use ours (p. 5, copied on both sides of the page). We also provide a clipboard with attached pencil for each participant.

5. Battery-operated light pointers, available from photography stores. It's good to have at least two of these: one bright and one dim. The easiest way to dim a pointer is to replace one of the batteries with a "dummy" battery consisting of a block of wood, plastic, or metal which has about the same dimensions as a battery, but that provides a short-circuit electrically through the length of the block. With the "dummy" battery installed, the bulb gets current supplied by only one battery, which makes it just the right brightness for pointing out stars and saves battery and bulb life to boot.

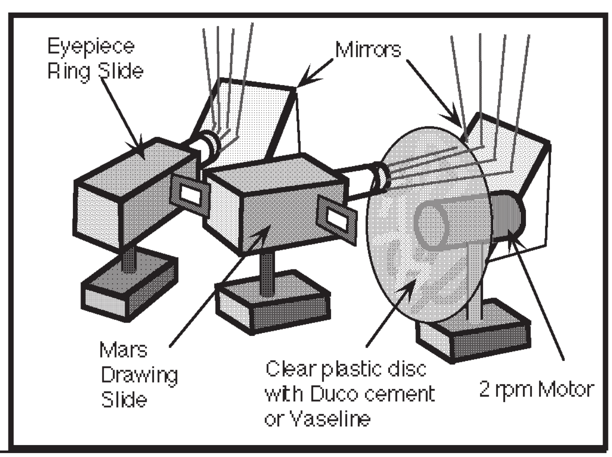


Image	Optical Data Corp. Astronomy VideoDisc #	Slide Source*
1. Optional - Eyepiece Ring	n/a	Lawrence Hall of Science
2. Telescope View of Mars	11802	ASP, Hansen, Hale
3. Mars Drawing (Fuzzy Mars Effect)	n/a	Charles Capen, Hansen
3a. †Mars Photo/Drawing Comparisons:	11958-11965	n/a
4. Lowell at his Telescope	7056	ASP (“Astronomers of the Past”)
5. Lowell’s Drawing of Mars	11832-11835	Lowell Observatory
6. Mariner Spacecraft	n/a	NASA, Finley-Holiday
6a. †Martian Dust Storm (sequence)	11941-11947	Lowell Observatory
7. Mars Global View	11980	NASA (Mariner 9; orbit 117: A80S/B87V)
8. Mars - Crescent, with Ice Clouds	12162	ASP, Hansen, NASA
9. Mars - 1/2 Disc Showing V. Marineris	12030	ASP, Hansen, NASA, Finley-Holiday
10. Valles Marineris Close-up	12203	ASP, Hansen, NASA, Finley-Holiday
11. Olympus Mons	12487, 12603	ASP, Hansen, NASA ,Finley-Holiday
12. Olympus Mons Caldera	12604	ASP, Hansen, NASA
13. River Channels	n/a	ASP, Hansen, NASA, Finley-Holiday
14. Viking Lander	11990	ASP, Hansen, NASA, Finley-Holiday
15. Viking Digs a Trench	12814	ASP, Hansen, NASA, Finley-Holiday
15a.†Airplane Ride Around Olympus Mons	30233-31379	Finley-Holiday
15b.†Airplane Ride through Valles Marineris	n/a	Finley-Holiday
16. Mars Meteorite	n/a	ASP, NASA, Finley-Holiday
17. Space Telescope Views of Mars	n/a	ASP, NASA, Finley-Holiday
18. Pathfinder and Sojourner	n/a	ASP, NASA, Finley-Holiday
19. Martian Rocks	n/a	ASP, NASA, Finley-Holiday
20. Red Hop Flier	n/a	Bonnie Dalzell
21. Gliding Green Carnivore	n/a	Bonnie Dalzell
22. Outrigger Ribbon Fish	n/a	Bonnie Dalzell
23. Bandersnatch	n/a	Bonnie Dalzell
24. Paul’s Martian	n/a	Fantastic Adventures, 1939
25. Mars Climate Orbiter	n/a	ASP, NASA, Finley-Holiday
26. Mars Polar Lander	n/a	ASP, NASA, Finley-Holiday
27. Sample-Return Mission	n/a	ASP, NASA, Finley-Holiday
28. Mars Space Transportation Depot	n/a	ASP, NASA, Finley-Holiday
29. Geologist on Mars	n/a	ASP, NASA, Finley-Holiday

† Optional Images or Movies

Materials (continued)

6. **Reading lights for the students.** In our permanent planetarium, 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 draw on their activity sheets and look back up at the sky easily. The program can also be done by turning up the daylight for people to study their charts, and then turning down for sky examination. In our portable inflatable planetarium, we use the reading light system described in PASS Volume 4, pp. 21-22.

7. **(Optional) An Opaque Projector** allows participants to have their own drawings projected onto the dome for discussion. We use an inexpensive opaque projector (a "Brumberger #290 Project-0-scope" or a "Rainbow Crafts M100"), sold in art supply stores. This produces quite an adequate image two feet in diameter in our dome. Better projectors are available at higher cost.

* Slide/Image Sources:

ASP: Astronomical Society of the Pacific, 390 Ashton Ave., San Francisco, CA 94112

Hansen: Hansen Planetarium, 15 South State St., Salt Lake City, UT 84111

Finley-Holiday: Finley-Holiday Film Corp., P.O. Box 619, Whittier, CA 90601

Bonnie Dalzell: National Air and Space Museum, *Smithsonian* (Oct. 1974, pp. 84-91)

LHS: Lawrence Hall of Science, University of California, Berkeley, CA 94720

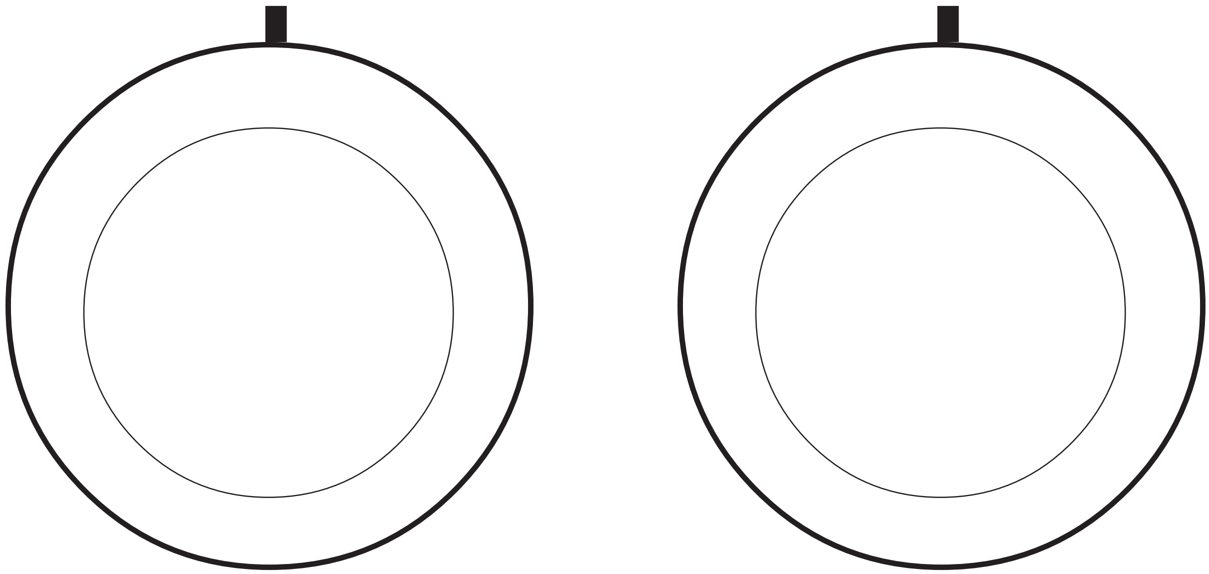
Optical Data Corporation, 30 Technology Dr., Warren, NJ 07060, (800) 524-2481

Complete slide sets may be purchased from

Eureka!
Lawrence Hall of Science
University of California
Berkeley, CA 94720
510-642-1016
http://www.lhs.berkeley.edu/AST300.html

or

Learning Technologies, Inc.
59 Walden St.
Cambridge, MA 02140
(800) 537-8703.



Beings from the Planet Earth

William K. Holt Planetarium
Lawrence Hall of Science
University of California, Berkeley, CA 94720

Beings from a Mars-Like Planet

This Planet Has: (1)Weaker gravity, (2) Thinner atmosphere, and (3) Colder weather than Earth

The Mars Observation Activity was developed by Sheldon Schafer, Lakview Museum Planetarium, Peoria, Illinois.

Set-Up

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

1. Latitude: Home.
2. Precession: Current.
3. Time: Early springtime—Diurnal set so Orion is about 20 degrees above the western horizon and Arcturus about 10° above the eastern horizon.
4. Mars set a few degrees to the right 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.

Recommendations About Using the 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 into 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 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 questions to which the audience is expected to respond, in ***bold italics***. There is no point in memorizing word-for-word, since what you need to say will depend upon the participants. The language you use and the number and kind 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 that 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.

Script

My name is _________, and I'd like to welcome you to the _______ Planetarium. One of the most exciting things about science is that it places you in a position to discover new things. Today, 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; 400 years ago when people first looked through a telescope; and much more recently when cameras aboard spacecraft began giving us our first close-up views of 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. As your eyes grow accustomed to the darkness, you will see the sky as it looks in early springtime. Imagine yourself centuries ago, looking up at the night sky.

Finding Red Stars Activity

Can we discover Mars right now? Everybody, please look all around the night sky, and let's see how many orange-red points of light we can find. ***Please let me know when you have found an orange 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 orange-red objects are found.

We now have three candidates, orange 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?

Someone may mention the idea that stars twinkle, but planets have a steady glow. This is not always true; it depends on atmospheric conditions. Even under good seeing conditions, it is often difficult for novice observers to perceive the difference between stars and planets.

Each of these reddish points of light 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 they 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 assigned object carefully. Look at its position compared with the stars around it, so that your 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 the stars will be nearly in their same positions. But will any of our 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 to tell for sure which one is a planet. Watch your object again.

Turn up daylight, turn down stars and planets. Advance Mars another 10 degrees East, etc.

What happened to your point of light now, eight weeks after we started?

Now a few will have decided theirs did not move, but the Mars group will be sure that 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. Perhaps members of that group would venture a prediction as to where the object will be in another 4 weeks.

Allow a member of the group to use the pointer to show whare they think it will move.

Let's all watch their object very carefully this time and see if it indeed moves against the background of stars.

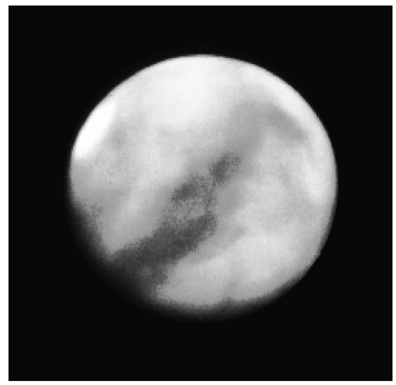
Repeat 4 week motion sequence a final time.

Did it move? (Yes.) ***Is it where you predicted it would be?*** So we have found the planet Mars by its motion, the same way the ancients did. In fact our word "planet" comes from the Greek word "planetes," meaning "wanderer." Because the Earth is turning, all the stars and planets appear to move slowly every night, together. The planets, due to their motion around the Sun, appear to turn a little faster or a little slower than the distant stars. Stars and planets have many other important differences, but we can't tell without a telescope. The way Mars drifts against the starry background convinced astronomers centuries ago that the planets travel in orbits around the Sun, not around the Earth.

We have found it: that red dot of light is the planet Mars, as people have seen it throughout the ages. We find other celestial objects just as red as Mars in the early spring sky. Here's Aldebaran in Taurus, for example, and Betelgeuse in Orion — both are red-giant stars (point out the red stars named). Following the curve of the Big Dipper's handle leads us to Arcturus, in Boötes (point out). Antares, the name of a red-giant star in the summer sky, means "rival of Mars."

Telescope Views

We have discovered Mars just as it was when it was first discovered: using our unaided eyes. Just about 400 years ago, Galileo discovered a new way of looking at Mars: through a telescope.

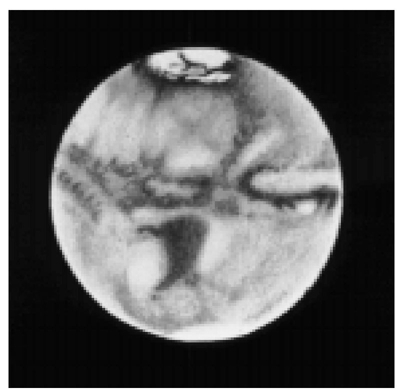


Optional Image 1: Eyepiece Ring

Image 2: Mars Through a Telescope.

This red circle represents the eyepiece of a telescope, and we are looking at one of the clearest photographs ever taken of Mars though a large telescope on the Earth.

What features do you see in this photograph? (*Color, dark shapes, white polar cap.*) The features - the light and dark areas - are not so very sharp. In fact, they are kind of blurry. ***Why do you think that this picture looks so blurry?*** *(Atmospheric turbulence on Earth.)*



Now we are going to see Mars as it would look through a large telescope.

Turn on Special Effect:
Telescopic View of Mars. (Image 3)

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 through a large telescope.

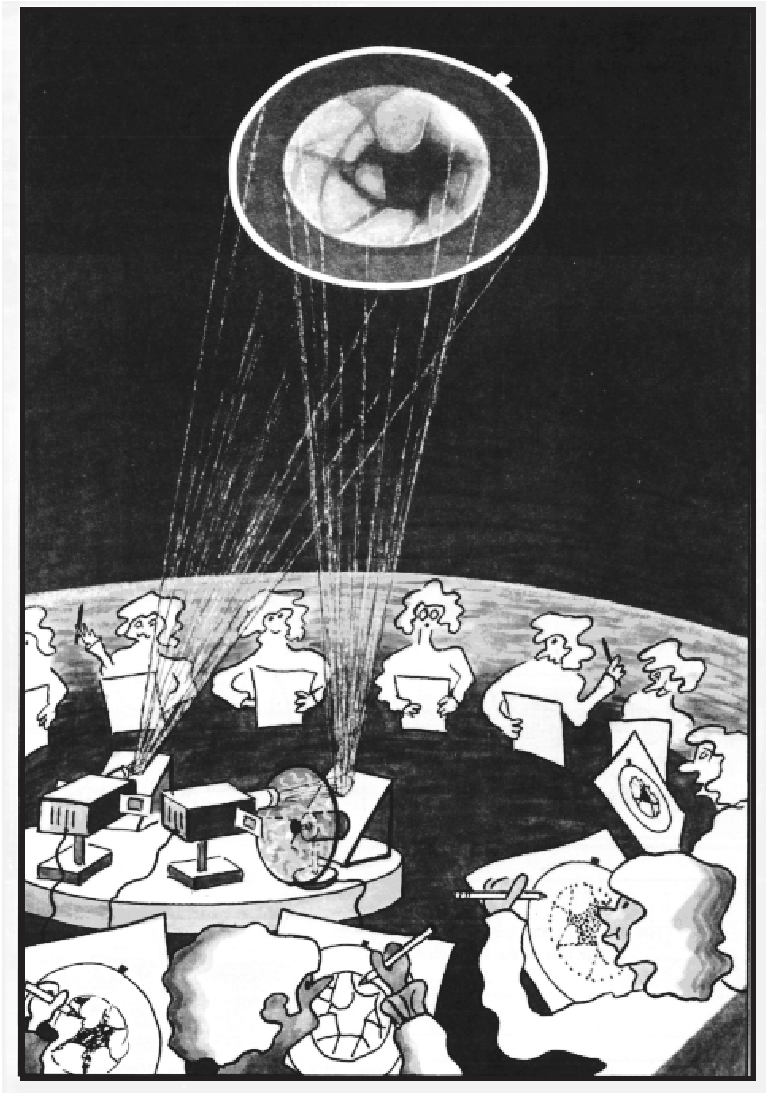
Any photograph we take through any telescope on Earth must also look through the constantly changing atmosphere of the Earth. The turbulent air makes stars twinkle, and planets look blurry. Every minute or so on very clear nights the atmosphere directly along our line of sight may happen to be less turbulent than normal, and for a fraction of a second, we might get an unusually clear view. But cameras don't know when these moments will occur, and 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 rely on their eyesight and memory, and sketch details by hand.

There are some fine details in this view of Mars that I can just barely make out. As astronomers, we would try to establish as much detail as possible by seeing if there are any 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 there 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 a few 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.

Please recall the telescope photograph of Mars that you saw a few minutes ago. ***Which contains more details, your drawings or that photograph?*** Any one of your drawings has more detail than that photograph which was one of the best ever taken from the planet Earth. ***Compare your sketch with the person sitting next to you. Did they see some details you didn't?***

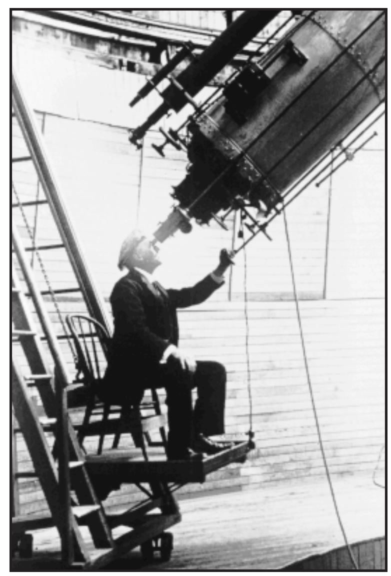
Walk around the room, select one or two examples and show using the opaque projector. These sketches are all different, although some of the features show up on most of them. Ask students to name the features on the projected image that are similar to the features on their own drawing.

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 as new and difficult to observe as this. We cannot agree perfectly on what is really there, but we can come to agreements on broad structure. Even with all the inherent limitations of drawings, many of the best and most detailed images of Mars have come from drawings by amateur and professional astronomers, not from photographs.

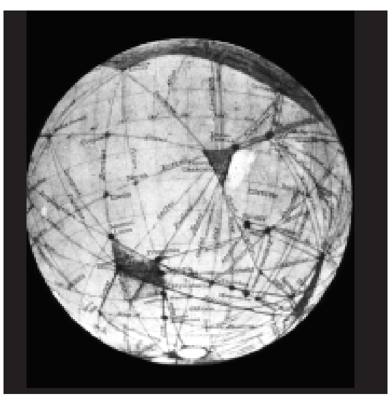
Optional: Show the series of comparison images from the Optical Data Corporation's "Astronomy" laser viedeodisc or slides, showing first a telescope photograph of Mars at a given time, then a corresponding astronomer's drawing of the same side of Mars created at the same time as the photograph. (See image list, page 4.)

Lowell and Canals

Image 4: Lowell.



Sharp-eyed observers with telescopes discovered the length of a Martian day is 24 hours and 37 minutes — not much more than one Earth day. They measured the planet's smaller size, a little more than half the diameter of Earth. They noticed that many of Mars' mysterious markings seem to darken and lighten as the polar ice caps grow and shrink with the seasons. In 1877, two tiny moons were discovered orbiting close to the red planet. They are named Phobos and Deimos.



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 controversial features that were very hard to see. Let's look at one of his drawings, showing Mars as Lowell saw it.

Image 5: Lowell's Drawing.

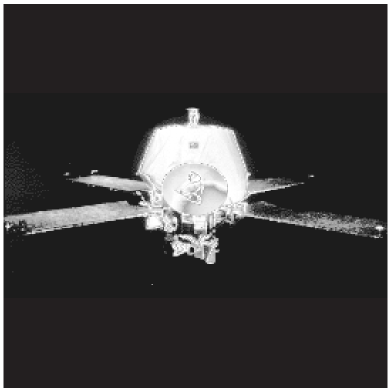
Lowell saw and named hundreds of fine lines criss-crossing the planet. He noted they seemed to connect the poles, which had white caps like the arctic regions of Earth, with the rest of the planet. Many astronomers never could see these fine lines, but several others agreed with Lowell that the lines 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 that there was a civilization of intelligent Martians.

Mars has always excited the human imagination, and Lowell's ideas about the possibility of intelligent beings on the Red Planet fired worldwide popular enthusiasm. The canal debate continued on through much of the 20th century. People wondered what the Martians might look like? Would they be hostile, or friendly? The canals of Mars also inspired countless stories, radio plays, movies, and TV shows. ***Do you have a favorite story or movie about Mars?***

The Mariner 9 and Viking Missions

Image 6: Mariner 9 Spacecraft. Slowly rotate diurnal so it looks as if the spacecraft is moving.



The Mariner and Viking missions of the 1970s sent us our first high-quality views of Mars from space. In 1976, the Viking Landers gave us our first really close-up look at the Martian surface. In the space age, once more we see the Red Planet in a new way.

When Mariner 9 arrived in 1971, a planet-wide dust storm covered Mars for months, obscuring surface features. Earth-based telescopes have observed such dust storms on Mars.

Optional: Video images of Martian dust storm (see image list on p. 4).

The dust finally settled, revealing giant volcanoes larger than any mountains on Earth, a vast canyon system over 2500 miles long and five times deeper than our Grand Canyon.

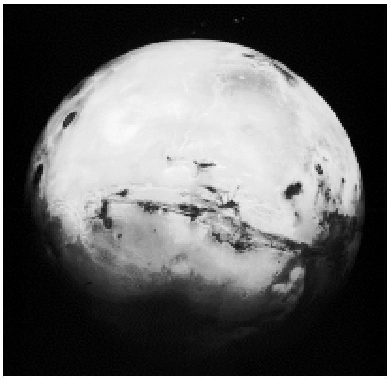


Image 7: Mars Global View. Point out Valles Marineris.

This huge feature, Valles Marineris, named after the Mariner spacecraft, turns out to be one of the narrow lines drawn on Lowell's canal maps.

Image 8: Mars Crescent. Point out Olympus Mons.

Here's the largest volcano, Olympus Mons. The Mariner and Viking Orbiter images also show sand dunes, craters from meteor impacts, and striking evidence of water erosion on the Martian surface.

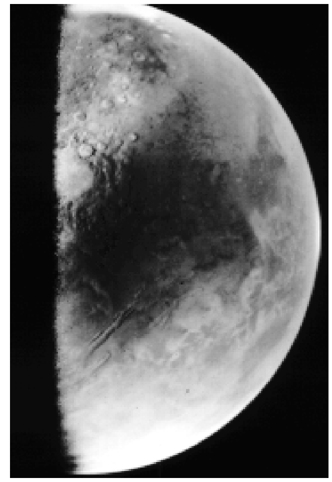


Image 9: Mars 1/4 Phase.

Image 10: Valles Marineris Close-up.

In this beautiful close-up of part of Valles Marineris, you can see fog drifting along the canyon's floor.

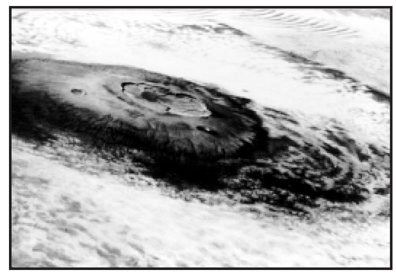


Image 11: Olympus Mons.

The base of the Olympus Mons volcano would almost cover the entire state of Arizona!

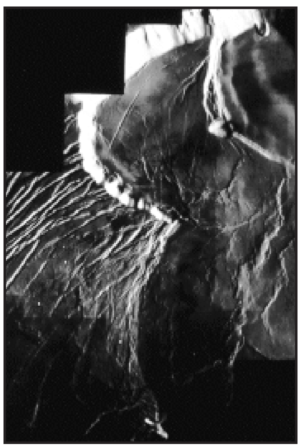


Image 12: Olympus Mons Caldera.

Very few meteor craters show up here at the summit of Olympus Mons, so the volcano may have erupted in recent geologic times. Underground, perhaps it is warm enough for liquid water to exist.

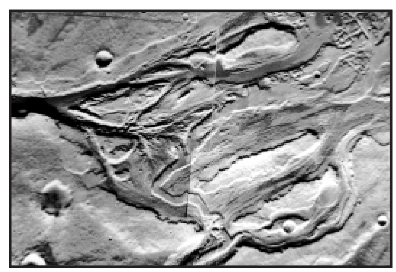


Image 13: River Channels.

Here is a striking picture. How do you interpret this photo? These look like water-cut river channels with streamlined islands — but there is no liquid water on the Martian surface now. This raises a very important question: Where did the water come from and where has it all gone? Was the climate on Mars once much more like the Earth, with lakes and oceans in which life could have arisen?

The Surface of Mars

In the summer of 1976, two Viking spacecraft entered orbit around Mars. Two landers detached, descended, and touched down successfully.

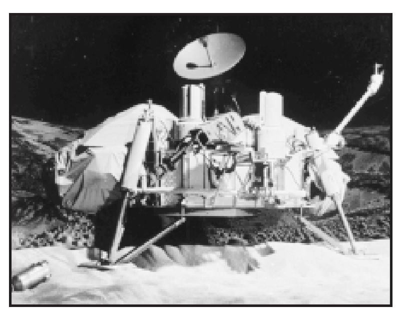


Image 14: Viking Lander.

Soon, we saw the first photographs ever taken of the Martian landscape and could imagine standing next to one of the Viking landers, with rocks, sand and dust at our feet.

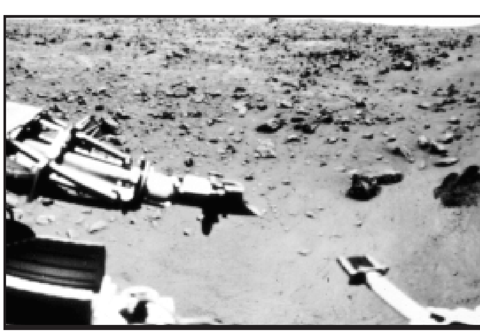


Image 15: Viking Digs a Trench.

The surface of Mars looks like a rocky desert. There is no running water. The ground is very cold, even though the polar ice caps lie far away. The sky is colored salmon-pink. The air is extremely dry and thin. Many rocks are covered by a layer of fine red dust. The color of Mars is due to reddish minerals rich in iron-oxide — rust!

The Viking Landers each used a robot arm with a scoop at the end to dig into the Martian soil. This image shows how the digging arm gathered soil for experiments. Sensitive instruments on the landers searched for signs of microscopic life, but the results gave no clear evidence that life exists today (or ever has existed) on Mars.

Viking carried out many other interesting science experiments: measuring the weather on Mars, searching for Marsquakes, analyzing the air and the soil, and looking for magnetic particles. Mars'atmospheric pressure is only 1/100 that of Earth, and the air is mainly carbon-dioxide. The average temperature on a mid-summer afternoon is 30 degrees below zero, Celsius. Dry ice can easily form on the red planet's surface, especially in the south polar winter!

The Viking results tell us that Mars' environment today is even more hostile to life than we had thought from Earth-based observations. Still, the Vikings landed far from the ancient river channels, canyons, and polar ice caps. Might we yet find traces of microorganisms or even fossil remains of past lifeforms elsewhere on Mars?

Optional: Video image 25a (movie) flight around Olympus Mons.

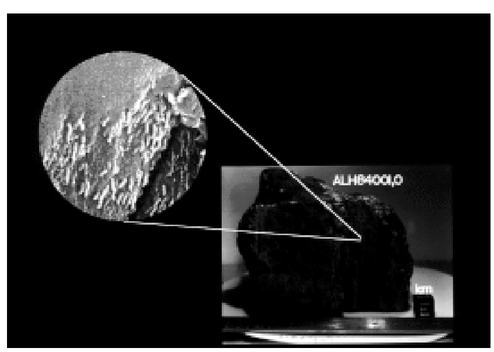
Using the data from the Viking spacecraft and some pretty fancy 3-D computer animation techniques, NASA imaging scientists have allowed us to "fly around Mars," and "land on Mars." What you are about to see is a motion picture of what it would look like if you were in an airplane flying around Olympus Mons, the largest volcano in the Solar System. The Viking orbiter sent us radar data which is coded in this movie as different colors for different elevations. It is experiences like that in addition to the enormous wealth of new knowledge that make our space program so exciting and so well worth our support.

Optional: Video image 25b: Airplane ride through Valles Marineris.

Optional: Martian Meteorite

One intriguing possibility is that we may *already* have discovered evidence of ancient life on Mars embedded in a Martian meteorite

Image 16: Mars Meteorite.



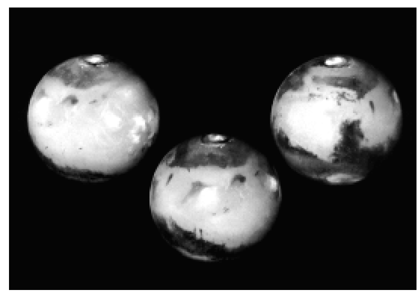
The Viking analysis of Martian soil allows us to identify the Red Planet as the origin of a few rare meteorites such as this one, the Allan Hills meteorite (ALH 84001). A huge impact on Mars sixteen million years ago blasted fragments spaceward; and this one fell to Earth some 13,000 years ago. It was found in Antarctica. What a stroke of luck that we have found a new way to explore Mars with pieces of it dropping so "conveniently" to

Earth. ***Could these tiny, tube-like structures inside the Alan Hills meteorite be fossilized bacteria?*** (Maybe.) If so, they may have been alive on Mars several billion years ago! This idea is both tantalizing and controversial. The only way to settle the mystery is future expeditions to the Red Planet.

The Space Telescope and Canals

In the space age, there are so many exciting new questions about the Red Planet! But whatever happened to the famous canals, the long straight lines that Lowell imagined must be giant irrigation channels carrying water to Martian farms? Only a few features photographed by spacecraft, such as the "grand canyon of Mars," Valles Marineris, correspond to any of the narrow lines on Lowell's canal maps.

Image 17: Space Telescope Views of Mars.

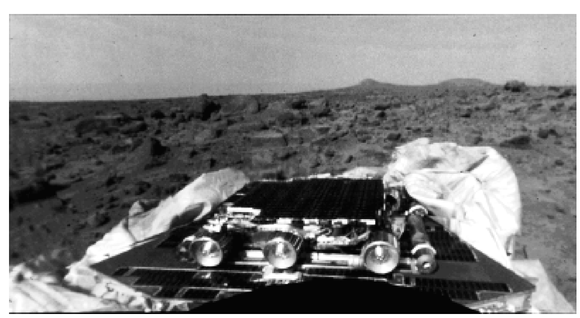


These three views of Mars were taken recently by the Hubble Space Telescope, launched in 1990. They show the entire surface of the Red Planet. The the Hubble Space Telescope images are far sharper than any ever taken from Earth, and they show details smaller than any Earth-based observer sees. Do you see a network of narrow lines that looks like the canal map Lowell drew?

You have seen how hard it is to see details on Mars telescopically from Earth's surface. Very few other astronomers could see all the lines Lowell drew. As long as we had to look up through Earth's blurry atmosphere, we could never see Mars clearly enough to be certain about the canals. Now we can see Mars clearly, any time we choose, from Earth orbit. We cannot see Lowell's canal network.

Lowell did a lot of very valuable work in planetary photography, studies of nebulae, and determination of the rotation rates of the planets. He popularized many imaginative ideas about the possible forms of life on other worlds. But his observations of Martian "canals" were not correct. Apparently, the human mind "helps" the eye by filling in details that the eye only partially sees.

Mars Pathfinder



Mars once may have been a warmer world, with flowing water, and a much thicker atmosphere. How, why, and when did it evolve to the frigid dry desert planet we find today? To investigate these questions, a new era of robotic exploration recently began.

Do you remember anything about the Mars Pathfinder spacecraft? (Accept any memories.) Its final fall was cushioned by giant airbags, bounced and rolled to a safe landing on Mars on July 4th, 1997.

Image 18: Pathfinder and Sojourner.

Its landing site is near the mouth of a vast ancient outflow channel named Ares Valles. There, mission scientists hoped to find a variety of rocks swept together and deposited long ago by catastrophic floods.

Pathfinder's cameras sent back superb color and 3-D views of the Martian landscape, distant hills and dunes, and blue-white clouds of water-ice in the reddish-orange sky at dawn. A small solar-powered robotic rover rolled out on six wheels from the main lander to explore the wind-blown and water-worn terrain, photographing and analyzing the Martian rocks. The rover was named Sojourner after the 19th-century abolitionist Sojourner Truth; while Pathfinder's base was named the Carl Sagan Memorial Station, after the famous 20th-century astronomer Carl Sagan, a leading enthusiast for planetary exploration.

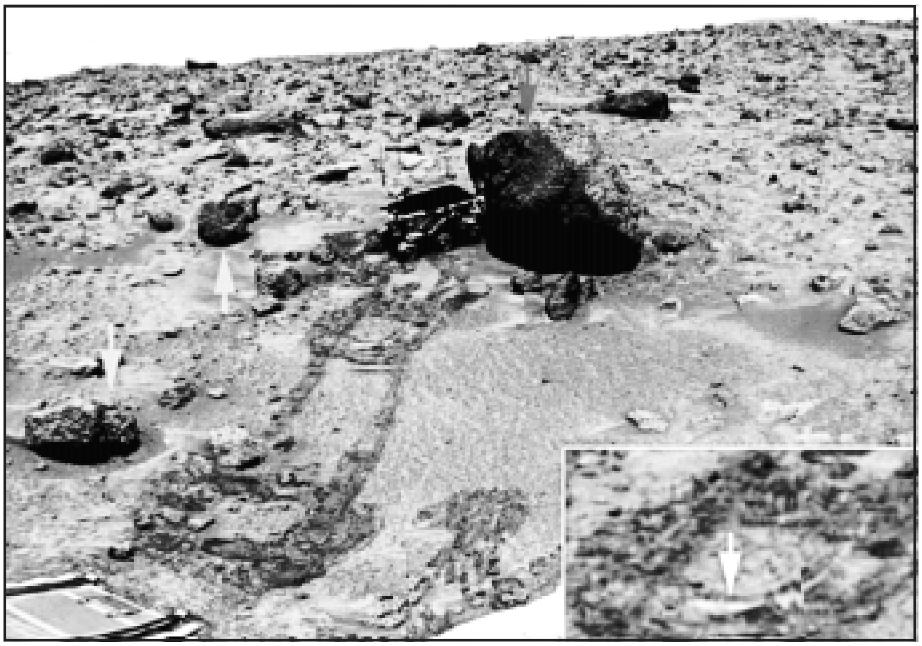


Image 19: Martian Rocks.

Many of the rocks were named for cartoon characters such as Barnacle Bill. Volcanic rocks are common. Rounded pebbles suggest they were shaped by flowing waters; other rocks are sculpted by winds. Some rocks are distinctly layered, possible evidence of sedimentary deposits in ancient lakes and oceans.

For 83 days, Pathfinder and Sojourner enthralled the public, created the biggest Internet event in history, and set the stage for future Mars exploration. A companion spacecraft, Mars Global Suveyor, arrived to map the Red Planet from polar orbit. Pathfinder and Global Surveyor showed the value of our new innovative, low-cost missions to Mars; and, most importantly, Pathfinder left no doubt that enormous floods of liquid water once splashed across the surface of Mars. Long ago, the climate of Mars may well have been warmer, wetter, and more favorable to life's origin.

Optional: Internet Images of Mars. If your planetarium can display recent images from Mars missions (As this is edition goes to press, Mars Global Surveyor is sending back spectacular views of the canyons, volcanos, and polar ice caps; and the Mars Climate Orbiter spacecraft has just been launched toward the red planet!)

Exobiology Activity

The idea of intelligent beings on Mars sounds as fantastic to us today as it did a century ago, when Lowell and others suggested it. But 20th century space exploration has revealed Mars as a world of exciting new possibilities for life: as a potential abode of life in the past, perhaps still harboring life which has adapted to the increasingly harsher environment.

The idea of intelligent life existing somewhere in the universe besides Earth is a very reasonable one, an idea that many scientists today share. Beyond our star, the Sun, there are billions of other stars in our galaxy that might have that may support other forms of life, even intelligent life. We're only just beginning to discover planets around other suns.

Scientists today who investigate the possibility of life on other planets are called **exobiologists**. Exobiologists try to determine what life forms might exist on other planets with conditions different 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 Dazell 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 evolved to help them survive on planets other than Earth.

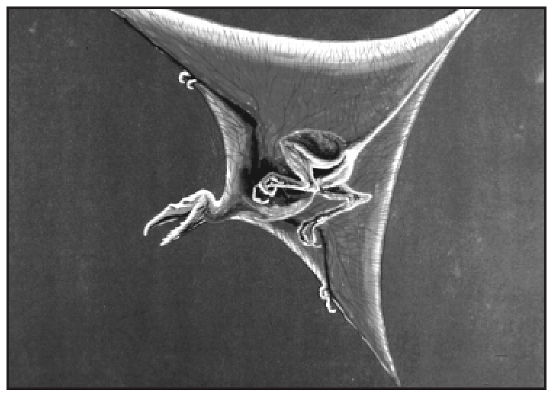


Image 20: Red Hop Flier.

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 wing, the Red Hop Flier gets around nicely.

Does the shape of the Hop Flier's wing look at all familiar? Where have you seen that shape before? Hang gliders on Earth look very similar. Although air is thinner on a low-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.

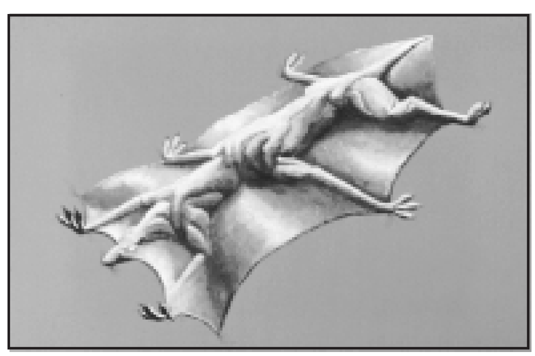


Image 21: Gliding Green Carnivore.

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 far due to the high gravity.

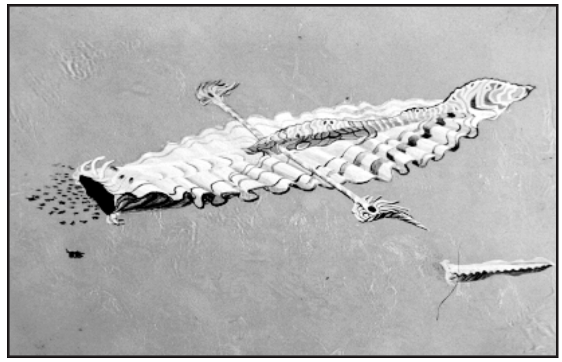


Image 22: Outrigger Ribbon Fish.

Here is a huge fish by Ms. Dazell designed for a planet with lots of ocean and very high gravity. The creatures this fish seems to be eating may be about the size of whales!

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 a huge creatures from collapsing under gravity's pull.

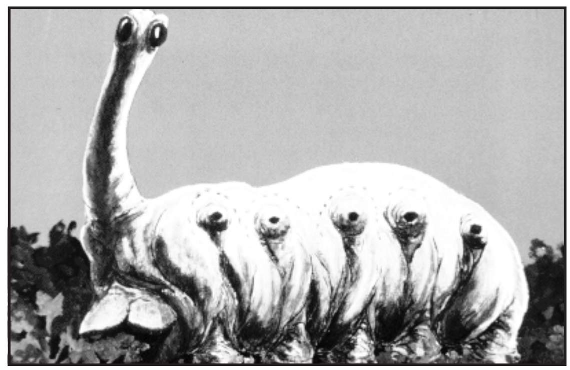


Image 23: Bandersnatch.

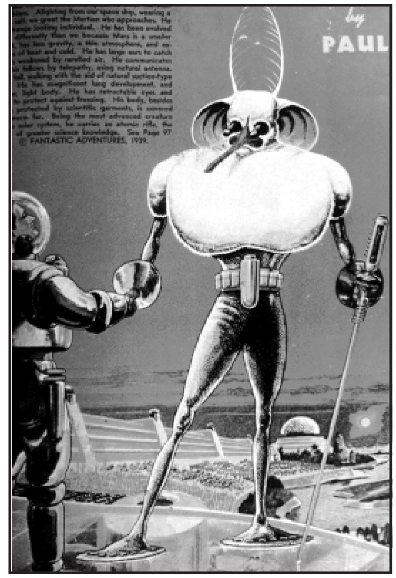
Here is a creature designed for the land of a high-gravity planet. ***What features does the Bandersnatch have to help him survive on his high-gravity planet?*** Very thick and sturdy neck, ten short and thick legs, large, low mouth to eat plants that grow close to the ground.

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. ***How is Mars different from the Earth?*** *(It has lower gravity, much thinner atmosphere, and much colder weather.)* The gravity is only about 1/2 Earth's gravity. Temperatures are below zero most of the time on Mars. Martian atmospheric pressure is only 1/100 that of Earth. Now close your eyes and picture in your mind a creature that would be adapted to lower gravity, colder weather, and much thinner atmosphere.

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. ***In the blank box, please make a rough sketch of the imaginary being that you pictured in your mind that would be adapted to life on a Mars-like planet.***

Note: Adults are often shy about this open-ended activity. Encourage them to give it a try. Sometimes injecting humor helps a lot. Give people time to draw. Optional: Play music suitable for drawing Martians. Ask people to compare their ideas with their neighbors. 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



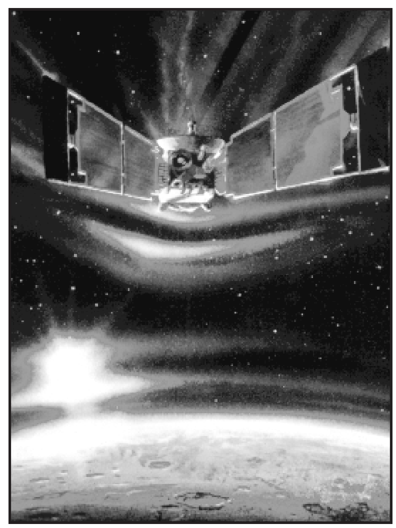
Your drawings are good speculation. Modern scientists are working on very similar concepts in the quest for life on other worlds! Meanwhile, in classic science fiction stories and films Martians will always be with us.

Image 24: Paul's Martian.

What do you think of this drawing made by an early exobiologist in 1939? 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 legs due to light gravity; fur and retractable nose and eyes for cold temperatures.)

Are there really Martians who would build canals and farm the desert planet? Given what we have learned from Mars exploration missions, does it seem likely that Martians like this exist now on the Red Planet? We have found no evidence of their existence. But could life have flourished on Mars in ages far more ancient? Could some lifeforms have adapted gradually to the harsher environment of present-day Mars? We hope clues to solve these mysteries await us in our future explorations of the Red Planet.

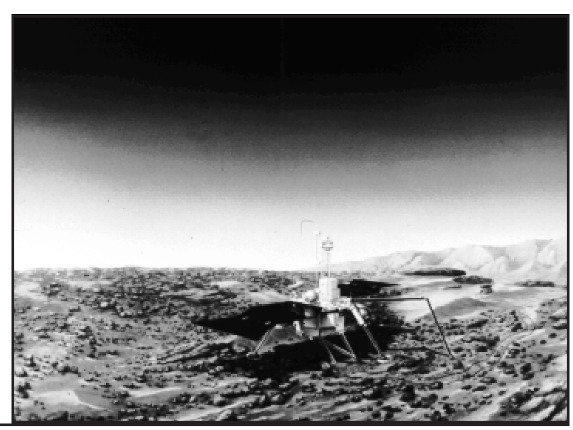
Future Mars Exploration



Inspired by the extraordinary success of Mars Pathfinder, NASA plans to launch two low-cost missions to the red planet every two years when Mars and Earth are favorably placed. The Mars Climate Orbiter arrives in polar orbit in September 1999.

Image 25: Mars Climate Orbiter.

It was designed to make daily global maps of Mars, monitor short-term and seasonal changes in the surface features, cloud patterns, dust storms, frost and polar ice. It was also made to measure planetary temperatures and atmospheric gases, to help us determine the composition of the Martian surface.



The Mars Polar Lander was built to touch down in 1999 only 500 miles from the planet's South Pole.

Image 26:
Mars Polar Lander.

The Polar Lander is the first step in exploring the Martian ice caps for evidence of a moist warm climate in Mars' past, when life may once have existed. Its stereo camera was designed to send back spectacular views of glacial deposits and rugged terrain which the polar ice covers and uncovers in its seasonal climate cycle. It was also equipped with a robotic arm to scoop soil samples for analysis and weather instruments to add to our understanding of the Martian environment.

Future landers and orbiters will follow: in 2001 a rover named Marie Curie, sister to Sojourner; in 2003 a larger rover named Athena designed to gather samples to be brought back to Earth by a later round-trip mission.

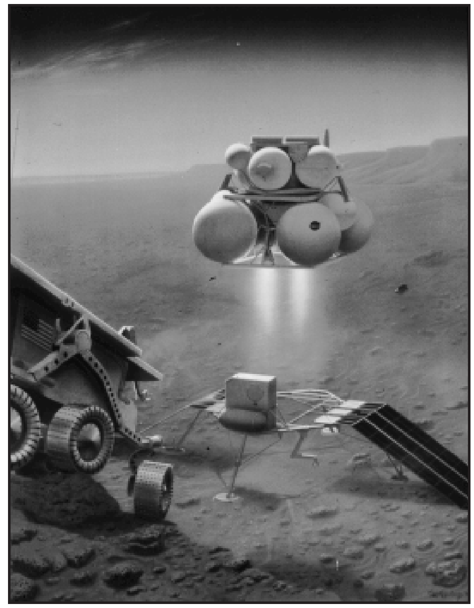


Image 27: Sample-return Mission.

A solar-powered robotic airplane may be sent to Mars to soar over the flood-carved canyons of Valles Marineris.

Optional: Video of Mars flyover, from The Planets, narrated by Patrick Stewart — source of image is NASA/JPL.)

Other nations are sending missions to Mars, and ultimately, major efforts involving international cooperation will be needed to explore the planets. A new era of discovery and exploration will begin when humans travel to Mars in the 21st century

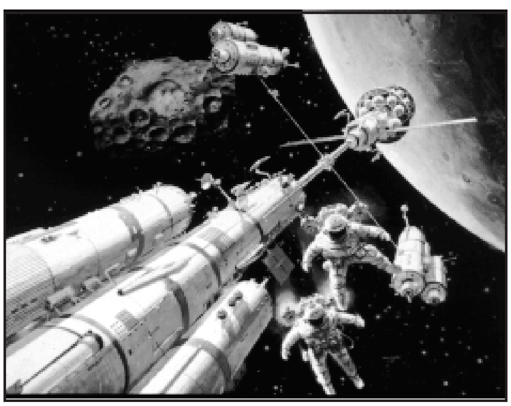
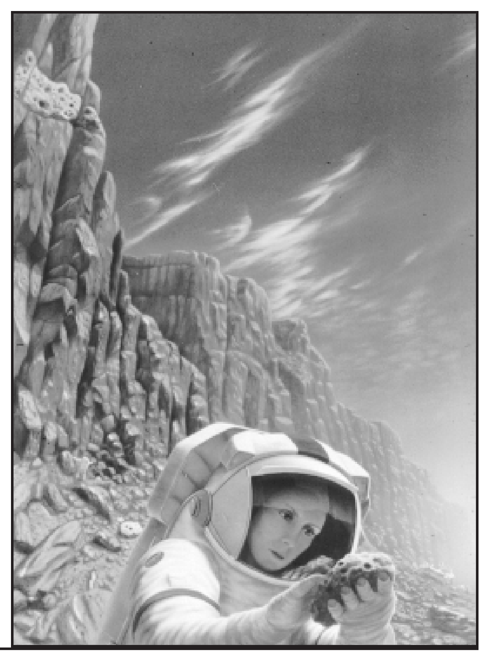


Image 28: Mars Space Transportation Depot.

Perhaps one of you will be among the first to land on Mars, searching for clues to life on the Red Planet...

Image 29: Geologist on Mars.



Then, we will be the Martians! We will discover and experience Mars in many new ways. Imagine yourself looking up into the evening sky of Mars. Earth looks like a bright, blue-white star in the night, just a tiny dot of light drifting slowly through the constellations.

And, there is certainly no reason for exobiology to stop at Mars. There are hundreds of billions of stars in our galaxy alone. There may be countless planets similar to the Earth and Mars. The red planet already has taught us much about how planets form, how they behave, how they can change, and how to look for possible life forms. . The search for life in the universe continues.

Discover More About Red Planet Mars

Worldwide Web Connections

and update information may be found at **http://www.lhs.berkeley.edu/pass**

Books

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The Red Planet Mars

Classroom Activities

Simulating the Solar System

This 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.

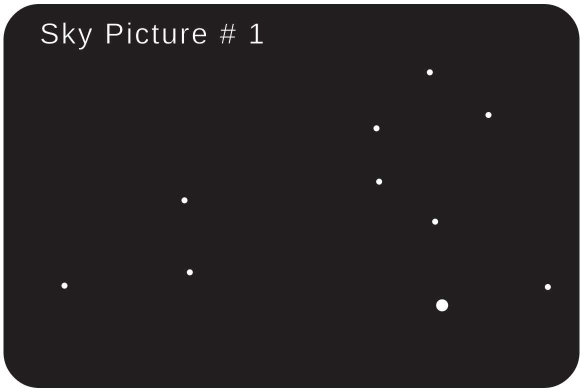
2) Draw three large boxes on the chalkboard. Use white or yellow chalk to draw stars in each of the boxes as shown on page 23. These drawings show the planet Saturn as it moves through the constellation Leo. All the stars should be the same size except for the bright star Regulus (in the lower right). Stars should be in the same positions in all three boxes except for the starlike object that is really Saturn (just above Regulus in the first picture). Another option which has the advantage of reusability is to make three large posters.

3) Cover the second two boxes with sheets of paper taped over them. If using posters, 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 huge hot balls of gas like the Sun. Planets are cooler balls of material like the Earth. Planets circle around stars in "orbits" and are almost always much smaller than stars. It takes the Earth one full year to complete its orbit around the Sun.

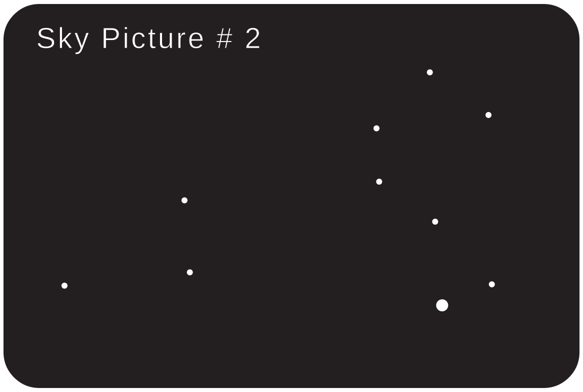
Here is a picture of the planet Saturn among the stars. ***Which one of these points of light do you think is Saturn?***



Direct students' attention to sky picture #1, and invite them to guess which dot is Saturn. Most students will guess the bright dot.

Hide picture # 1 and show picture #2.

Here is another picture made one month later, 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?*** Let's compare with last months picture side by side.



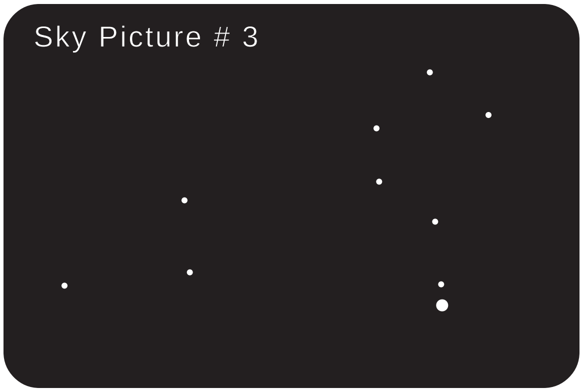
Expose pictures #1. and #2 side by side.

Where do you PREDICT Saturn will appear one month later?

Allow time for students to answer your question

Well, let's see if you are right.

Expose picture #3.

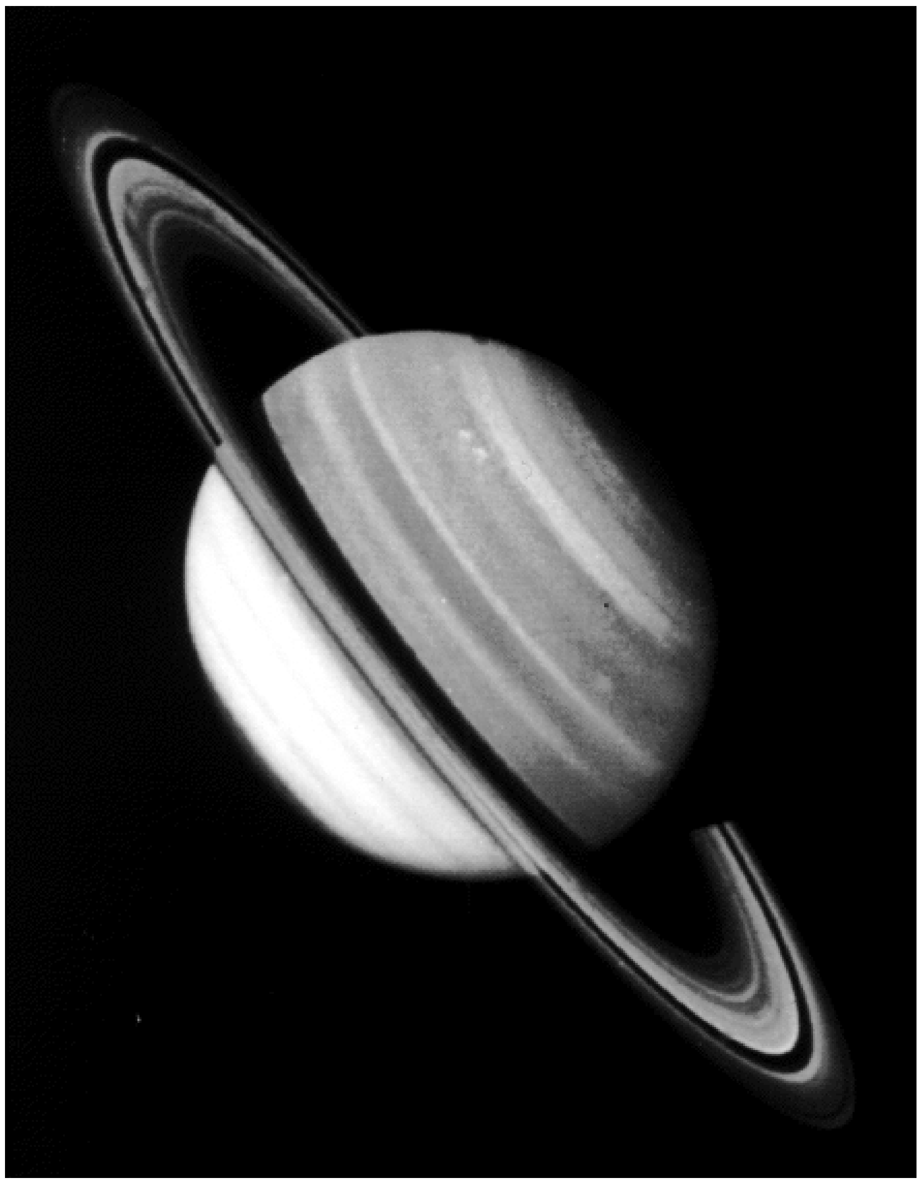


Here is how this pattern of stars appeared one month later. Who would like to describe how Saturn "wanders" against the background stars?

The planets appear to wander at different speeds and in different directions from month-to-month. Teachers who would like to learn more about these motions are encouraged to consult a "sky calendar" article in one of the many astronomy periodicals. Several good ones are listed in the section on periodicals in PASS Volume 3.

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 (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.

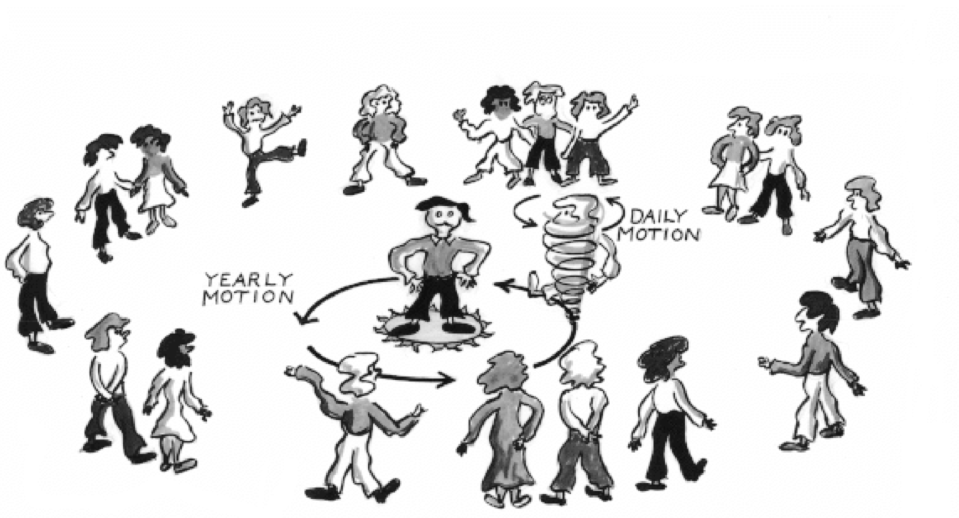
The students move a little closer or further apart so they are spaced unevenly around the circle. Optional: have the students hold signs which represent the various constellations. (See PASS Volume 2, "What's Your Sign?")

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 365 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.

Now it's the second team's turn. ***Who is the explainer? The Earth? The Sun?*** . . . .

SCALE MODEL OF THE SOLAR SYSTEM

(2 inches = 1 million miles)

Planet	Size*	In Model	Distance**	In Model***
Sun	864,000	(1.7") ping pong ball	0	0
Moon	2,000	(.004") tiny grain of sugar	0.25	0.5"
Mercury	3,000	(.006") small grain of sugar	36	6' 0"
Venus	7,500	(.015") large grain of sugar	67	11' 0"
Earth	8,000	(.016") large grain of sugar	93	15' 6"
Mars	4,000	(.008") medium grain of sugar	142	23' 6"
Jupiter	89,000	(.18") large mustard seed	483	80'
Saturn	75,000	(.15") small mustard seed	886	148'
Uranus	29,000	(.058") cake decoration	1,783	297'
Neptune	28,000	(.056") cake decoration	2,787	454'
Pluto	2,000	(.004") tiny grain of sugar	3,670	612' †
Nearest Star	800,000	(1.6") ping pong ball	24,000,000	760 miles

* Approximate diameter in miles. A good exercise: convert this whole table to metric units.

** Average distance in millions of miles from sun, except for the moon entry which refers to distance from earth.

*** In feet (') and inches (").

† In point of fact, Pluto is now slightly closer to the Sun than Neptune in its current position in its noncircular orbit. It will again become the furthest planet from the Sun in 1999, as it was before 1979 when it became “the 8th planet.”

Follow-Up Activities

1) Have the students extend their simulation of the solar system to include three, four, or even nine planets.

2) 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 32 with permission of the developers.

3) Gerald Mallon of the Methacton School District Planetarium suggests a larger scale initially to compare the Earth and Sun. He uses a blue 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! (Such balloons are available from Edmund Scientific Co., Barrington, New Jersey.)

4) Sheldon Shafer from the Lakeview Museum of Arts and Sciences suggests the following activity for students to do during the school bus ride to the planetarium:

Use the ride to establish a scale model of the solar system, with size and distance to the same scale, where your school is Pluto and the Sun is at the planetarium. The following chart will help you and/or your students work out the mathematics:

D is the distance (in miles) from your school to the planetarium.

Example: if your school is 10 miles from the planetarium, the Earth would be 1.35 inches in diameter and about 1/4 mile from the planetarium (9-3/4 miles from your school).

Planet	Miles from School	Scale Size of Planet (in inches)
Pluto	0	0.033 x D
Neptune	0.24 x D	0.51 x D
Uranus	0.51 x D	0.54 x D
Saturn	0.76 x D	1.27 x D
Jupiter	0.87 x D	1.51 x D
Mars	0.96 x D	0.072 x D
Earth	0.9738 x D	0.135 x D
Venus	0.98 x D	0.127 x D
Mercury	0.99 x D	0.052 x D
Sun	D	14.7 x D

Note: Ron Hipschman of the Exploratorium in San Francisco, California, has created a web page containing a "Make a scale model of the Solar System" calculator/chart. The page requires a JavaScript capable browser.
It's at http://www.exploratorium.edu/ronh/solar_system/.

You may find other WWW links for solar system models at the "Solar System Scale Model Meta Page" at http://www.vendian.org/mncharity/dir3/solarsystem/.

5) **Interplanetary Olympics**

Gravity is a force (or pull) which attracts matter in the universe to all other matter. All bodies in the universe, even planets and stars, are affected by gravity. By lifting an object, you can feel the force of gravity between that object and the Earth. Your own weight is a measure of the force of gravity between you and the Earth.

By doing some simple calculations, you can determine your weight on the Sun, planets, and moon. Simply multiply your weight by the gravity factor in the table below. Note that Earth has a gravity factor of 1, often referred to as 1 "g."

Planet	Gravity Factor	Your Weight
Pluto	0.03	
Neptune	1.23	
Uranus	0.93	
Saturn	1.07	
Jupiter	2.87	
Mars	0.38	
Earth	1.00	
Venus	0.90	
Mercury	0.38	
Sun	27.80	
Moon	0.16	

You can also compare distances objects in olympic events would travel. The objects can be human, such as in high jump or long jump, or they can be inanimate such as shot put, discus, javelin. Your students can, for example, throw a rubber ball "shot put" and measure the distance it travels. To compute the corresponding distance if the Olympic event were taking place on another planet, simply divide by the gravity factor in the table. The column "Your Weight" in the table can be replaced by "Distance," or "Height," depending on the particular event.

Creatures From Omicron

This science activity is designed for students in grades four through eight. It can be presented by teachers with no special preparation in science. "Creatures From Omicron" 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 and a copy of **one** of the three Creature photos on pages 32-34. One third of the class gets copies of photo 1, another third of the class gets photo 2, and the remaining students get copies of photo 3. For example, if there are 30 students in your class, you will need 10 copies of each creature photo.

2. Clear three large areas on the blackboard or wall on which to display the students' work.

3. On the blackboard, write:

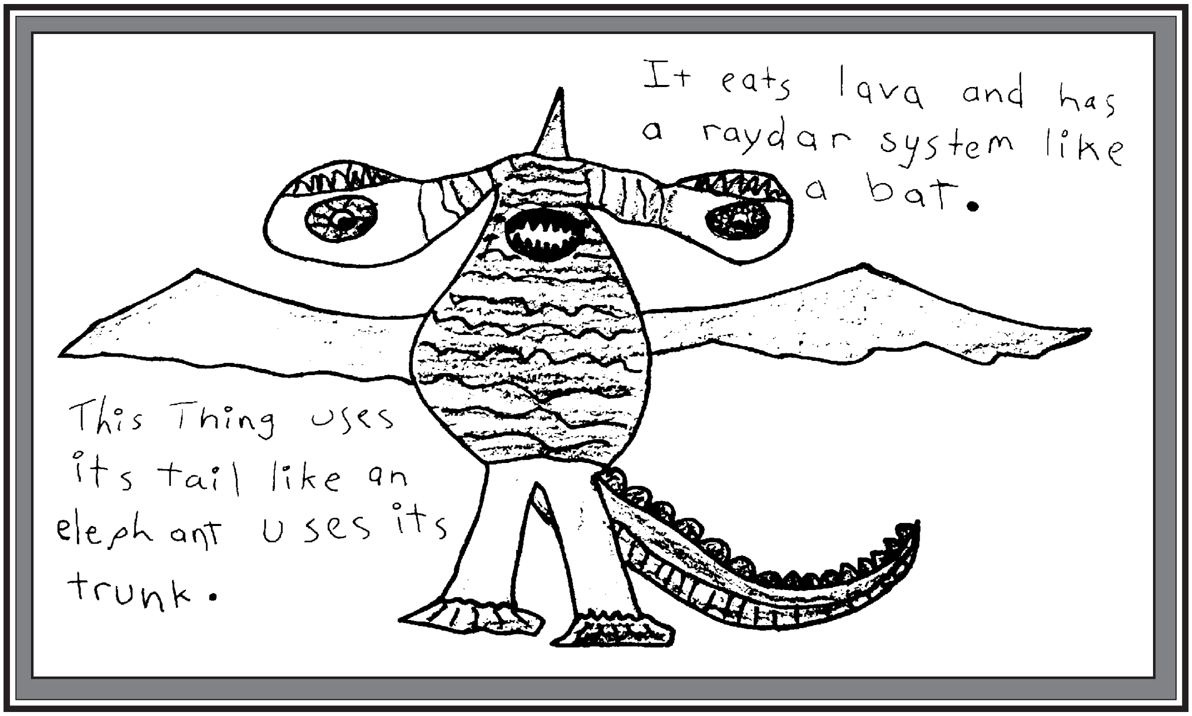
Omicron has:

(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 without seeing the work of students in the other groups.



Part A. Exploring Omicron

Today's activities will help you discover 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?***

Indicate the list of conditions written on the board. Have the students discuss their own experiences of similar conditions on Earth. What adaptations would a creature need to survive in such conditions?

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. Have the students sit in three assigned team areas. Give the students in each team the same creature picture. Be sure they do not see pictures given to the other teams. 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? Do any of the creatures look like Earth creatures?*** *(eg., two eyes, one tail)* ***Would creatures on another planet necessarily be like us? What are some of the most imaginative creatures?***

Have the students discuss their answers to these questions. Then, move on to the second group of drawings and ask the same set of questions. Repeat for the third group of drawings. At the end of each discussion, display the photo seen by that team. Then, hand out the second sheet of paper and give the last assignment.

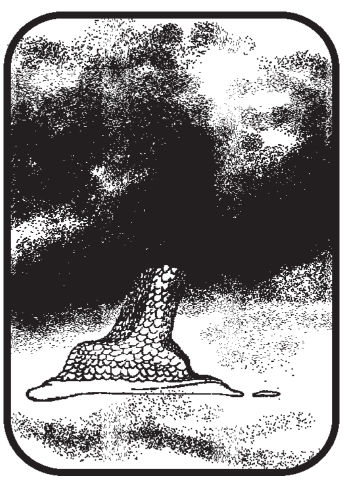


Photo 1

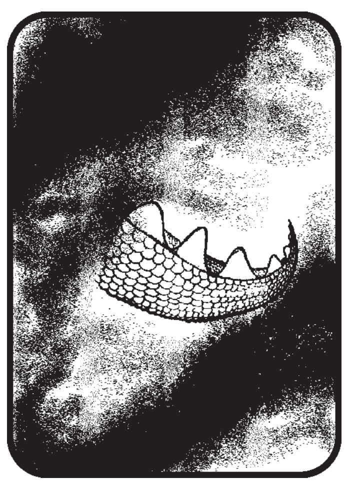
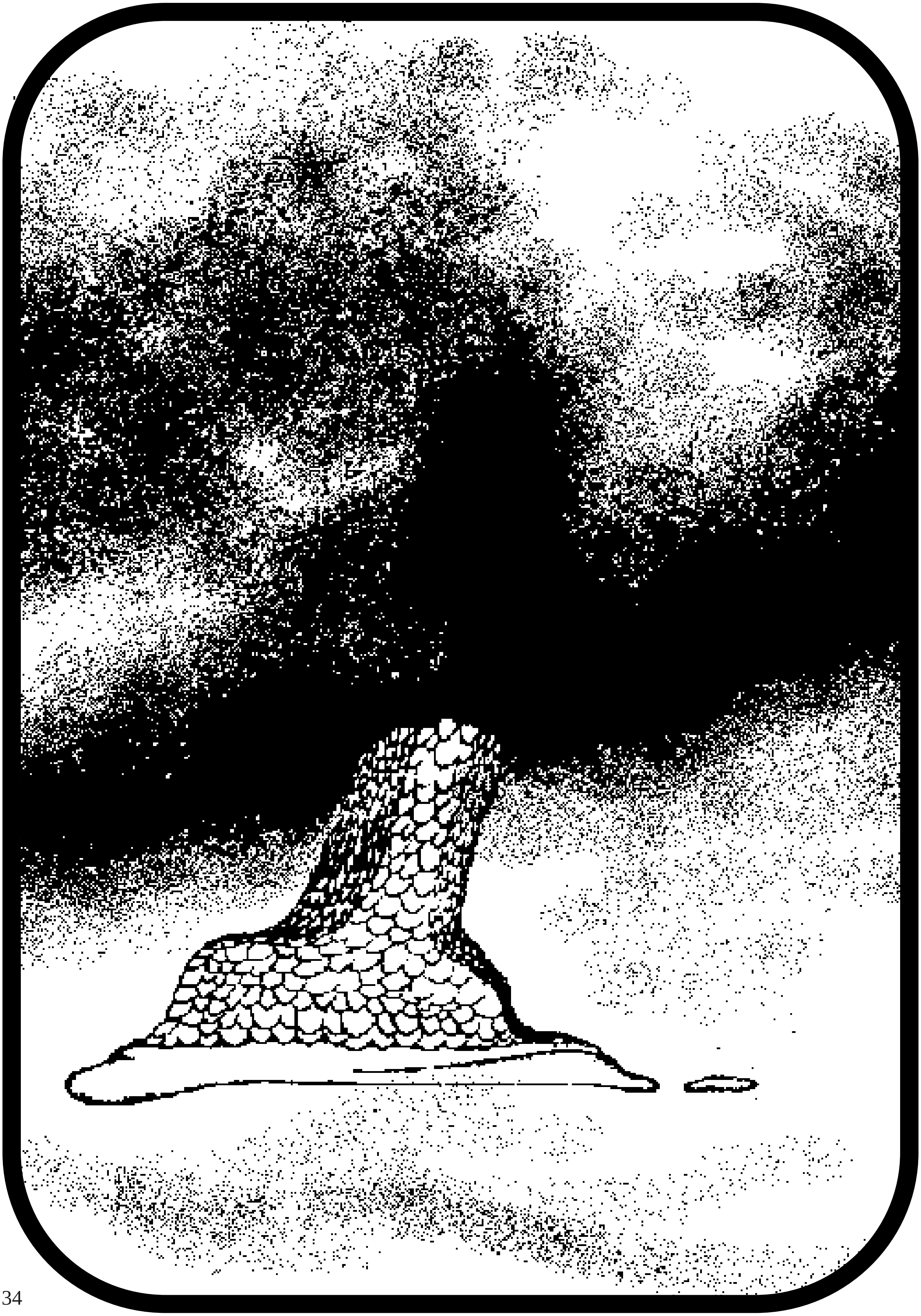


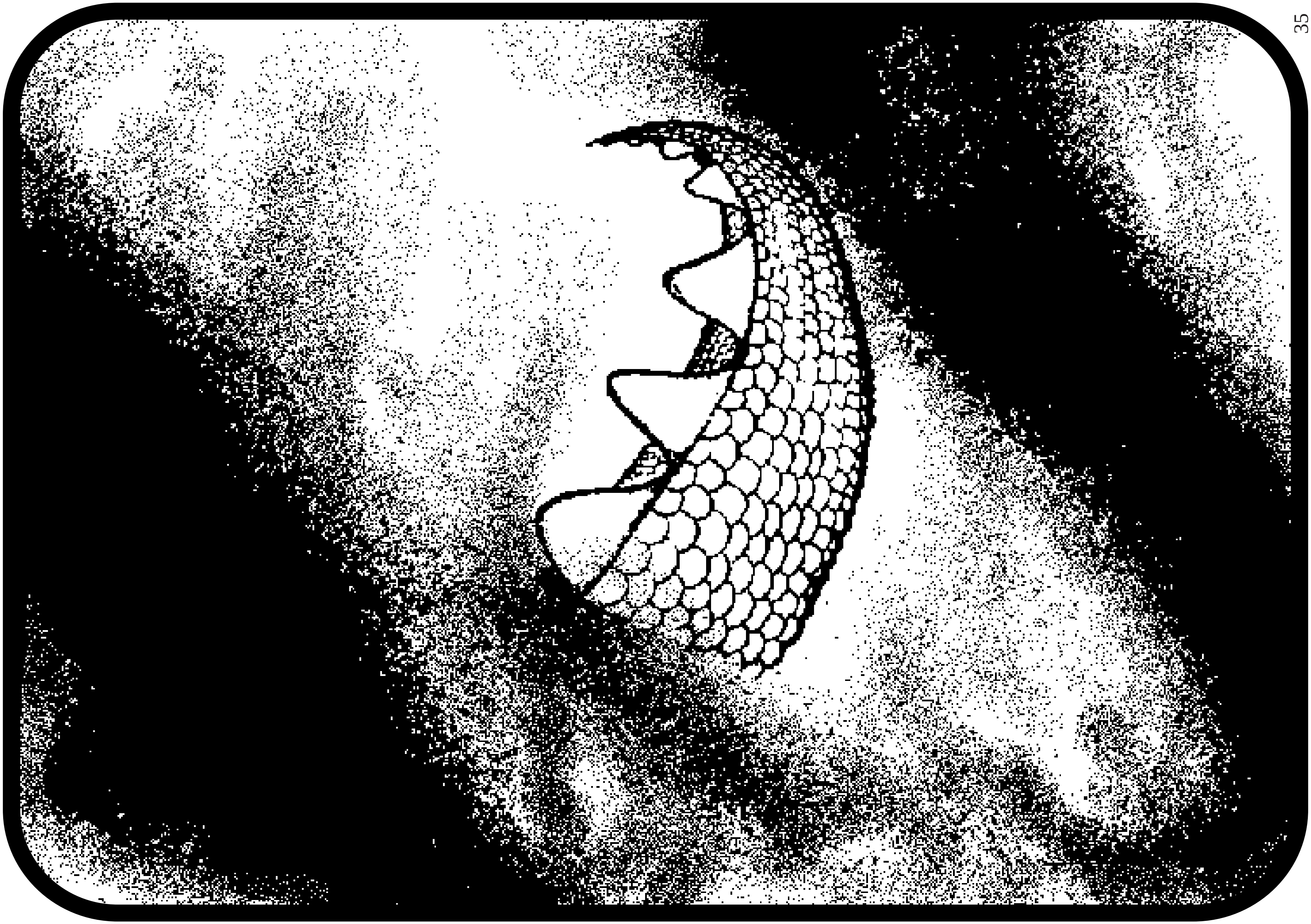
Photo 2

Photo 3

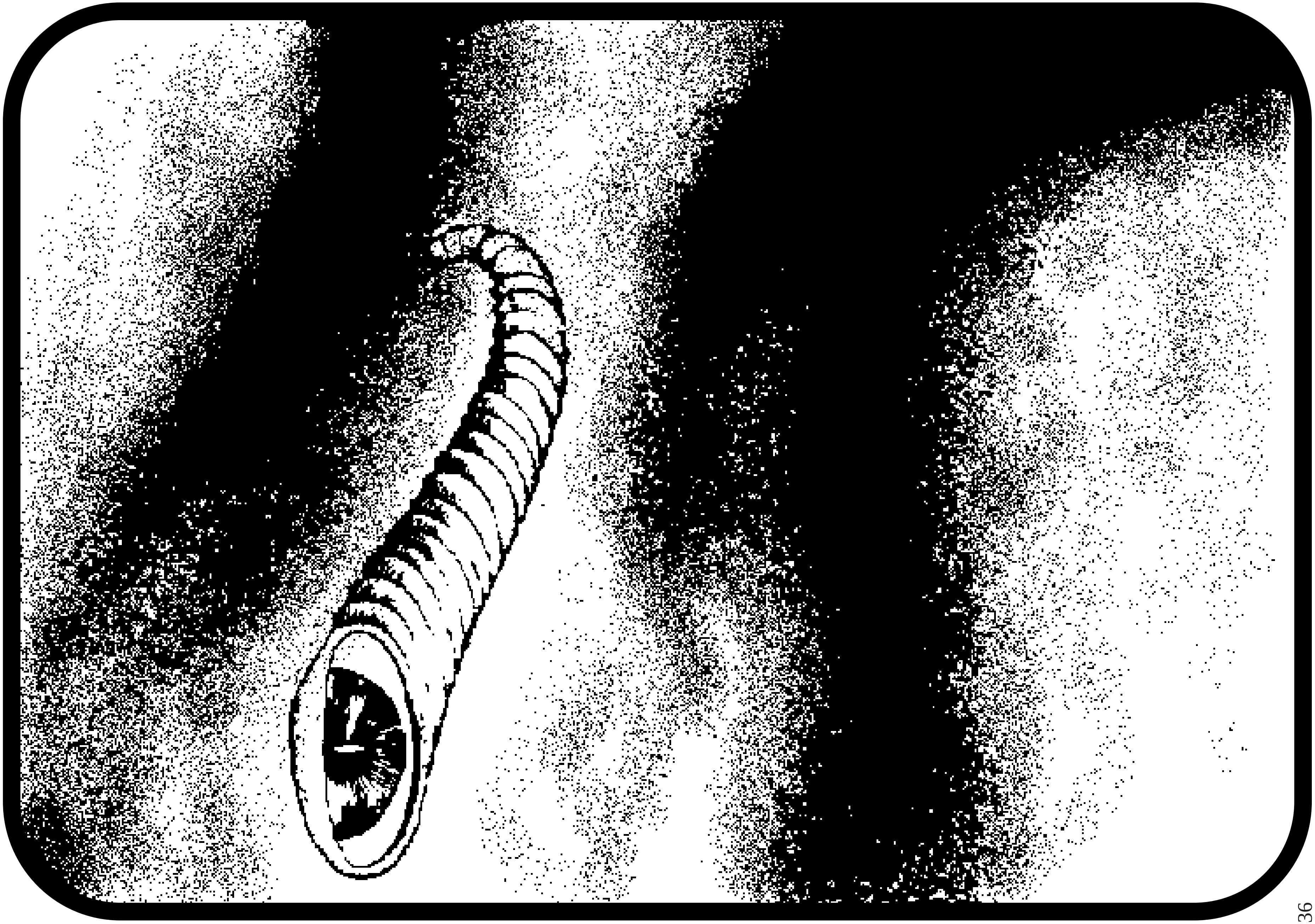
Omicron Creature Photo 1

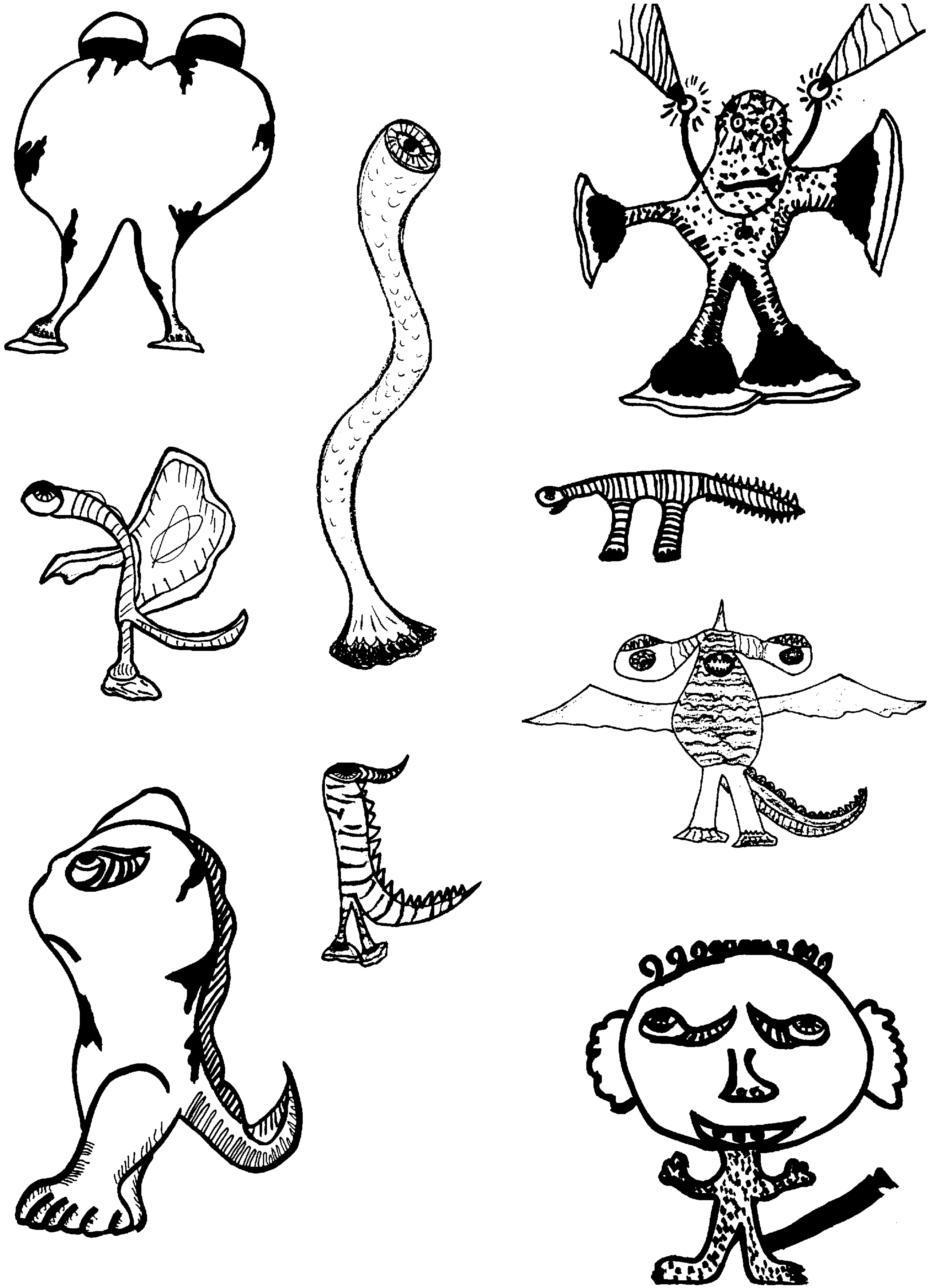


Omicron Creature Photo 2



Omicron Creature Photo 3





Part 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 entire creature looks like. Label your drawings to 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 to Omicron.

Follow-Up Activities

1. "Creatures from Omicron" 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 (OBIS activities are available from Delta Education, Inc., P.O. Box M, Nashua, NH 03061, (800) 258-1302).

2. "Creatures From Omicron" 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. For grades 7 and up, the computer program *Planetary Construction Set* (Sunburst Communications, 101 Castleton St., Pleasantville, NY 10570-3498, (800) 628-8897) offers a simulation of creating a planet to meet the needs of a specific alien.

5. The quiz which follows may be used as a pre-test or post-test. Please note that some questions refer to "Simulating the Solar System" while others refer to "Creatures from Omicron" or *RED PLANET MARS*. You should revise this test as needed to fit your particular classroom situation.

Answers to the PLANETS Astronomy Quiz:

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.

PLANETS Astronomy Quiz

1. "Planet" is just another word for "star." True False Don't know

2. Without a telescope, a planet looks a lot like a star. True False Don't Know

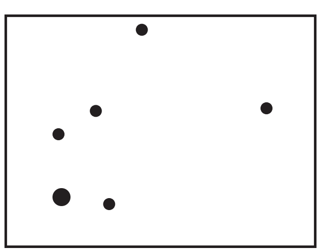
3. If you see a planet next to a certain star, you will always find it next to the same star. True False Don't Know

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:

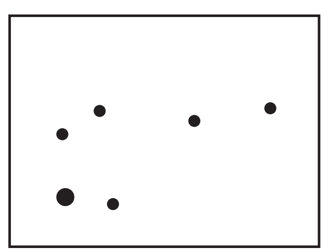
Picture A

First Night



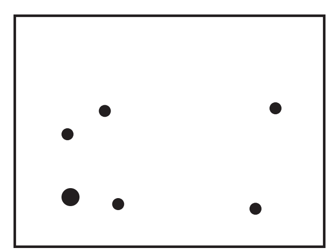
Picture B

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.

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 it is: 1) very cold, 2) very thin atmosphere (not much air), 3) 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.

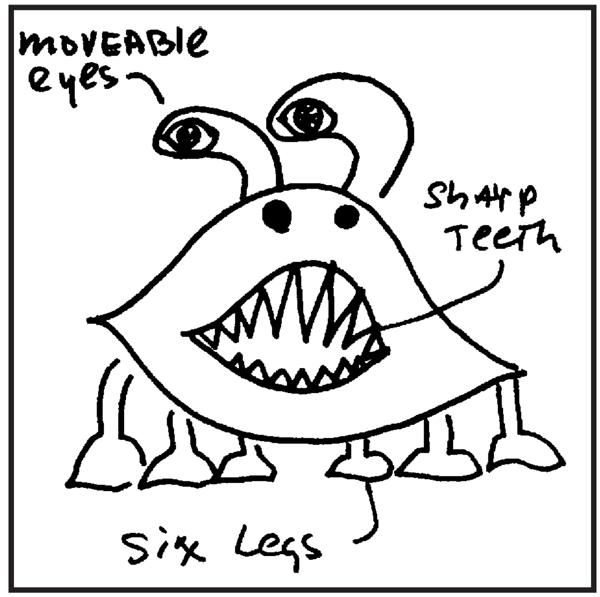
In the space below, describe the features of this animal which help it survive under ALL THREE CONDITIONS.

8. Three students drew these pictures of animals that might live in an underwater volcano where it is: 1) very hot, 2) very little air, 3) water environment.

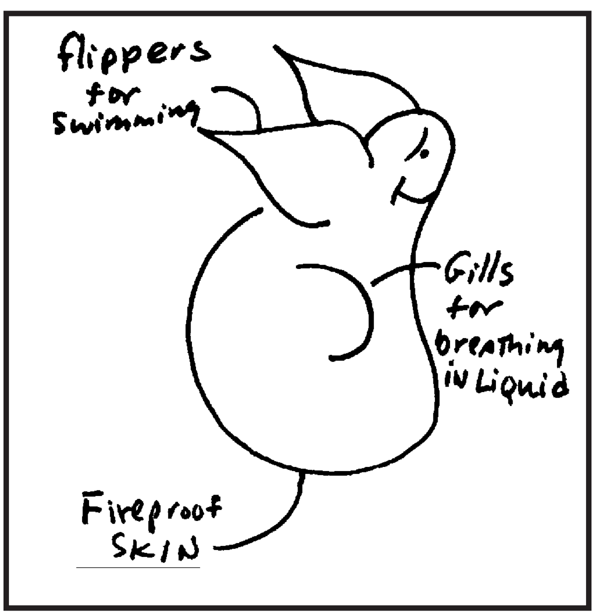
Which of the animals below do you think will survive best in a volcano?

(Circle the letter of the best answer.)

A



B



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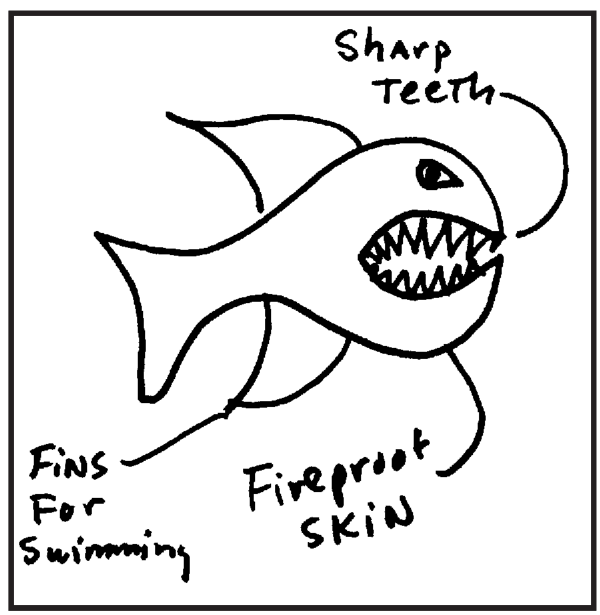

D

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) Different people may report different observations when they find something new.

C) Some of the astronomers were tired and not paying attention.

D) Astronomer #1 is older and knows more.

10. The three astronomers mentioned above agree that exactly the same signal from this star can be heard every night. 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) There is no way to learn which is best.