DESTINATION: MARS

ACTIVITY PACKET

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Astromaterials Research and Exploration Science (ARES)

Houston Museum of Natural Science
Burke Baker Planetarium
Houston, Texas

ABOUT DESTINATION: MARS

CONTENTS

The lessons are designed to increase students' knowledge, awareness, and curiosity about the process of scientific exploration of Mars. As scientists look for evidence of life on Mars, they will focus much of their search in areas where volcanic heat and water interacted early in the geologic history of the planet. Two lessons in this packet on volcanoes and mapping river channels reinforce these basic geologic processes. These lessons lead directly to a set of simple activities that help students develop an understanding of the microbial life scientists will be searching for on Mars. The hands-on, interdisciplinary activities reinforce and extend important concepts within existing curricula.

ACKNOWLEDGEMENTS

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EDUCATIONAL VIDEO

The *Destination: Mars* educational video presents a useful parallel with the lessons. The 33 minute video chronicles a simulated human mission to Mars in 2018. The six astronauts narrate their exploration through "real time" log reports. *Destination: Mars* is available as an educational video from NASA CORE, Lorain County Joint Vocational School, 15181 Route 58 South, Oberlin, OH 44074, (440) 774-1051, ext. 249 or 293, Fax (440) 774-2144. It is also a multimedia planetarium program available from Spitz Inc., P. O. Box 198, Route 1, Chadds Ford, PA 19317, contact John Schran (610) 459-5200, Fax (610) 459-8330.

INTERNET

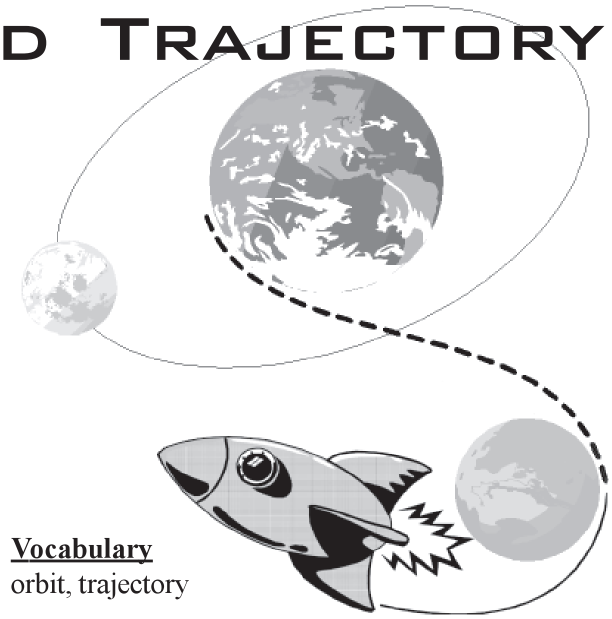
NASA Johnson Space Center, Astromaterials Research and Exploration Science (ARES)
http://ares.jsc.nasa.gov/education
Contains educational material and information about astrobiology, astromaterials, and planetary missions and science.

Lunar and Planetary Institute
http://lpi.usra.edu
Contains educational material and Lunar and Mars images.

Mars Exploration at NASA, Jet Propulsion Laboratory
http://mars.jpl.nasa.gov

LESSON ONE GETTING THERE!

NAVIGATION AND TRAJECTORY



About This Lesson

In Activity One students represent the orbital paths of Earth and Mars through dramatic group demonstrations.

In Activity Two students working in pairs plot the paths (trajectories) of a spacecraft traveling between Earth and Mars in the year 2018 and returning in 2020. These paths use the minimum amount of fuel, and take about six months to fly from one planet to the other.

Objectives

Students will:

- consider the relationships of the planets as they move around the Sun.
- consider expenditure of time/fuel for payload in space travel.
- develop awareness of what actually happens on minimum fuel orbits.
- plot the paths of spacecraft leaving Earth in 2018 for Mars and leaving Mars in 2020 for Earth.

Background

Major considerations for traveling to Mars are the amount of time the trip takes, the amount of fuel needed for the trip, and the size of the payload. A fast trip would be advantageous to the crew by reducing the time they are exposed to weightlessness, radiation, and other dangers inherent to space travel. However, fast trips require more fuel and that means less payload. People, equipment, and supplies would be reduced as larger amounts of fuel are carried to increase the speed of the trip.

Earth and Mars move at different speeds around the Sun. The Earth completes its solar orbit every 365 days while Mars completes its orbit every 687 days. This happens for two reasons. First, the Earth is closer to the Sun so it travels less distance. Secondly, it travels faster in its orbit. Planets closer to the Sun travel faster.

Vocabulary

orbit, trajectory

ACTIVITY ONE —

DANCING WITH THE PLANETS

Materials

- ☐ Student Procedure, *Dancing with the Planets* (pg. 7), one per group
- ☐ costume and prop materials as needed

Procedure

Advanced Preparation

1. Read background and Student Procedure. Research other sources of information as needed.
2. Gather materials.
3. Determine the time and space limitations that will best fit the learning situation.

Classroom Procedure

1. Divide the class into groups of 4-6.
2. Hand out the Student Procedure.
3. Discuss the time and space limitations for groups to consider in planning their dramatic demonstrations. Encourage the use of music, props, and choreography.
4. Allow adequate time for presentation and discussion of observations.

ACTIVITY TWO —

PLOTTING THE PATHS OF SPACECRAFT

Materials

- ☐ Student Procedure, *Plotting the Paths of Spacecraft* (pg. 8)
- ☐ Student Sheets, *Earth to Mars* and *Mars to Earth* (pgs. 9-10)
- ☐ pencils
- ☐ drawing compass
- ☐ Teacher Answer Key (pgs. 5-6)

Procedure

Advanced Preparation

1. Gather materials.
2. Review background.
3. Complete the plotting exercise for practice.

Classroom Procedure

1. Have students share familiar experiences that require aiming at a moving target. Their examples might be passing a football, catching a fly ball, driving vehicles in paths to avoid being hit, or playing dodge ball. Lead students to discuss the how and why of the movements.
2. Have students work in pairs. They may switch jobs for each plotting exercise.
3. Hand out Student Procedure and Student Sheets.
4. Help students become familiar with the data. Check for understanding. It is essential that students understand that Earth and Mars are moving and that the slashes on the Earth orbit represent the first of each month.
5. Help students plot the first date — May 11, 2018.

Note: When plotting the distance from Sun point, the compass point is always put on the Sun; when plotting the distance from Earth, the compass point is put in a different place each time. The point should be put on the slash mark that represents where the Earth will be located on that date.

5. Make answer keys available to students so they can check their work. If their orbits are not similar to the answer key, encourage them to redo the procedures to find their error.
6. Instruct students to apply the procedures to plot the return to Earth.
7. Closing discussion should encourage students to think about how a six month flight effects planning trips to Mars.

More background information is contained in the Destination: Mars Educational video. See pg. 2 to order.

Suggested Questions

1. What are the orbital challenges of traveling from one planet to another?

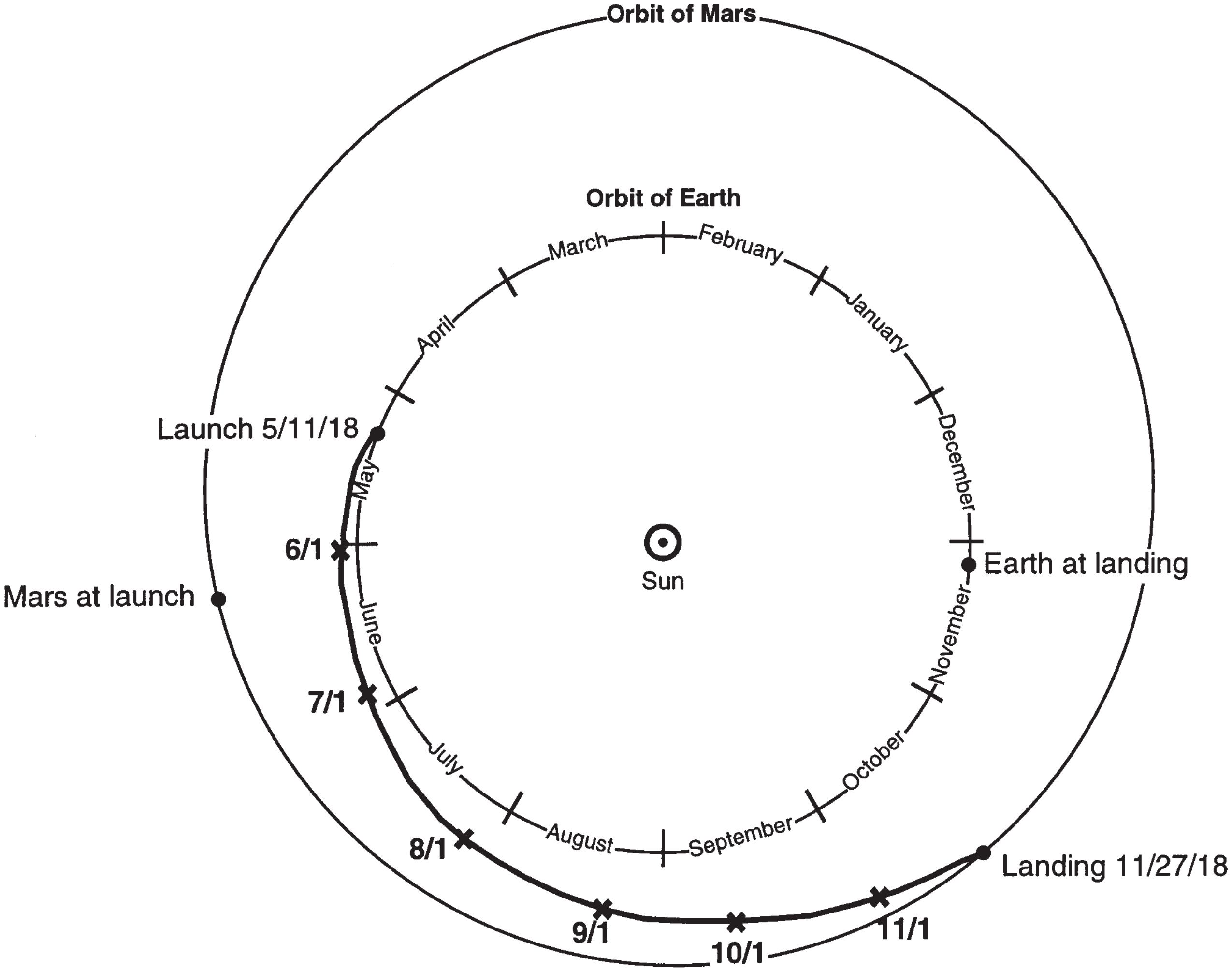
2. What are some possible paths for a spacecraft traveling from Earth to Mars?

3. What could make a spacecraft get to Mars faster?

4. What are some of the problems considered by engineers and scientists as they design trips to Mars?

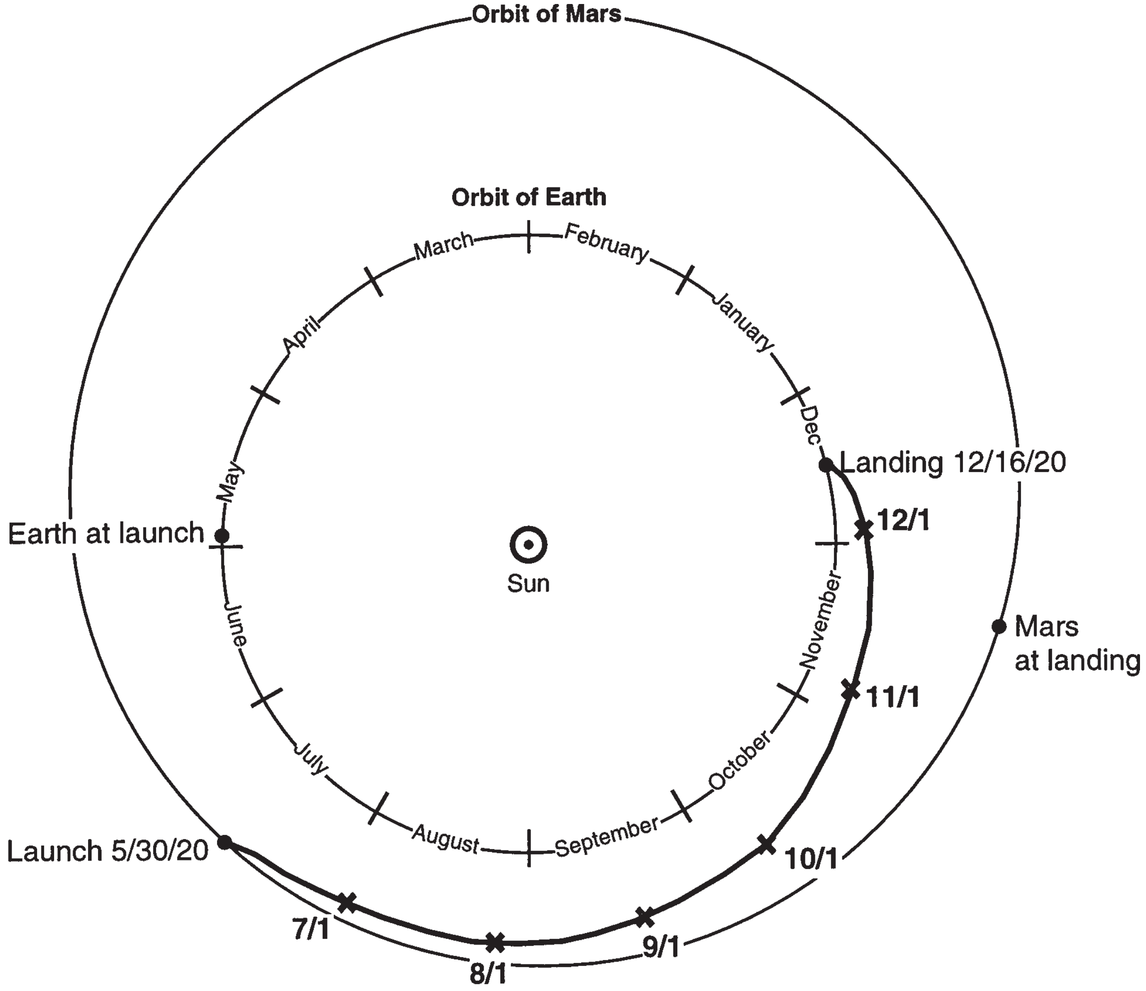
EARTH TO MARS

TEACHER ANSWER KEY



MARS TO EARTH

TEACHER ANSWER KEY



DANCING WITH THE PLANETS

Student Procedure

As scientists and engineers plan for travel to other planets, they have to deal with some basic planetary science.

- Earth and Mars move at different speeds around the Sun.
- Earth's orbit is about 150 million kilometers (km) from the Sun.
- Mars' orbit is about 200 million km from the Sun.
- Earth completes a solar orbit every 365 days.
- Mars completes a solar orbit every 687 days. (The difference in orbit times is about a 2 to 1 ratio Mars/Earth.)
- Earth completes its orbit in shorter time because it is closer to the Sun and has less distance to travel.
- Earth travels faster in its orbit. Planets closer to the Sun travel faster.

Using these facts, demonstrate dramatically the movement of Earth and Mars around the Sun. Incorporate music, costumes, and props in your demonstration for added effects. Your group may gather other information about Earth and Mars. Make your presentation scientifically accurate demonstrating as many facts as possible.

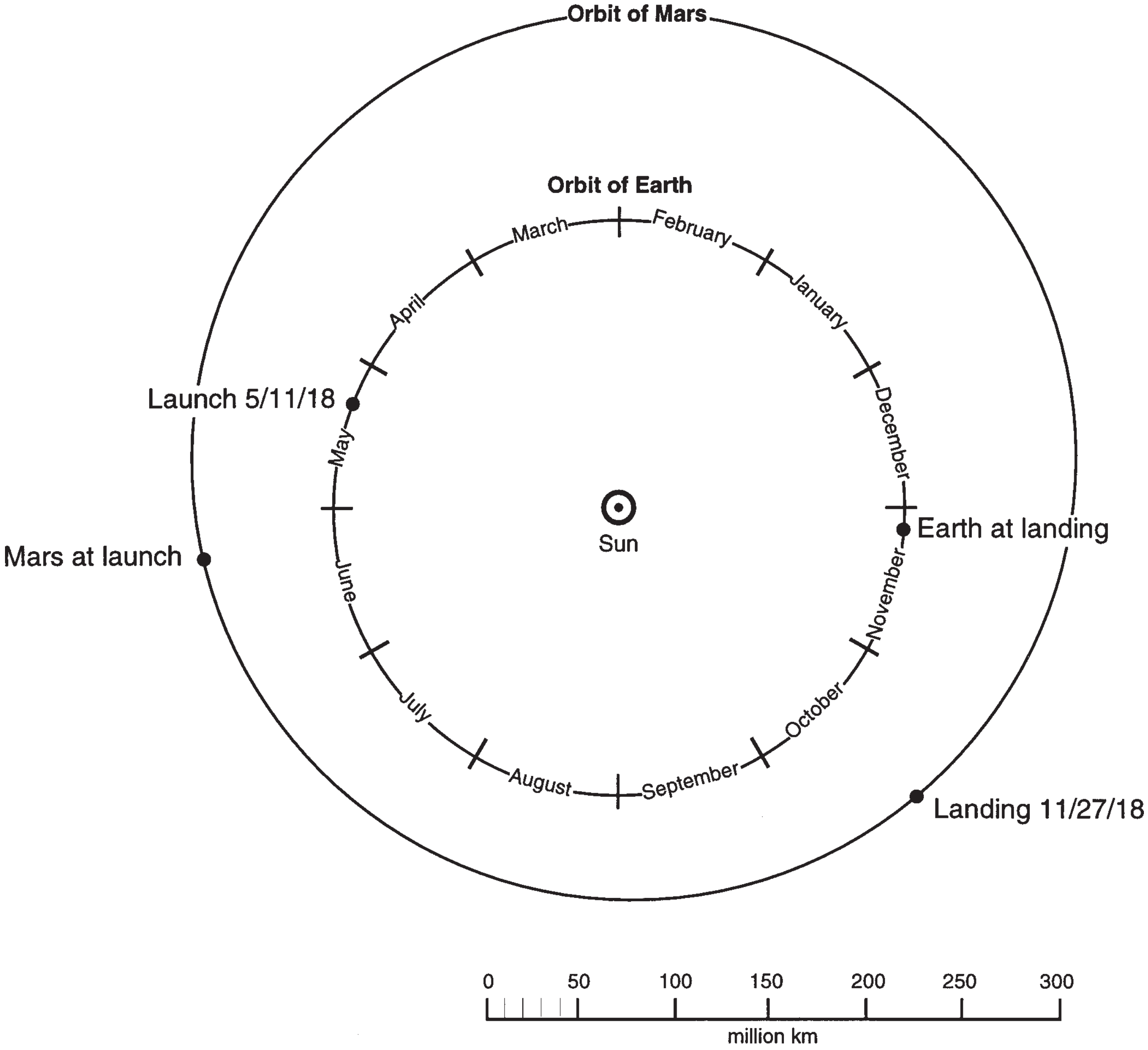
PLOTTING THE PATHS OF SPACECRAFT

Student Procedure

1. **Locate the following on the *Earth to Mars* Student Sheet;**
    - Earth and Mars orbit paths
    - Earth and Mars on launch date
    - Earth and Mars on landing date
    - the Sun
    - the scale in millions of kilometers(km)
    - the location of Earth on the first of each month
2. **Review the Spacecraft Position Data Table at the bottom of *Earth to Mars* Student Sheet.** The Data Table shows the position of the spacecraft on the first day of each month. The first column is the distances of the spacecraft from the Sun in million km. The second column is the distances of the spacecraft from the Earth in million km. **Note**: Remember the Earth is moving. Each month it will be in a different place.
3. **Plot the path (trajectory) of the spacecraft.**
    - **a.** Put the point of the compass on 0 on the scale and extend the angle until the pencil reaches the first *distance from Sun* measurement given in the Data Table (152 million km). Pick up the compass and place the point on the Sun in the diagram. Line the compass up with the first date given. Strike an arc.
    - **b.** Since the *distance from Earth* measurement is 0, the first point is where the *distance from the Sun* arc crosses Earth's orbit.
    - **c.** Using the second set of data, measure the *distance from the Sun* (155 million km) on the scale with the compass. Place the compass point on the Sun and draw a circle. Measure the *distance from the Earth* (5 million km) on the scale with the compass. Place the point of the compass on the June 1 slash mark and draw a circle. **Notice that there are two points where the circles intersect. Choose the intersection which is closest to the launch site. This intersection represents the location of the spacecraft.** Label location with the date (June 1).
    - **d.** Repeat this process using each set of data. Each time, the intersection that is nearer the launch site represents where the spacecraft is located on that date.
    - **e.** Repeat these steps with each set of measurements on a given date.
    - **f.** When all 8 points have been plotted, connect the points. This line is the path the spacecraft will follow on its trip to Mars.
4. **Using the key, check that your line is similar to the model.** If the two lines differ, find the place in the process where the error occurred. Make sure you understand the process before going to step 5.
5. **Plot the trajectory of the return trip to Earth from Mars using the second diagram and Data Table.** Follow steps 1-4.
6. **A minimum fuel trip between Earth and Mars takes about 200 days.** Think about how this effects planning trips to Mars. Because of this long time in space, what must happen? What cannot happen? What might happen? These are the questions that mission planners must answer. What are other questions that might be asked about planning trips with minimum fuel orbits?

EARTH TO MARS

STUDENT SHEET

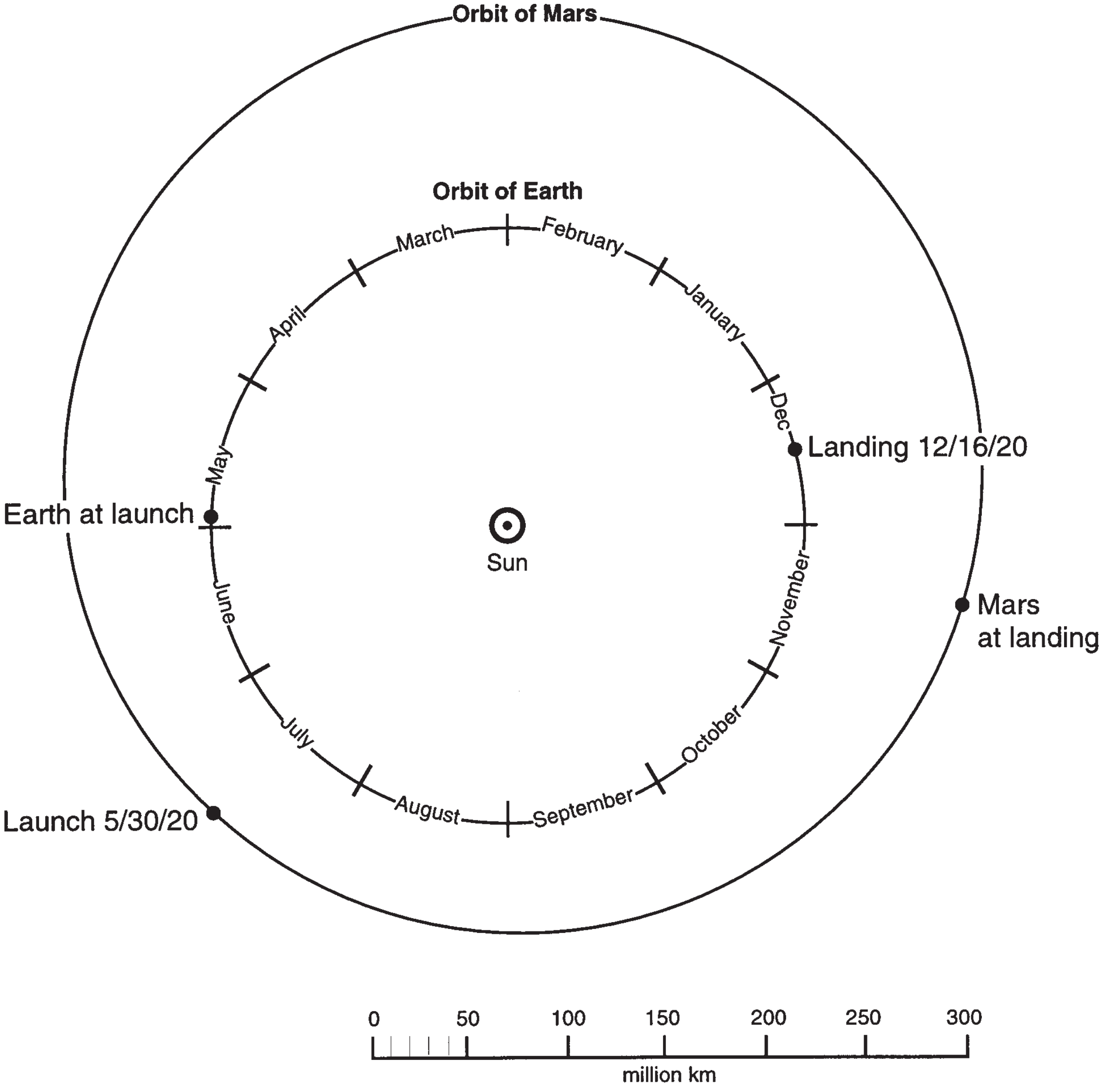


Spacecraft Position Data Table

	Date	Distance from Sun (million km)	Distance from Earth on this date (million km)	
(1)	May 11, 2018	152	0	Launch from Earth
(2)	June 1	155	5	
(3)	July 1	164	12	
(4)	Aug 1	176	25	
(5)	Sep 1	188	46	
(6)	Oct 1	199	76	
(7)	Nov 1	208	113	
(8)	Nov 27	213	147	Landing on Mars

MARS TO EARTH

STUDENT SHEET



Spacecraft Position Data Table

	Date	Distance from Sun (million km)	Distance from Earth on this date (million km)	
(1)	May 30, 2020	212	153	Launch from Mars
(2)	July 1	207	115	
(3)	Aug 1	198	80	
(4)	Sep 1	187	50	
(5)	Oct 1	174	28	
(6)	Nov 1	161	14	
(7)	Dec 1	151	4	
(8)	Dec 16	148	0	Landing on Earth

INVESTIGATING PLANETARY SOILS

About This Lesson

Students working in teams will read paragraphs describing the soil samples and record information on the appropriate chart. Students will then examine and test unknown soil samples and record test observations. Using the charts, each unknown sample will be identified. Students will be asked to defend their decisions.

Objectives

Students will:

- extract pertinent information from written soil descriptions. They will organize information using a fact chart.
- examine characteristics of three soils or soil simulants.
- identify soils by matching the given descriptions with their own observations of the soil properties.
- identify properties of soils from different bodies in our solar system and note similarities and differences.

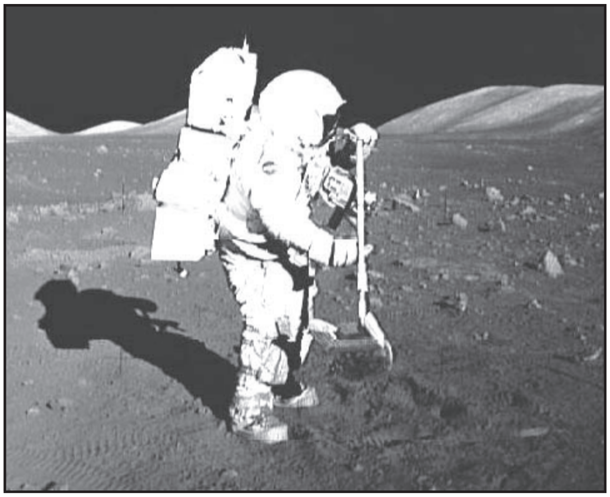
Background see *Soil Information Sheet*

Soil Samples

1. Obtain Lunar and Mars simulants from **Johnson Space Center, Houston, Texas, 77058, Attention: Carl Allen/SR.** (Allow several weeks. Simulants are free in small quantities.)
2. Earth soil that is red or brownish orange can be found outdoors in many parts of the country. You will need to write your own description if you are not using a typical east Texas orange soil.

Vocabulary

properties, robotic, analyze, simulant, composition, meteorite, impact, organic, mare, texture



Apollo 17 astronaut using rake to collect small lunar rock samples.

Materials

❑ Student Sheets, one each per group, *Soil Information Sheet*, *Chart of Known Soil Data*, and *Chart of Unknown Soil Properties* (pgs. 13-16)
❑ transparencies of the handouts (optional)
❑ sets of 3 soil samples (1 set per group) each set contains Mars simulant, Lunar simulant, Earth soil (in containers - bottles, vials, or jars)
❑ 1 magnet per group (Protect the magnet with thin paper so that it is easier to remove fine particles.)
❑ 1 magnifier per group
❑ 1 metric ruler per group

Procedure

Advanced Preparation

1. Obtain soil simulants.
2. Make copies of Student Sheets.
3. Prepare sets of 3 soil samples. Label them #1, #2, #3. Keep a record Sample Key.
4. Assemble and distribute equipment per Classroom Procedure.

Classroom Procedure

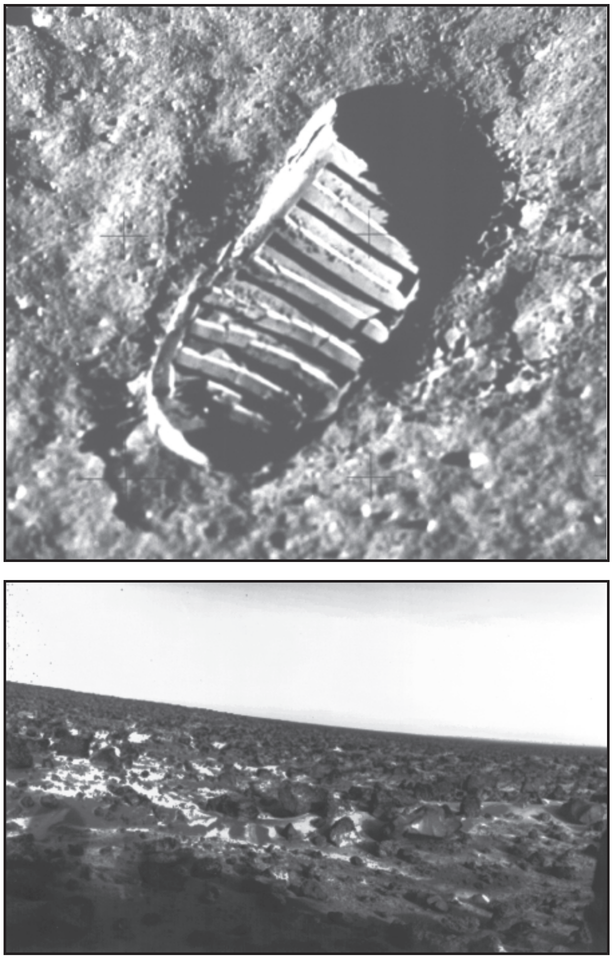
1. Divide the class into groups (3-4 per group).
2. Explain to the students that they are going to be acting as real scientists. Scientists need to be very organized and often keep their information in charts. Students will record data in chart form.
3. Hand out *Soil Information Sheet* and the *Chart of Known Soil Data.* Have the class or teacher read the introduction. Groups read the soil description paragraphs and fill in the chart (10 to 20 minutes).
4. Hand out the *Chart of Unknown Soil Properties* and the three unknown soil samples. Direct students to examine the samples and record their observations. Students should refer to the previous chart to aid their data collection on unknown samples.
5. Using the information from both charts, ask the students to decide which known sample matches which unknown sample. Record the names at the bottom of the *Chart of Unknown Soil Properties.*
6. Lead a discussion that examines the similarities and differences in the soil properties.

- For some classes, comparing the samples with the chart could be done as a class.
- For more advanced students, the reasoning behind the choices could be debated either verbally or in writing.
- Ask students to write their own description of the properties of a different soil sample, possibly samples they have provided.

Apollo astronaut collecting lunar rocks with tongs, on Apollo 12.

TRICKY TERRAIN

SOIL INFORMATION SHEET



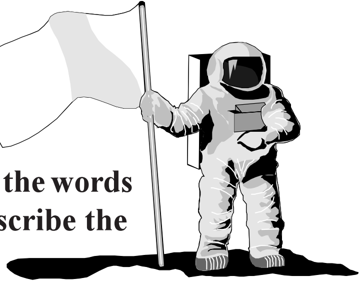
***Top:** Apollo 11 footprint on the Moon.*
***Bottom:** The surface of Mars taken from the Viking Lander.*

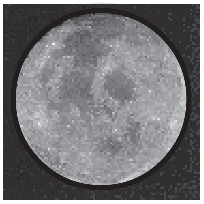
Human and robotic trips to the Moon have returned a few hundred kilograms of rocks and soil. Spacecraft have landed on the Mars surface and analyzed the soil, but no samples have been returned from the red planet. In order to become better prepared for future visits to both the Moon and Mars, scientists use the information already known about these planetary bodies. The information helped scientists find material on Earth for use as substitutes for the Moon and Mars soils. These substitutes, called soil simulants, are used to test equipment and techniques for future space exploration.

What is commonly called dirt is sample material for scientific studies. Scientists have special ways to study soils. Scientists determine the composition of the soils by using advanced scientific equipment. Many kinds of soils form in our solar system. Data from instruments on spacecraft help scientists know more about the soils of other planets. Everything in our solar system formed from similar materials. Similar processes formed Earth and other parts of our solar system. Therefore, scientists are able to find soils on our planet that fairly closely match the soils of the Moon and Mars.

Lunar soil is composed of rock that has been broken and melted by meteorite impacts. Mars soil is probably volcanic material, altered by contact with water. Earth soil is also the product of weathered rock minerals, but usually it also has organic material from dead plants and animals.

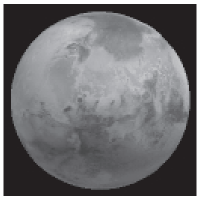
- **Read the descriptions on the next page and complete the *"Chart of Known Soil Data."* Pay special attention to the words scientists use to describe the soil materials.**





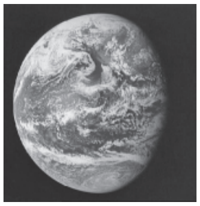
JSC-1
THE MOON

JSC-1 is a powder made from crushed volcanic ash. The ash erupted from a volcano in Arizona. JSC-1 is uniformly dark gray in color. Most of the powder is very fine, with an average size of 0.1 mm. The finest portion can be separated from the coarser material by repeated shaking. The finer material looks slightly lighter gray than the coarser material. Chunks larger than 1 mm are generally masses of the fine powder, easily broken down with moderate pressure. The powder contains a small percentage of material that can be separated using a magnet. JSC-1 closely matches the color, size, and composition of soil in the mare areas of the Moon.



JSC MARS-1

JSC Mars-1 is a powder made from weathered volcanic ash. The ash was erupted from a volcano in Hawaii. JSC Mars-1 is orange-yellow in color. Individual particles are smaller than 1 mm. The finest portion can be separated from the coarser material by repeated shaking. The finer portion is considerably more yellow than the coarser material. The powder contains about fifty percent dark material which can be separated using a magnet. JSC Mars-1 closely matches the color and approximates the size and composition of soil in the bright areas of Mars.



EARTH ET-1

Earth ET-1 is from Polk County in East Texas. It is not volcanic. Earth ET-1 is orange in color. Most particles are bigger than 1 mm in size. The finest portion can be separated from the coarser material by repeated shaking. There is no difference in color between the fine and coarse material. A very small percentage of the material can be separated from the rest using a magnet. Some organic material may be present. Earth ET-1 is only one of many different soils on our planet.

TRICKY TERRAIN — CHART OF <u>KNOWN</u> SOIL DATA

Read all paragraphs on *Soil Information Sheet.* Record the information about each known soil sample in the space below.

Properties	**JSC Mars 1 (Mars)**	**JSC - 1 (Moon)**	**Earth ET - 1 (Earth)**
What happens when a magnet is put in the soil?			
What color is the soil?			
What color are the very small pieces (particles) of soil?			
How big are the particles of soil? measure in mm			
Does the soil stick together (cling)?			
How do you divide the smaller particles from the big pieces?			

STUDENT SHEET

TRICKY TERRAIN — CHART OF UNKNOWN SOIL PROPERTIES

Examine the three unknown soil samples using the techniques and information from the *Chart of Known Soil Data.*
Record your detailed observations of the properties of the unknown samples below.
In the lines provided at the bottom, write the sample name from the *Chart of Known Soil Data* that most closely matches your observations.

Observed Properties

Magnetism (give a quantity in percent or at least try to say how much i.e. most or little)			
Color - overall			
Particle size - mm			
Color - fine particles			
Texture (clumps or not)			
Describe what happens when the soil sample is shaken vigorously.			
Write the sample name that matches the properties you have observed. Use the soil names from the *Chart of Known Soil Data.*	**Unknown # 1** ______________	**Unknown # 2** ______________	**Unknown # 3** ______________

MAKING AND MAPPING A VOLCANO

(Original activity is from *Exploring the Moon,* a Teacher's Guide with Activities for Earth and Space Sciences, NASA Education Product EP-306 1994.)

PART 1—

VOLCANO CONSTRUCTION EXPERIMENTS

About This Lesson

The focus of this activity is on the sequence of lava flows produced by multiple eruptions. Baking soda, vinegar, and play dough, are used to model fluid lava flows. Various colors of play dough identify different eruption events. Students will be asked to observe where the flows travel, make a model, and interpret the stratigraphy.

Objectives

Students will:

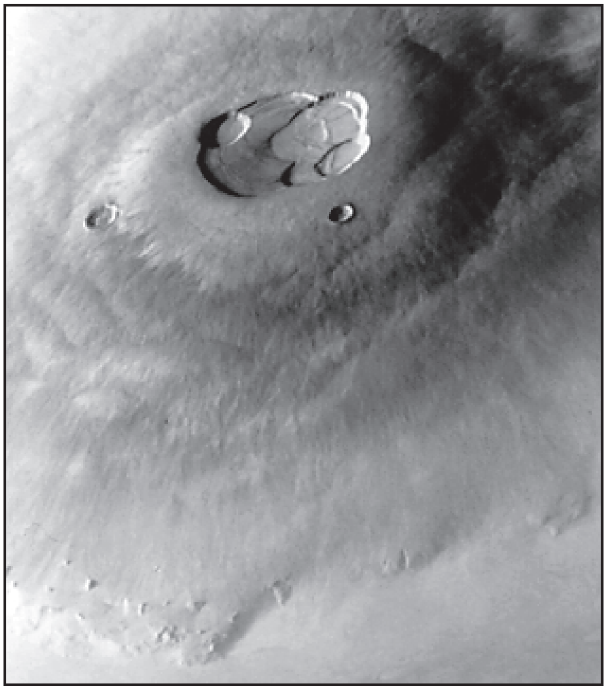
- construct a model volcano.
- follow a procedure to produce a sequence of lava flows.
- observe, draw, record, and interpret the history of the volcano.

Background

Volcanoes and/or lava flows are prominent features on all large rocky planetary bodies. Even some asteroid fragments show evidence of lava flows. Volcanism is one of the major geologic processes in the solar system. Mars has a long history of volcanic activity from the ancient volcanic areas of the southern highlands to the more recent major volcanoes of the Tharsis bulge. Olympus Mons is a volcanic mound over 20 km above the surrounding plains. This one volcano would cover the entire state of Arizona!

Where volcanic heat and water interact here on Earth, scientists are finding life. In the hot springs of Yellowstone Park they have found abundant life forms including some very small bacteria. There is a possibility that life may have found a place in the ancient volcanic terrain of Mars.

Some of the volcanoes on Mars are basaltic shield volcanoes like Earth's Hawaiian Islands. Interpretations of photographs and soil analyses from the Viking and Pathfinder missions indicate that many of the lava flows on Mars are probably basalt. Scientists believe that basalt is a very common rock type on all the large bodies of the inner solar system, including Earth.



Olympus Mons, a martian shield volcano, as seen by the Viking Orbiter.

In addition to shield volcanoes, there are dark, flat layers of basaltic lava flows that cover most of the large basins of Mars and the Earth's moon. The eruption sources for most of the basin lava flows are difficult to identify because source areas have been buried by younger flows.

Generally, the overall slope of the surface, local topographic relief (small cliffs and depressions), and eruption direction influence the path of lava flows. Detailed maps of the geology of Mars and the Moon from photographs reveal areas of complicated lava layering. The study of rock layering is called stratigraphy.

Older flows become covered by younger flows and/or become more pocked with impact craters. Field geologists use differences in roughness, color, and chemistry to differentiate between lava flows. Good orbital images allow them to follow the flow margins, channels, and levees to try to trace lava flows back to the source area.

Vocabulary

eruption, source, stratigraphy, slope, layers

Materials Per Volcano Team

- ☐ 1 paper cup, 100 ml (4 oz.) size, cut down to a height of 2.5 cm
- ☐ 2 paper cups, 150-200 ml (6-8 oz.) size
- ☐ cardboard, approximately 45 cm square (other materials may be used: cookie sheet or box lid)
- ☐ play dough or soft clay — at least 4 fist-size balls, each a different color
- ☐ tape
- ☐ spoon
- ☐ baking soda (4-10 spoonfuls depending on number of flows)
- ☐ vinegar, 100-150 ml (4-6 oz.) depending on number and size of flows
- ☐ paper towels
- ☐ marker or grease pencil
- ☐ paper and pencil
- ☐ optional food coloring to color the vinegar if desired, 4 colors; for example, red, yellow, blue, green
- ☐ Student Sheet, *Lava Layering - Part 1* (pgs. 19-20)

Procedure

Advanced Preparation

1. Review background information and procedure.
2 Gather materials.
3. Prepare play dough using recipes provided or purchase play dough.
4. Cover flat work area with newspaper to protect from spills.

Classroom Procedure

1. This activity may be done individually or in cooperative teams. Groups of 2-4 usually work well.
2. Follow procedure on Student Sheet, *Lava Layering-Part 1.*
3. Discuss the progression of flows, noting that the youngest is on top and the oldest is on the bottom.
4. If Lava Layering Part 2 will be completed at a later time, be sure to cover the volcanoes securely with plastic.

Recipes

Play Dough (stove-top recipe)

Best texture and lasts for months when refrigerated in an air tight container.

2 cups flour	*1/3 cup oil, scant*
1 cup salt	*2 cups cold water*
4 teaspoons cream of tartar	
food colorings (20 drops more or less)	

Make this large batch one color or divide ingredients in half to make 2 colors. You will need 4 colors total. Combine ingredients and cook mixture in a large sauce pan, stirring constantly, until the dough forms a ball. Turn dough out onto a floured surface to cool. Then kneed until smooth and elastic. Cool completely; refrigerate in air tight containers.

Play Dough (no-cooking recipe)

2 cups flour	*2 tablespoons oil*
1 cup salt	*1 cup cold water*
6 teaspoons alum or cream of tartar	
food colorings (as above)	

Make this large batch one color or divide ingredients in half to make 2 colors. You will need at least 4 colors. Mix ingredients and kneed until smooth and elastic. Store in air tight containers.

LAVA LAYERING — PART 1

Materials

- ☐ 1 paper cup, 100 ml (4 oz.) size, cut down to a height of 2.5 cm
- ☐ 2 paper cups, 150-200 ml (6-8 oz.) size
- ☐ cardboard or other surface, approx. 45 cm sq.
- ☐ playdough or soft clay, 4 fist size balls, each a different color.
- ☐ tape
- ☐ spoon
- ☐ baking soda, 50 ml (1/4 cup)
- ☐ vinegar, 100 ml (1/2 cup)
- ☐ paper towels
- ☐ marker or grease pencil
- ☐ paper and pencil
- ☐ optional: food coloring to color vinegar if desired.

Procedure

1. Take one paper cup that has been cut to a height of 2.5 cm and secure it onto the cardboard. (You may use a small loop of tape on the outside bottom of the cup.) This short cup is your eruption source and the cardboard is the original land surface.
2. Mark North, South, East, and West on the edges of the cardboard.
3. Fill a large paper cup about half full with baking soda.
4. Place one heaping spoonful of baking soda in the short cup.
5. Pour vinegar into a large paper cup leaving it half full.
   (optional: Fill 4 cups with 25 ml (1/8 cup) of vinegar. To each paper cup of vinegar add 3 drops of food coloring; make each cup a different color to match playdough. Set them aside.)
6. Set aside 4 balls of playdough, each in a different color.
7. You are now ready to create an eruption. Slowly pour a small amount of vinegar into your source cup and watch the eruption of simulated lava.
8. When the lava stops, quickly draw around the flow edge with a pencil or marker.
9. Wipe up the fluid with paper towels.
10. As best you can, use a thin layer of playdough to cover the entire area where lava flowed. Exact placement is not necessary. Match flow color and playdough if available.
11. On a separate sheet of paper record information about the flow. Indicate color, shape, direction of flow, and thickness. Indicate where this flow is in the sequence; first, second, etc.
12. Repeat steps 7 - 11 for each color of play dough available. Four to six flows show a good example of a shield volcano.

NOTES: You may add fresh baking soda to the source cup or spoon out excess vinegar from the source cup as needed. Be sure you mark where the lava flows go over previous flows as well as on the cardboard. Cover the entire area of each succeeding flow. This will resemble a strange layer cake with new flows overlapping old ones.

RESULTS

1. Look down on your volcano and describe what you see. Add your written description to the paper where you recorded the information about the flows. Include observations of flows covering or overlapping other flows. Make a quick sketch.

2. Where is the oldest flow?

3. Where is the youngest flow?

4. Did the flows always follow the same path? (be specific)

5. What do you think influences the path direction of lava flows?

6. If you had not watched the eruptions, how would you know that there are many different layers of lava? Give at least 2 reasons.

7. Which of the reasons listed in answer 6 could be used to identify real lava layers on Earth?

8. What are other ways to distinguish between older and younger layered lava flows on Earth?

9. Which of the reasons listed in answer 8 could be used to identify lava layers on Mars or the Moon?

10. What are other ways to distinguish between older and younger layered lava flows on Mars or the Moon? Look at orbital photographs if possible.

PART 2—

VOLCANO MAPPING EXTENSIONS

About This Activity

Students will simulate a mapping and field exercise. It is very similar to the first steps that geologists employ when they map and interpret the geologic history of an area. Student teams will map and study the volcanoes produced by another team in Lava Layering, Part 1. Lava Layering, Part 2 is designed to promote the use of higher order thinking skills and encourages the questioning, predicting, testing, and interpreting sequence that is important to scientific inquiry.

Objectives

Students will:

- produce a map of an unknown volcano and show the sequence of lava flows.
- interpret the map data and infer the subsurface extent of the flows.
- predict where excavations will give the most information.
- simulate both natural and human excavations.
- write a short geologic history of the volcano.

Background

In the solar system, volcanism is a major process active now and in the past. All the large, solid inner solar system planetary bodies have surface features that have been interpreted as lava flows and volcanoes. Mars has spectacular volcanoes. Where volcanic heat and water are close together, hot springs likely formed. These thermal springs could have harbored microbial life.

The thought processes and sequence of observing, taking data, and interpreting that students use when completing this exercise are very similar to the real investigations done by field geologists. Photo geologists use pictures taken by planes and spacecraft to interpret the history of a planet's surface. If they can get to the surface, they do field work by making maps and collecting samples. Geologists used pictures taken from Mars orbit to interpret the history of the planet's surface. Soon there will be some new data to add to the knowledge of Mars. The Mars Global Surveyor arrived at Mars in the fall of '97 and will return photos and other data about the surface of Mars. Pathfinder landed on July 4, 1997, and returned valuable data on weather, rocks and soil**.**

Materials

- ☐ volcano made of play dough from Lava Layering - Part 1, one volcano per team
- ☐ colored pencils or crayons
- ☐ metric rulers (two per group)
- ☐ straight edge for cutting (dental floss and wire cut play dough if knives are not permissible)
- ☐ large width straws (one per group, or one 5 cm-long piece per student.)
- ☐ Student Sheet, *Lava Layering - Part 2* (pgs. 25-26)
- ☐ toothpicks, 5-10 per volcano

Procedure

Advanced Preparation

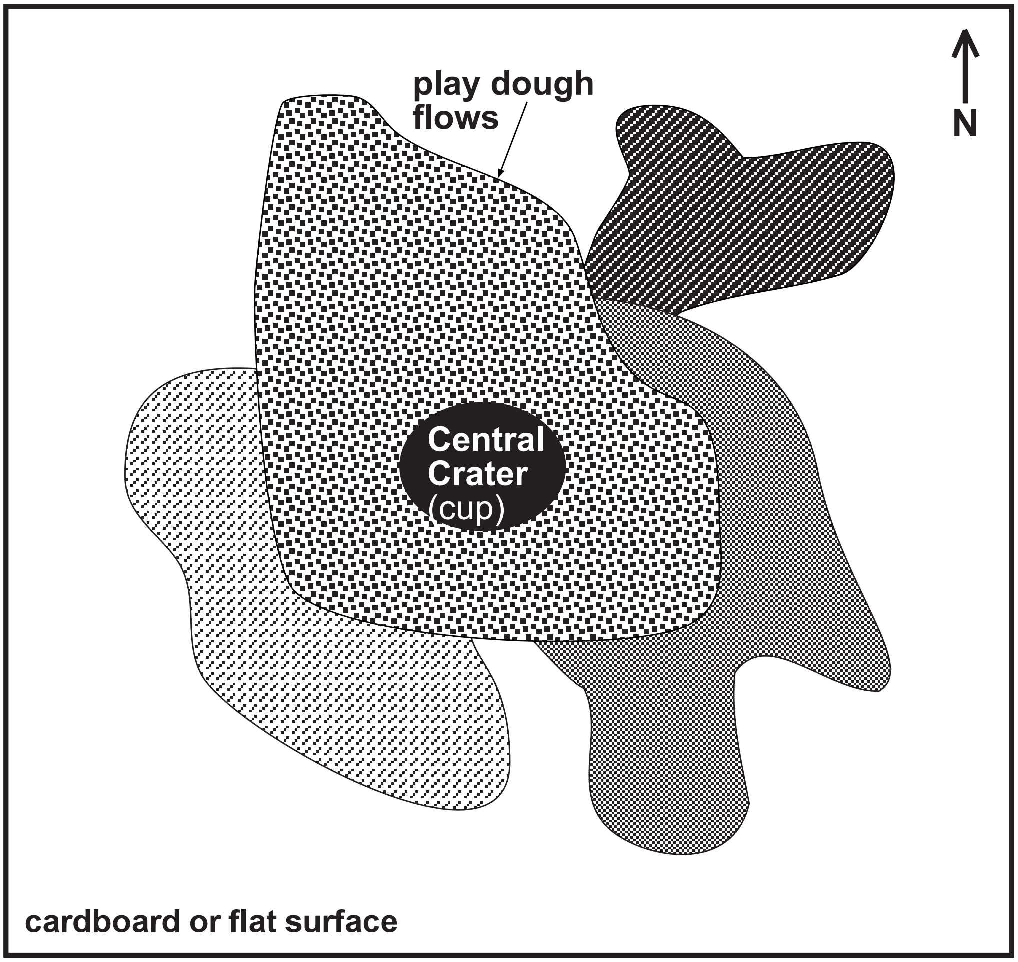
1. Gather materials.
2. Read procedure and background.
3. Small groups of students assemble volcanoes according to directions in Lava Layering- Part 1.
4. Mapping may be done immediately after volcano assembly or several days later. The play dough volcano must be covered with plastic if left more than a few hours.
5. Review map skills such as keys, scales, and measuring techniques.

Classroom Procedure

(This activity can easily be simplified as needed.)

1. Have teams trade volcanoes so that they will map a volcano with an "unknown" history. They may give the volcano a name if desired.
2. Ask groups to draw a map (birds-eye view) of the volcano. This may be made in actual size or they may make a scale drawing. The map should include a North direction arrow. An example drawn on the board or overhead may be helpful if students are not familiar with transferring measurements to a grid. Students will need to make careful observations and measurements to map the volcanoes accurately. Color and label the map.
3. Answer the questions on Student Sheet. **Note:** Some volcanoes may be more complex than others—each will be different!! There may be flows that are completely covered, some flows that have two separate lobes, and some flows for which the sequential relationship can not be determined at the surface.
4. Lead the students to question what they cannot see below the surface. Where do the flows extend under the exposed surface? Lead them to name ways they can see what is below the surface without lifting the play dough. They may suggest drill holes or cores, river erosion and bank exposure, earthquakes, or road cuts and other excavations.
5. Have groups make a plan that shows on their map where they want to put the subsurface exposures. They should indicate how the proposed cores and cuts will maximize the information they might gain from excavations. Limit the number of exposures each group may use, i.e., five drill cores and one road cut and one river erosion.
6. Make the cuts or cores.
   - Remove drill core by pushing a straw vertically into the play dough, twisting if necessary, and withdrawing the straw. Blow through the open end of the straw to remove the core. Put the core on a toothpick and place it by the hole for reference.
   - River valleys may be made by cutting and removing a "v" shape in the side of the volcano (open part of "v" facing down slope).
   - To make road cuts, use knife or dental floss to cut and remove a strip about 1 cm wide and as deep as you want from any part of the volcano.
   - To make earthquake exposures, make a single cut and lift or drop one side of the fault line. Some support will be necessary.
7. Record cuts and cores on the map and in notes. Be sure to use location information, i.e., core # 2 is located on the blue flow in the Northeast quadrant of the volcano.
8. Observe hidden layers. Interpret data and draw dotted lines on the map indicating the approximate or inferred boundaries of the subsurface flows.
9. On a separate paper, write a short history of the volcano that relates sequence of flows and relative volumes of flows (or make a geologic column, a map key to the history that shows oldest geologic activity at the bottom and youngest at the top). Math classes may try to figure the volume of the various flows.
10. Compare the history developed by mapping in Part 2 with the original history from the group that made the volcano in Part 1. Write how they are similar or different.
11. Conduct debriefings at several stages of this activity.

Example of bird's eye view map of lava flows.



LAVA LAYERING — PART 2

Directions

Make a map of a volcano model. Do this from a birds eye view. Label flows and features.

1. How many flows can you see on your map?
2. Beside the map make a list of the lava flows, starting with the youngest flow at the top and finishing with the oldest flow at the bottom. Example: Top flow is a long, skinny, green flow.
3. Can you easily determine the sequence of flows (which came first, which came last) or are there some flows where you can't say which are younger or older? Put a question mark by the uncertain flows in the list on the map.
4. Are there parts of any flows that might be covered? Which ones?
5. What would you need to tell the sequence and shape of each flow? How could you get that information without lifting the play dough?
6. Think about what techniques will help you learn more about the interior of your volcano. Your teacher will lead a class discussion about these techniques before you experiment. Stop here and wait for the teacher to continue.

7. Document why each proposed experiment will be helpful in revealing information about your volcano. Conduct the experiments and record locations and the information gained.

8. Finish your map. On a piece of paper, write a description of the sequence that tells the history of the volcano. Compare your sequence to the history written by the group that originally made the volcano. Was your interpretation accurate? Explain.

9. Why would it be harder to map lava flows on Mars using spacecraft photos?

LESSON FOUR MAPPING MARS

GEOLOGIC SEQUENCE OF CRATERS AND RIVER CHANNELS

About This Lesson

Students will approach studying the surface of Mars in the same way as photogeologists. After drawing a simple features map, they will have the tools to state the general geologic history of a part of Mars' surface. Students focus on the evidence showing river channels that once flowed and caused erosion. The evidence for water and volcanoes (see Lava Layering) on Mars points to possible environments where life could have existed.

Objectives

Students will:

- observe photographic details.
- make a simple features map.
- interpret the geologic history of a part of Mars' surface.
- analyze and discuss sequencing.

Background

Scientists use maps to illustrate the geologic history of a planet or moon. Geologic maps show present day features and evidence of past events. The maps show features that were formed earlier or later than others, giving scientists a relative time sequence of events (not precise dates). On Earth these maps are made using photographs taken from airplanes and spacecraft, and from research on the Earth's surface. To make maps of other planets we must use photographs taken by spacecraft and use lander information from the planet's surface.

Vocabulary

crater, ejecta, eroded, channel, sun angle, sequence, Chryse Planitia (cry´ sēē plän ĭ´ tiə)

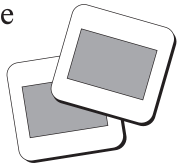
Materials - For activity using paper photos

- ☐ photo of Mars surface showing outflow channels emptying into northern plains of Chryse Planitia. Photo available on the World Wide Web at:
  http://lpi.usra.edu/expmars/channels.html
- ☐ Student Sheet, *Mars Mapping* (pg. 31)
- ☐ tracing paper or transparencies, one per paper photo
- ☐ tape or paper clips
- ☐ colored markers (3 colors - red, green, and blue are used in the discussion below)

Materials - For group version using slide

- ☐ slide projector
- ☐ large sheet of paper (not shiny) or a non-shiny erasable white board may be used — test first
- ☐ masking tape
- ☐ slide of Mars surface showing outflow channels emptying into northern plains of Chryse Planitia. Slide # 24 "Outflow Channels Emptying into Northern Plains of Chryse Planitia" in the Set THE RED PLANET: A SURVEY OF MARS

Order Department
Lunar and Planetary Institute
3600 Bay Area Boulevard
Houston TX 77058-1113
Phone: (281) 486-2172
Fax: (281) 486-2186
e-mail: order@lpi.usra.edu



Note: A high quality transparency from a photo developer works well. Use the slide to make the transparency. Project with classroom overhead projector.

Procedure

Advanced Preparation

1. Gather materials.
2. Become familiar with the important features in the Mars photo.
3. Practice determining the up and down slopes of the features by paying attention to the Sun illumination angle and the shadows on the features.

Procedure for Paper Copy of Photograph

Steps below are for individuals or pairs using a paper copy of the Mars image.

1. Secure a transparency or sheet of tracing paper to the top of the Mars photo.
2. Distribute materials.
3. Tell students that this is a spacecraft photograph of an area on Mars around 20° N latitude and 55° W longitude, at the northern edge of Chryse Planitia. The image shows impact craters and river channels. The area is about 200 kilometers across. No one has ever been there, but we can figure out things about this part of Mars by mapping and thinking.
4. Show students an example of a crater with a continuous, sharp-edged, unbroken rim. Note that they should draw the rim and not the fairly flat interior (see drawing on student sheet).
   If time and skill allow, students may also note and draw the ejecta for the fresh sharp rimmed craters. The ejecta is the material that is blasted out of the crater and falls outside the rim of the crater. The ejecta is usually more irregular than most of the craters. **Review with students how to tell what is a depression and what is a hill slope by knowing the direction of illumination from the Sun.**
5. Have students carefully outline the **rims** of all sharp-edged craters red.
6. Show students an example of a crater with an uneven, eroded, broken rim (see student sheet).
7. Have students carefully outline the **rims** of all eroded craters green.
8. Show students an example of a river channel.
9. Have students color (not outline) all channels blue. They may try to show both sides of the channel but a single line in the middle of the channel is adequate.
10. Have students lift the transparencies and look at them. Ask the student what they have made. **(They have made a simple feature map.)**
11. Answer and discuss the questions on Student Sheet.

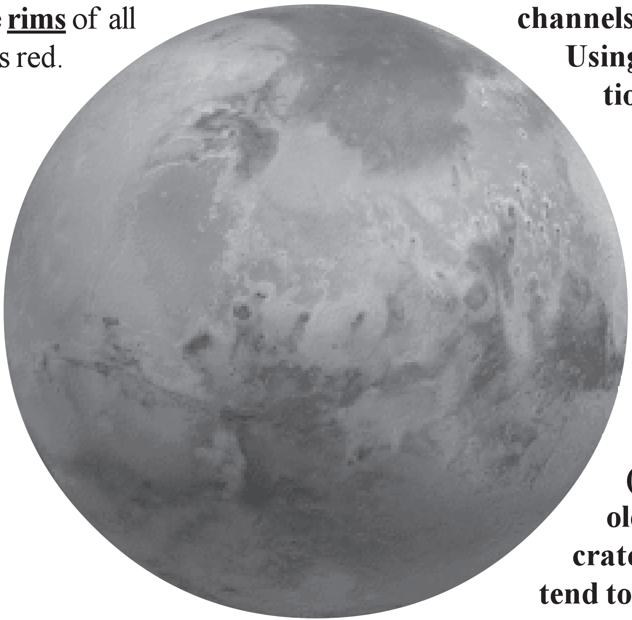
Group Procedure Using a Slide

Steps below are for a large group activity using a slide.

1. Tape a large sheet of paper to the wall.
2. Project the slide on the paper, so the image is as large as possible.
   Be aware that it will be easier to clearly distinguish details on the image from several feet away due to projector focusing. When students draw on the paper they will either need to ask for some help from classmates or step back frequently. This leads to a good cooperative activity.
3. Tell students that this is a spacecraft photograph of an area on Mars around 20° N latitude and 55° W longitude, at the northern edge of Chryse Planitia. The image shows impact craters and river channels. The area is about 200 kilometers across. No one has ever been there, but we can figure out things about this part of Mars by mapping and thinking.
4. Show students an example of a crater with a continuous, sharp-edged, unbroken rim. Note that they should draw the rim and not the fairly flat interior (see drawing on student sheet).
   If time and skill allow, students may also note and draw the ejecta for the fresh sharp rimmed craters. The ejecta is the material that is blasted out of the crater and falls outside the rim of the crater.

The ejecta is usually more irregular than most of the craters.

5. Have a student or group of students carefully outline the **rims** of all sharp-edged craters red.
6. Show students an example of a crater with an uneven, eroded, broken rim (see Student Sheet).
7. Have students carefully outline the **rims** of all eroded craters green.
8. Show students an example of a river channel.
9. Have students color (not outline) all channels blue. They may try to show both sides of the channel but a single line is adequate.
10. Turn off the overhead projector and ask the students what they have made. **(They have made a simple feature map.)**
11. Answer and discuss questions on Student Sheet.



Questions and Answers

1. Which are older - river channels or green craters? How do you know? **Green craters are older. When a river channel met a green crater the water broke through the rim, entered the crater, broke out somewhere else, and kept going.**

2. Which are older - river channels or red craters ? How do you know ? **River channels are older. When an impact formed a red crater on top of a river channel the crater covered the channel, but the crater was not eroded. The river had stopped flowing.**

3. Which features are oldest, youngest, and of medium age? **Green craters are oldest, red craters are youngest, river channels are of medium age. Using the data from questions 1 and 2, the green craters were there before the channels, and the channels were there before the red craters.**

4. Are big craters older or younger than small craters? **Big (green) craters are older than small (red) craters. The green craters tend to be larger while the red ones are generally smaller. The same observation that the green craters were there before the channels and the red craters were formed after the channels sets the larger green craters as being older.**

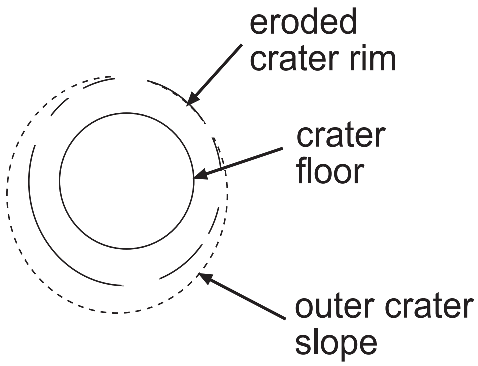
5. Write a simple geologic history of this part of Mars. **First large meteorites hit the surface and made big craters. Later flowing water formed river channels which cut through some of the old craters. After a while the rivers stopped flowing. Even later smaller meteorites hit the surface. Some of these formed craters on top of the dry channels and on older craters.**

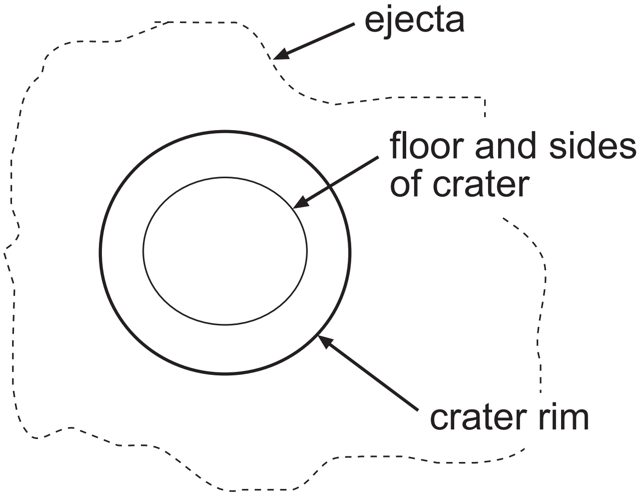
Extra credit

6. What caused the difference in size between the young craters and the older craters? **Most of the big meteorites hit a long time ago. Later only smaller meteorites were left. The earlier meteorites were very large pieces of planetary material that**

were still being pulled together through the process of solar system accretion (gathering of material into planetary bodies). As time passed, the impacts were caused by the smaller pieces of material leftover from the accretion process, thus making smaller craters.

7. Which way does the land slope? **The land slopes downwards from the west to the east. River channels combine as you go downhill. A map of the Mississippi River or some other terrestrial river basin may be used as a comparison. These Mars channels do not show a delta formation as some may suggest.**





STUDENT SHEET

MARS MAPPING

Objective

To make a simple features map and interpret the geologic history of a part of Mars' surface.

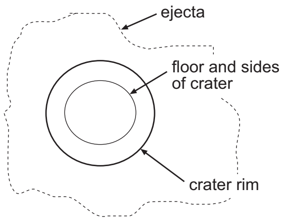
Background

Scientists use maps to illustrate the geologic history of a planet or moon. Geologic maps show present day features and evidence of past events. The maps show features that were formed earlier or later than others, giving scientists a relative time sequence of events, although not precise dates. On Earth these maps are made using photographs taken from airplanes and spacecraft, and from research on the Earth's surface. To make maps of other planets we must use photographs taken by spacecraft and use lander information from the planet's surface.

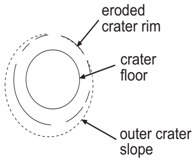
The area in the photograph of Mars is about 200 kilometers across and shows impact craters and river channels. Mark these features on the photograph using the examples below. Then answer the questions on the back of this page.

Features found in the photograph are:

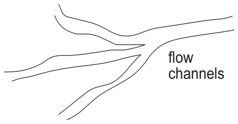
1. Craters with continuous, sharp-edged, unbroken rims.
   Carefully outline the rims all such craters **Red**.



2. Craters with uneven, eroded, broken rims.
   Carefully outline the rims of all such craters **Green**



3. River channels.
   Color (not outline) all channels **Blue**.



Questions

Use the map to answer the questions.

1. Which are older — river channels or green craters? How do you know?

2. Which are older — river channels or red craters? How do you know?

3. Which features are oldest, youngest, and of medium age?

4. Are big craters older or younger than small craters?

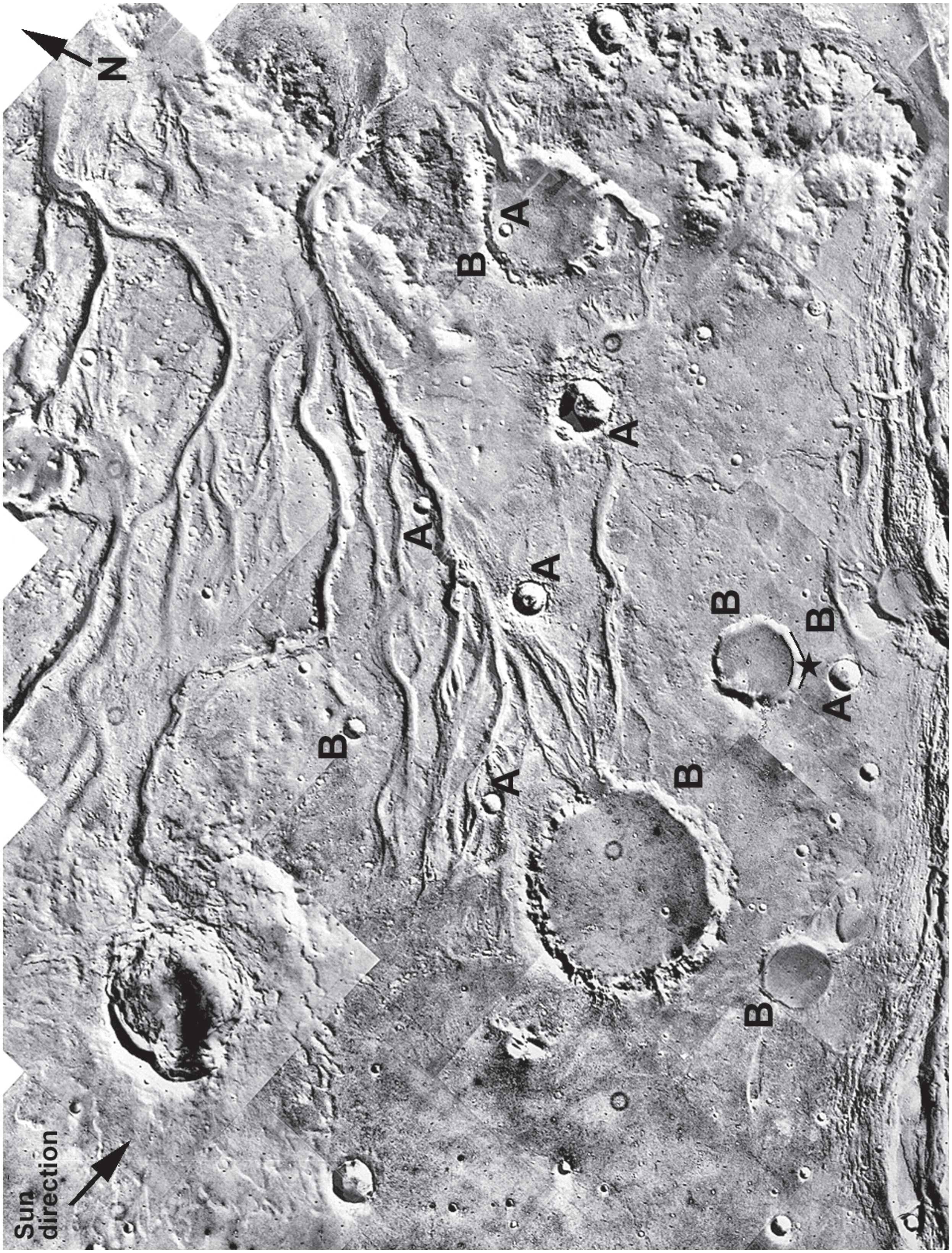
5. Write a simple geologic history of this part of Mars.

Challenge

What caused the difference in size between the young craters and the older craters?

Which way does the land slope?

MAPPING MARS KEY



A = sharp-edged crater   B = eroded crater   ★ = crater wall as seen in sunlight

LESSON FIVE

SEARCHING FOR LIFE ON MARS

This lesson contains four exercises within three activities. The activities have been grouped to encourage students to think about the characteristics of life and about the possibility of looking for life on Mars.

Activity 1 — Imaginary Martians

Students will listen to one or more excerpts from science fiction that describe a fictional living organism from Mars. They will then draw their interpretations of the creatures and compare them to what they already know about life on Mars today.

Activity 2 — Looking for Life

Part A: An Operational Definition of Life Students will research characteristics of living organisms and develop a chart that will help them define important features of a living organism.

Part B: It's Alive! They will then use their definition to determine whether there is anything alive in three different soil samples, an experiment similar to the Mars Viking Lander in 1976 that looked for signs of life. Students will record their observations and draw pictures as they collect data from the samples.

Activity 3 — Mars Critters

Students will design a plant or animal life form that might survive on Mars.

ACTIVITY 1—

IMAGINARY MARTIANS

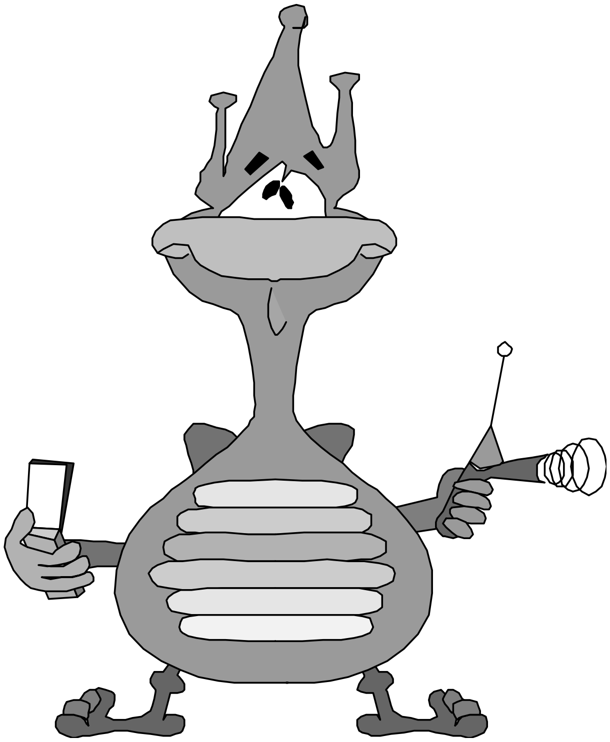
About This Activity

Students will listen to one or more excerpts from science fiction that will describe fictional living organisms from Mars. They will then draw their interpretations and compare them to what they already know about life on Mars today.

Objectives

Students will:

- draw their interpretation of a Martian after listening to a science fiction reading.
- analyze the realism of this Martian based on today's knowledge of Mars environment.
- discuss the popularity of Mars in literature.



Background

There are many science fiction stories related to Mars. Each one has its own explanation of how a Martian might look. The descriptions are based on the author's imagination and the known information about Mars from the time period. In this interdisciplinary activity, students will interpret an author's description of a Martian (language arts and art) and evaluate the possibility of such a creature living on Mars (science).

Vocabulary

interpretation, atmosphere, radiation

Materials

- ☐ drawing paper
- ☐ coloring utensils
- ☐ Student Sheet, *If You Went to Mars* (pg. 37)
- ☐ excerpts from science fiction novels Examples are Mars by Ben Bova (chapter 7), Out of the Silent Planet by C. S. Lewis (chapter 7), The Martian Chronicles by Ray Bradbury (February 1999-YUa), The Day The Martians Came by Frederick Pohl (chapter 17)

Procedure

Advanced Preparation

1. Check various novels and choose excerpt(s) to use.
2. Practice reading the excerpt(s).
3. Distribute student supplies.
4. Distribute the *If You Went to Mars* student sheet.

Classroom Procedure

1. Explain to the students that people in the past have had very different ideas of what life is like on Mars and that you would like to share some of these interpretations with them.
2. Ask the class to close their eyes and listen to the reading(s).
3. Read the excerpt(s) with animation and sound effects.
4. Tell the students to open their eyes, take the drawing materials of their choice, and draw what they think the author(s) described.
5. Ask the students why they think the author wrote the descriptions in this way. Discuss answers in terms of the literature and the time when the story was written.
6. Ask the students why they think there is so much literature about the planet Mars?
7. Ask each student to explain why the alien drawn could or could not really be found on Mars.
8. Discuss what it would be like to live on Mars. Use the *If You Went to Mars* student sheet.

Alternatives

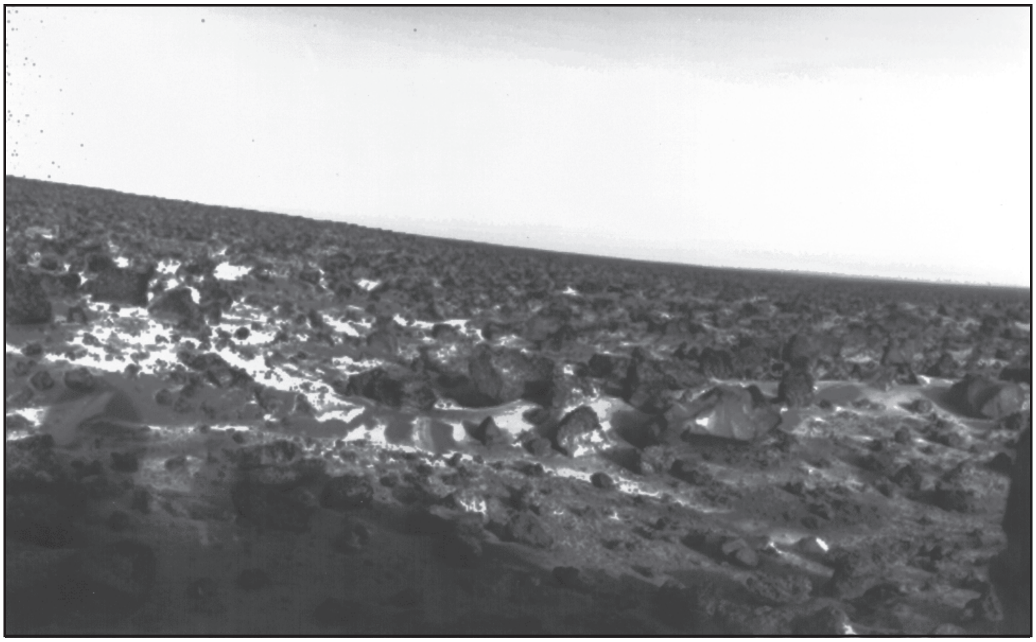
1. Instead of a standard sheet of paper, have the students work in groups using a large sheet of butcher paper. Then you can also discuss how differently we each interpret what we hear. Display art.
2. Divide the class into teams and read several different excerpts, each team drawing an interpretation of a separate excerpt, then comparing the team drawings. Display art.

If You Went to Mars

from "Guide to the Solar System,"
by The University of Texas, McDonald Observatory

Mars is more like Earth than any other planet in our solar system but is still very different. You would have to wear a space suit to provide air and to protect you from the Sun's rays because the planet's thin atmosphere does not block harmful solar radiation. Your space suit would also protect you from the bitter cold; temperatures on Mars rarely climb above freezing, and they can plummet to -129ºC (200 degrees below zero Fahrenheit). You would need to bring water with you; although if you brought the proper equipment, you could probably get some Martian water from the air or the ground.

The Martian surface is dusty and red, and huge duststorms occasionally sweep over the plains, darkening the entire planet for days. Instead of a blue sky, a dusty pink sky would hang over you.



STUDENT SHEET

FUNDAMENTAL CRITERIA FOR LIFE CHART

Fill in Criteria after the class has made observations and the teacher has grouped the observations.

Living Organism	**Criteria**	**Criteria**	**Criteria**	**Criteria**	**Criteria**

ACTIVITY 2—

LOOKING FOR LIFE

About This Activity

In Part A students will use research to develop their criteria for life. The class will combine their ideas in a teacher-guided discussion. In Part B they will then use their definition of life to determine whether there is anything alive in three different soil samples. They will make observations and draw pictures as they collect data from the samples and experiment.

Objectives

Students will:

- form an operational definition of life.
- conduct a simulated experiment with soil samples similar to the experiments on the Mars Viking Lander.
- state relationships between the soil samples using their operational definition of life.
- make an inference about the possibility of life on Mars based on data obtained.

Background

We usually recognize something as being alive or not alive. But when scientists study very small samples or very old fossilized materials, the signs of life or previous life are not easy to determine. Scientists must establish criteria to work with in their research. The tests for life used by the Viking Mars missions were based on the idea that life would cause changes in the air or soil in the same way that Earth life does. The Viking tests did not detect the presence of life on Mars. The Viking tests would not have detected fossil evidence of past Mars life or a life form that is very different from Earth life.

Vocabulary

criteria, characteristics, organism, replication, metabolic

PART A:

AN OPERATIONAL DEFINITION OF LIFE

About This Part

Students will conduct research to identify characteristics of living and non-living organisms. They will record their observations on a chart that will help the class to come to a consensus about how to identify living things.

Materials

- ☐ Student Sheet *Fundamental Criteria for Life Chart* (pg. 38)
- ☐ dictionaries and encyclopedias
- ☐ examples of living and non-living things (should include plants, animals, and microorganisms—pictures can be substituted for the real thing)

Procedure

Advanced Preparation

1. Gather materials.
2. Review Background and Procedure.

Classroom Procedure

1. Explain to students that their job is to come up with a definition of how living things can be detected.
2. Ask students to state (or write) what characteristics make an individual item alive or not alive. Encourage them to find pictures and definitions of living and non-living things. Allow the students use of dictionaries and encyclopedias. Use the examples on the following page to encourage the students but not to limit them.

Example: Consider a bear and a chair—they both have legs, but one can move on its own and the other would need a motor made by humans; therefore, independent movement might be one characteristic that indicates life.

Not every living organism needs legs or roots. But they do need a mode of locomotion or a way to get nutrients. Also, the bear breathes and the chair does not, another indication of life. Or consider a tree and a light pole. We know that a light pole can not reproduce— it is made by humans—and we know that the tree makes seeds that may produce more trees. The tree also takes in nutrients and gives off gasses and grows. The light uses electricity and gives off light, but it is strictly an energy exchange and there is no growth and there are no metabolic processes.

However, students might not list the fundamental criteria for life. They might go for the more obvious signs like methods of locomotion. The more subtle but fundamental signs of life are:

- metabolic processes that show chemical exchanges which may be detected in some sort of respiration or exchange of gases or solid materials.
- some type of reproduction, replication or cell division.
- growth.
- reaction to stimuli.

3. As a class, discuss the indications of life, asking for examples from a diverse sampling of living things. The teacher will paraphrase and group criteria on the blank chart, then guide the students to summarize the groupings to reflect the fundamental criteria for life.

4. Students will use these criteria for the following activities.

PART B: IT'S ALIVE!

About This Part

Students will take three different soil samples and look for signs of life based on the criteria from Part A.

Materials

- ☐ sand or sandy soil sample
- ☐ three glass vials, baby food jars, or beakers for soil per group
- ☐ sugar- 5 ml (sugar will be added to all soil samples)
- ☐ instant active dry yeast- 5 ml added to 50 ml of soil
- ☐ Alka-Seltzer tablets crushed- 1 tablet added to 50 ml of soil
- ☐ hot water - enough to cover the top of the soil in all jars (not hot enough to kill the yeast!)
- ☐ cups for distributing the water
- ☐ magnifying lens- 1 per group or individual
- ☐ Student Sheets *Data Chart I* and *Data Chart II* (pgs. 43-44)

Procedure

Advanced Preparation

1. Fill all jars 1/4th full of soil. (You will need 3 jars per team.)
2. Add just sugar to 1/3rd of the jars. Label these jars "A."
3. Add instant active dry yeast and sugar to 1/3rd of the jars. Label these jars "B."
4. Add the powdered Alka-seltzer and sugar to the remaining jars. Label these jars "C."
5. Give each group a set of three jars, magnifying lens, and the chart from previous activity.

Classroom Procedure

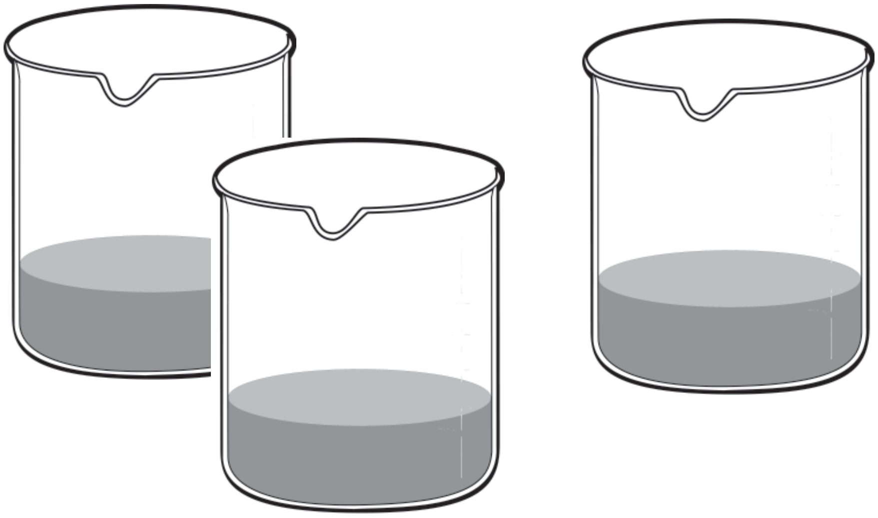
(Information for teacher only— do not share all the information with students!)

1. Explain to the students that each team has been given a set of soil samples. No one knows if there is anything alive in them. The assignment is to make careful observations and check for indications of living material in them — based on their criteria.
2. Ask students to observe all three samples. They can smell and touch the samples but not taste them. Encourage students to put a few grains on a flat white surface and observe them with a hand lens. Students should then record their data.
3. Give each group a cup of water. (Use hot tap water (~50ºC) for the best results, do not kill the yeast.) Ask students to pour the water so that each sample is covered with the water.
4. Repeat step 2 and record data on a second sheet or in a separate area of the first sheet. Students should look for and record differences caused by adding water. After recording the first observations have students go back and observe again. (After about ten minutes Sample B will show even more activity.)
5. Discuss which samples showed indication of activity (B and C).
   Does that activity mean there is life in both B and C and no life in Sample A?
   Are there other explanations for the activity in either B or C?

   - Both B and C are chemical reactions
   - Sample C reaction stops
   - Sample B sustains long term activity
   - Sample A is a simple physical change where sugar dissolves

Students should realize that there could be other tests that would detect life in Sample B. There might be microbes in the soil that would grow on a culture medium.

6. Determine which sample(s) contain life by applying the fundamental criteria for indicating life developed in Activity 2.
7. Tell students that Sample B contained yeast and Sample C contained Alka Seltzer. Discuss how scientists could tell the difference between a non-living chemical change (Alka Seltzer) and a life process (yeast) which is also a chemical change.
8. Discuss which of their criteria would identify yeast as living and Alka Seltzer as non-living.



STUDENT SHEET

IT'S ALIVE! DATA CHART I

Initial Descriptions (no water added):

Sample A:

Sample B:

Sample C:

Initial Drawings (no water added):

Sample A

Sample B

Sample C

IT'S ALIVE! DATA CHART II

Initial Descriptions (after water is added):

Sample A:

Sample B:

Sample C:

Initial Drawings (after water is added):

Sample A

Sample B

Sample C

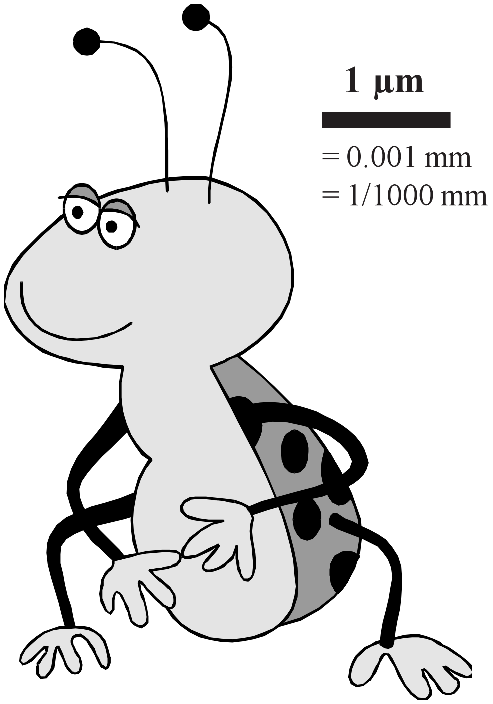
ACTIVITY 3—

MARS CRITTERS

About This Activity
In groups or as individuals, students will use their knowledge of Mars and living organisms to construct a model of a plant or animal that has the critical features for survival on Mars. This is a "what if" type of activity that encourages the students to apply knowledge. They will attempt to answer the question: What would an organism need to be like in order to live in the harsh Mars environment?

Objectives
Students will:
- draw logical conclusions about conditions on Mars.
- predict the type of organism that might survive on Mars.
- construct a model of a possible martian life form.
- write a description of the life form and its living conditions.

Background
To construct a critter model, students must know about the environment of Mars. The creature must fit into the ecology of a barren dry wasteland with extremes in temperature. The atmosphere is much thinner than the Earth's; therefore, special adaptations would be necessary to handle the constant radiation on the surface of Mars. Also the dominant gas in the Mars atmosphere is carbon dioxide with very little oxygen. The gravitational pull is just over 1/3rd (0.38) of Earth's. In addition, Mars has very strong winds causing tremendous dust storms. Another requirement for life is food—there are no plants or animals on the surface of Mars to serve as food!



Scientists are finding organisms on Earth that live in extreme conditions previously thought not able to support life. Some of these extreme environments include: the harsh, dry, cold valleys of Antarctica, the ocean depths with high pressures and no sunlight, and deep rock formations where organisms have no contact with organic material or sunlight from the surface.

Vocabulary
ecology, adaptations, gravity, geology, atmosphere, radiation exposure, weather, environment

Materials
- ☐ paper (construction, tag board, bulletin board, etc.)
- ☐ colored pencils
- ☐ glue
- ☐ items to decorate critter (rice, macaroni, glitter, cereal, candy, yarn, string, beads, etc.)
- ☐ pictures of living organisms from Earth
- ☐ Student Sheet, *Mars Critters* (pg. 47)
- ☐ Student Sheet - Activity 1, *If You Went to Mars* (pg. 37)
- ☐ Mars Fact Sheet (pg. 56)

Procedure

Advanced Preparation

1. Gather materials.
2. Set up various art supplies at each table for either individual work or small group work. This activity may be used as a homework project.
3. Review the "If You Went to Mars" sheet, Mars Fact Sheet, and the background provided above. Other research and reading may be assigned as desired.

Classroom Procedure

1. Ask students to work in groups to construct a model of an animal or plant that has features that might allow it to live on or near the surface of Mars. Have them consider all the special adaptations they see in animals and plants here on Earth. They must use their knowledge of conditions on Mars, consulting the Mars Fact Sheet, *If You Went to Mars*, and other resources such as web pages if necessary. Some key words for a web search might be "life in space" or "extremophile" (organisms living in extreme environments). They must identify a specific set of conditions under which this organism might live. Encourage the students to use creativity and imagination in their descriptions and models.
2. If this is assigned as homework, provide each student with a set of rules and a grading sheet, or read the rules and grading criteria aloud and post a copy.
3. Review the information already learned about Mars in previous lessons.
4. Allow at least 2 class periods for this project: one for construction, one for presentation.
5. Remind the students that there are no wrong critters as long as the grading criteria are followed.
6. Include a scale with each living organism.

STUDENT SHEET

MARS CRITTERS

In order to better understand what types of life scientists will look for when they go to Mars, you will construct a model or draw a picture of an organism that has features that might allow it to live on or near the surface of Mars.

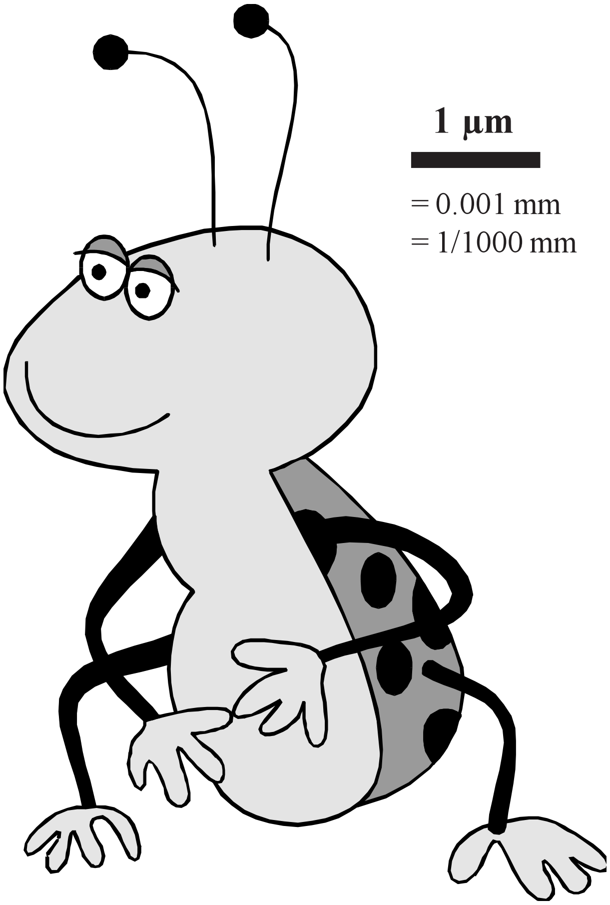
Conduct research about the environment on Mars. Consider the geology, gravity, atmosphere, radiation exposure, and weather. Choose a habitat somewhere in the Mars environment for the organism to live. Then construct a model of the plant or animal and include the special features it would need to live in that harsh environment. You may want to research the special adaptations animals and plants have to survive in difficult places here on Earth. Be creative and use your imagination.

Make a scale model or picture of your critter. Answer all the questions on the next page and attach them to the picture or model of your critter.

GRADING

1. Your entry will be graded on scientific accuracy (40%) and creativity (40%). Remember that everything on Mars must obey the laws of nature and your creature must have good martian survival traits. Provide a scale to indicate the true size of your critter.

2. Clear writing and correct grammar count for the remaining 20% of your total score.



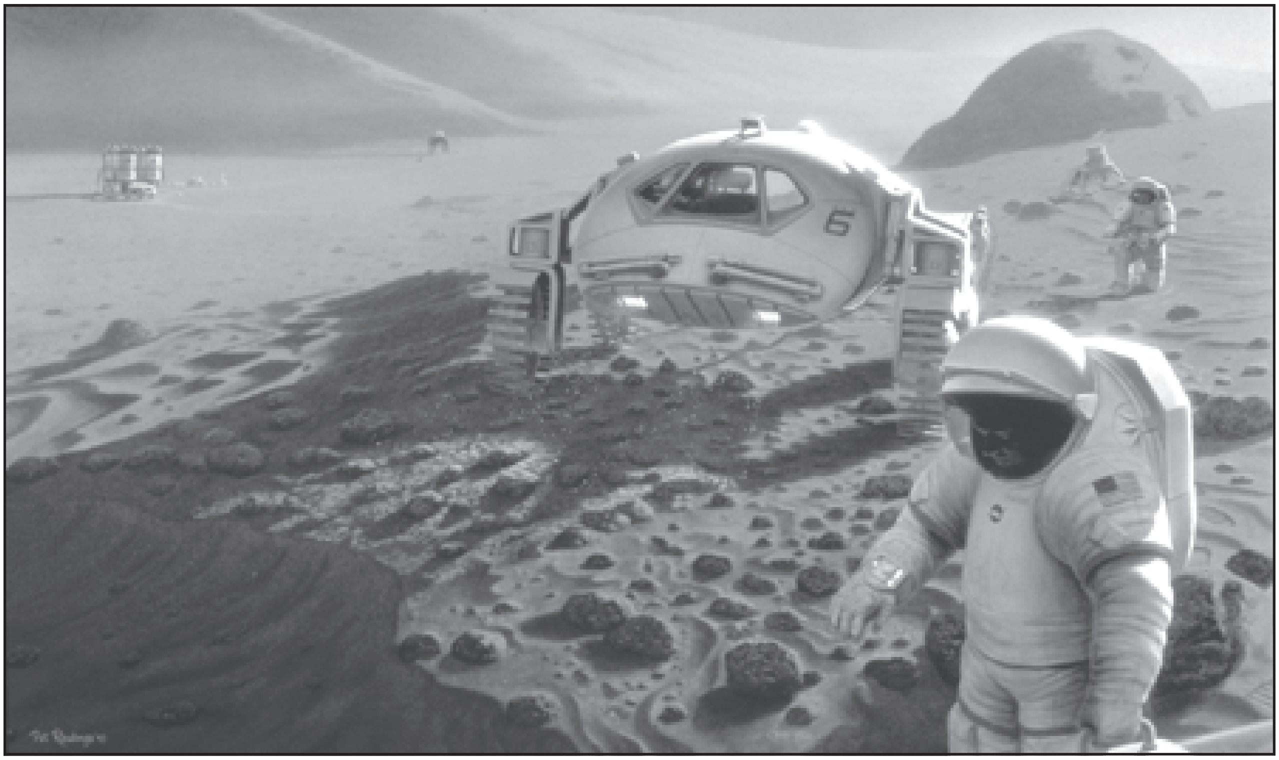
Description and Questions

Use another page if more space is needed.

1. The critter's name:
2. Describe the habitat and climate in which your critter lives:
3. How does it move? Include both the form and method of locomotion. (For example: The miniature Mars Gopher leaps on powerful hind legs).
4. What does it eat or use as nutrients? Is it herbivorous, carnivorous, omnivorous, or other? What is its main food and how does it acquire this food?
5. What other creatures does it prey on, if any? How does it defend itself against predators?
6. How does your creature cope with Mars' extreme cold, unfiltered solar radiation, and other environmental factors?
7. Is it solitary or does it live in large groups? Describe its social behaviors.
8. What else would you like others to know about your critter?

LESSON SIX

WHY DO WE EXPLORE?



About This Lesson

Students will work in small teams, each of which will be given a different reason why humans explore. Each team will become the expert on their one reason and will add a letter and summary sentence to an EXPLORE poster using their reason for exploration. With all the reasons on the poster, the word EXPLORE will be complete. Students will be using the skills of working in cooperative learning teams, reading, summarizing, paraphrasing, and creating a sentence that will best represent their reason for exploration. Students will also be illustrating and copying other teams' sentences so that each student will have a small copy of the large classroom poster for reference or extension purposes. The teacher will lead a discussion that relates the reasons humans explore to the planned and possible future missions to Mars.

Objectives

Students will:

- review the seven traditional reasons why people explore.
- write a summary of their reason why humans explore.
- illustrate their exploration summaries.
- relate the reasons for exploration to the missions to Mars.

Background

Students do not always realize that the steps in future exploration are built on a tradition of exploration that is as old as humans. This lesson is intended to introduce the concept of exploration through the seven traditional reasons that express why humans have always been explorers. Social scientists know that everyone, no matter how young or old, is constantly exploring the world and how it works. Space exploration, including the possible missions to Mars, has opened up a whole new world for us to explore. It is essential that students understand the traditional reasons why humans are reaching beyond the Earth to Mars and why continued exploration is important. Students will be able to make informed decisions regarding exploration and the future of humans in space only if they understand that our future as explorers holds its foundations in our past and in our very nature.

Resources

Berger, Melvin. *Discovering Mars The Amazing Story of the Red Planet.* New York, Scholastic Inc., 1992 pp. 52.
Vogt, Gregory L. *The Solar System Facts and Exploration.* New York, Twenty-First Century Books, 1995 pp. 95.
Wilford, John N. *Mars Beckons.* New York, Alfred A. Knopf, 1990 pp. 244.

Materials

- ☐ one large piece of butcher paper or art paper
- ☐ one set of large cut letters E-X-P-L-O-R-E
- ☐ tall sentence strips or sturdy pieces of paper cut to fit the poster (one per team)
- ☐ E-X-P-L-O-R-E paragraphs, one per group (pgs. 53-54)
- ☐ *The Exploration of Mars* background information sheet, overhead or handout optional (pg. 51)
- ☐ tape
- ☐ pencils
- ☐ markers
- ☐ Student Sheet, *Why Do We Explore?* (pg. 52)

Procedure

Advance Preparation

1. Read background and additional resource materials as necessary.
2. Make the poster by placing letters vertically on large butcher paper, spelling E-X-P-L-O-R-E. Laminate it if possible for reuse.
3. Duplicate the handouts.
4. Prepare for seven teams.
5. Put the students into teams.

Classroom Procedure

1. Explain to the students that all humans are explorers including each of them.
2. Give each team a set of materials and the handout for their team.
3. Read the introduction on the top of the student sheet to the students.
4. Have the students read about the traditional reason for exploration given to their team.
5. Have the students write a sentence that best explains or summarizes their team's reason for exploring. The team's sentence must begin with the letter assigned to the team.
6. Ask each team to draw an illustration for their sentence.
7. Have each team copy their sentence and illustration on a sentence strip.
8. Instruct each member of the team to copy the team's sentence and illustration on the paper provided.
9. The members of the team will place their sentence strip on the large poster and explain their sentence and illustration to the rest of the class.
10. Each student will copy the other teams' sentences onto their own paper so that they each will have a mini poster when the exercise is completed. The mini posters can be used for closure, extensions, writing prompts, review sheets for testing, and/or making other connections to Mars exploration.
11. Lead a discussion that connects the historical reasons for exploration with the desire to explore Mars using space craft, landers, robotic craft, and humans.

THE EXPLORATION OF MARS

Spacecraft	Country	Launch	Purpose	Result
Mars 1	USSR	1962	Fly-by	No data sent
Mariner 3	USA	1964	Fly-by	Lost during launch
Mariner 4	USA	1964	Fly-by	Sent 21 photos
Zond 2	USSR	1964	Fly-by	Sent no data
Mariner 6	USA	1969	Fly-by	Sent 75 photos
Mariner 7	USA	1969	Fly-by	Sent 126 photos
Mariner 8	USA	1971	Orbiter	Lost during launch
Mars 2	USSR	1971	Orbiter/lander	Sent no useful data
Mars 3	USSR	1971	Orbiter/lander	Sent minimal data
Mariner 9	USA	1971	Orbiter	Sent 7,329 photos
Mars 4	USSR	1973	Orbiter	Lost in space
Mars 5	USSR	1973	Orbiter	Sent some data
Mars 6	USSR	1973	Orbiter/lander	Sent minimal data
Mars 7	USSR	1973	Orbiter/lander	Sent minimal data
Viking 1 & 2	USA	1975	Orbiter/lander	Sent 50,000 photos, sample analyses, searched for life
Phobos 1	USSR	1988	Orbiter/lander	Lost in space
Phobos 2	USSR	1988	Orbiter/lander	Lost near Phobos, sent some data
Mars Observer	USA	1992	Orbiter	Lost near Mars
Mars '96	Russia	1996	Orbiter/lander	Lost during launch
Pathfinder	USA	1996	Lander	Surface photos rock analyses
Mars Global Surveyor	USA	1996	Orbiter	Continuing Data Set photos, altitudes, mineralogy
Nozomi	Japan	1998	Orbiter	Due at Mars Dec. 2003

continued on other side

THE EXPLORATION OF MARS

CONTINUED

Spacecraft	Country	Launch	Purpose	Result
Mars Climate Orbiter	USA	1998	Orbiter	Lost near Mars
Mars Polar Lander	USA	1998	Lander	Crashed on Mars
Mars Odyssey	USA	2001	Orbiter	In orbit around Mars
Mars Express	Europe	2003	Orbiter/lander	To be determined
Mars Exploration Rover	USA	2003	2 Landers	To be determined
Mars Recon. Orbiter	USA	2005	Orbiter	To be determined

Missions beyond 2001 have not been fully defined. NASA is planning to send an orbiter or lander at each opportunity. In addition to geologic, atmospheric, and radiation studies, the missions will seek evidence of past or present water and ice. Eventually humans will follow. The first people to walk on Mars are probably in school today.

WHY DO WE EXPLORE?

Whether we know it or not, we are natural-born explorers. There are many reasons why we explore. From birth we learn about life and how it works by exploring. No one can be satisfied for very long without exploring. Whether you are talking to someone next to you or looking around the room, you are exploring!

Directions:

1. You and your partners are helping to finish the EXPLORE poster on the wall.
2. Each team has a paragraph indicating one of the different reasons why humans explore.
3. At the beginning of the paragraph there is a letter designated for your team. You will use this letter to start a sentence that summarizes your team's reason for exploring.
4. Think of a sentence that describes the ideas from your paragraph. It has to begin with the letter listed on the top of your paragraph! Write the sentence on the sentence strip.
5. Now make an illustration to go with your sentence and put it on the sentence strip. Be colorful.
6. Each student should make a copy of your team's sentence and illustration on the paper provided.
7. Place your team's sentence and illustration on the poster and share them with the class.
8. Copy each team's sentence and illustration as they add them to the poster.

Your team has the letter "E" for the poster
People are curious about everything. We learn something new every day. If you get bored, you automatically look for something to do. That is the way we are. We like to learn new things. We also like to understand things and how they work. From the time you were born, you have been finding out how things work by exploring them. Curiosity makes us Explorers.

Your team has the letter "X" for the poster
Exploration looks ahead, not behind. We don't want to be stuck in the past. We want to move ahead. Exploration gives us the sense that anything is possible. Exploration leads to knowledge and understanding, and that means you make the world a better place. People have always tried to leave the world a better place for future generations. Exploration is one way we can do that. It is a gift that people of the past give people of the future. (You may use X or some other letter to start your sentence.)

Your team has the letter "P" for the poster
Leaders in space are leaders in the world. The countries that join together to go Mars and beyond will find new ways of working together and sharing their successes. Working together on major projects in space will help make nations on Earth more peaceful. Anytime you have to work with someone, you learn about them and yourself. Working together with common goals helps people understand each other. It is very hard to go to war with people you understand. Working together also makes us more creative.

Your team has the letter "L" for the poster
New places can be helpful to us because they have raw materials and natural resources. If we are going to explore new worlds, it can help our economy. Space exploration creates jobs and technology that make our world better. New worlds and new planets might have raw materials that are almost used up on Earth. We could also look for new, cleaner energy sources in space that might help protect our environment. Looking at Earth from space will give us a new view of our world and how to protect it.

Your team has the letter "O" for the poster
Exploration helps us understand our place in the universe. Where does the Earth, the third planet from the Sun, fit into things? Are people alone in the universe? Could there be life out there? If there are other life forms, what can we learn from them? What will they learn from us? Finding life in the universe could be the greatest discovery of all time.

Your team has the letter "R" for the poster
Exploration opens up new lands. Our country was once called the "New World" because the people of Europe found it when they thought only an ocean existed here. Europeans moved to the "New World," called it America, and we became our own country. We know no new lands exist on Earth to be discovered, so we look to other planets in our solar system. We might find a place to establish small colonies. Another home for humans might be made on a few bodies in our solar system, though it would take many years and a huge effort.

Your team has the letter "E" for the poster
We love adventure and when we explore new places, it is the best kind of adventure. Landing on another planet in a video game isn't nearly as exciting as landing there in person. Americans love adventure. From the time of the first colonies in America, we have spread across this great land and have loved the fun of finding new things. We have landed on our own Moon and sent spacecraft to the far reaches of the solar system. When humans explore, we make the universe our classroom for learning.

GLOSSARY

Adaptation: adjustments in an organism or its parts to help it live in its environment.

Analyze: to thoroughly test or investigate a sample to find specific information.

Atmosphere: mixture of gases that surround a planet.

Channel: a river-like depression that is longer than it is wide; a place or bed where fluid(water) flows or flowed.

Characteristics: the features that identify something.

Chryse Planitia: (cry´ s͞ee plän ĭ´ tiə) plain of gold.

Composition: the general makeup or characteristics of material such as rock or soil.

Crater: a hole or depression; most are roughly circular or oval in outline; on Earth most natural craters visible at this point in geologic time are of volcanic origin; on Mars and the Moon most craters are of impact origin.

Criteria: traits used to judge.

Ejecta: material thrown out from and deposited around an impact crater.

Environment: the many conditions surrounding an organism.

Eroded: physically changed rocky material; on Earth and Mars this especially includes weathering and transport of material by water and wind; on Mars there is also more evidence of erosion by repeated meteorite impacts.

Eruption: the outflow of hot lava and other materials like ash from a volcano or crack in rock.

Geology: the science of Earth and Earth history as well as solid bodies in the solar system.

Gravity: a physical force that explains the attraction of one mass to another.

Habitat: the natural place where an organism lives, including the surrounding environment.

Impact: the forceful striking of one body, such as a meteorite, against another body such as a moon or planet.

Interpretation: to consider scientific evidence or information and come to a logical explanation of something.

Layers: a bed of rock, often horizontal or slightly sloping.

Mare: dark area on the Moon covered by basalt lava flows.

Metabolic: having to do with chemical change taking place in living cells.

Meteorite: a metallic or stony body that has fallen from outer space and landed on a planetary body.

Orbit: the path of an object in space moving about another under gravitational attraction.

Organic: living or previously living material containing carbon.

Organism: a living complex being.

Properties: special identifying traits or features of something.

Radiation: energy given off by the Sun. Exposure to radiation is harmful to living organisms at some levels.

Replication: the process of reproduction.

Robotic: a spacecraft or other machine that operates remotely without direct human contact.

Sequence: a list of things or events in a special meaningful order.

Simulant: material that represents or is very much like something else.

Slope: a slanting surface.

Source: beginning or start of something, location where something comes from.

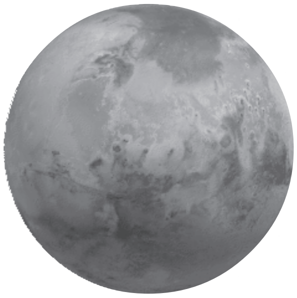
Stratigraphy: layers of rock, often as viewed sideways like a stack of pancakes.

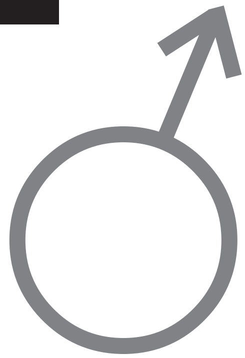
Sun Angle: the direction the Sun is shining on the planet surface measured from the horizon.

Texture: general physical appearance of minerals in a rock.

Trajectory: the curving path of a spacecraft.

MARS FACT SHEET





Fourth planet from the Sun

Distance from the Sun:
Minimum: 206,000,000 kilometers
Average: 228,000,000 kilometers
(1.52 times as far as Earth)
Maximum: 249,000,000 kilometers

Eccentricity of Orbit: 0.093 vs. 0.017 for Earth (0.00 is a perfectly circular orbit)

Distance from Earth: Minimum: 56,000,000 kilometers
Maximum: 399,000,000 kilometers

Year: 1.88 Earth years = 669.3 Mars days (sols) = 686.7 Earth days

Day: 24.6 Earth hours

Tilt of Rotation Axis: 25.2° vs. 23.5° for Earth

Size: Diameter: 6794 kilometers vs. 12,756 kilometers for Earth
Surface Gravity: 0.38 (or ~1/3) Earth's gravity
Mass: 6.4 x 1026 grams vs. 59.8 x 1026 grams for Earth
Density: 3.9 grams/cc vs. 5.5 grams/cc for Earth

Surface Temperature: Cold
Global extremes: -125°C (-190°F) to 25°C (75°F)
Average at Viking 1 site: high -10°C (15°F); low -90°C (-135°F)

Atmosphere: Thin, unbreathable
Surface pressure: ~6 millibars, or about 1 /200th of Earth's
Contains 95% carbon dioxide, 3% nitrogen, 1.5% argon, ~0.03% water (varies with season), no oxygen. (Earth has 78% nitrogen, 21% oxygen, 1% argon, 0.03% carbon dioxide.)
Dusty, which makes the sky pinkish. Planet-wide dust storms black out the sky.

Surface: Color: Rust red
Ancient landscapes dominated by impact craters
Largest volcano in the solar system (Olympus Mons)
Largest canyon in the solar system (Valles Marineris)
Ancient river channels
Some rocks are basalt (dark lava rocks); most others unknown
Dust is reddish, rusty, like soil formed from volcanic rock

Moons: Phobos ("Fear"), 21 kilometers diameter
Deimos ("Panic"), 12 kilometers diameter

From LPI/NASA EW-1997-02-127-HQ

SCIENCE PROCESS SKILLS

	Observing	Classifying	Communicating	Measuring	Inferring	Predicting	Experimental Design	Gathering and Organizing Data	Controlling Variables	Developing a Hypothesis	Extending Senses	Researching	Team Work	Mathematics	Interdisciplinary	Introductory Activity	Advanced Activity
Lesson One *Activity One* Dancing with Planets			X		X	X					X	X	X	X	X	X	
Activity Two Plotting Paths of Spacecraft			X	X	X	X		X		X		X	X	X	X		X
Lesson Two Tricky Terrains	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X
Lesson Three Lava Layering	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lesson Four Mapping Mars	X	X	X	X	X	X		X		X		X	X	X	X	X	X
Lesson Five *Activity One* Imaginary Martians			X		X	X					X	X	X		X	X	
Activity Two Looking for Life	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Activity Three Mars Critters			X	X	X					X	X	X	X	X	X	X	X
Lesson Six Why Do We Explore?			X			X						X	X		X	X	

SCIENCE AND MATH STANDARDS

	Science as Inquiry	Structure and Energy of the Earth System	Origin and History of the Earth	Earth in the Solar System	Geochemical Cycles	Physical Science	Populations and Ecosystems	Understanding about Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science	Problem Solving	Measurement	Computation and Estimation	Communication	Geometry and Advanced Mathematics	Statistics and Probability	Number and Number Relationships	Patterns and Functions
Lesson One *Activity One* Dancing with Planets	X	X		X		X			X		X			X			X	X
Activity Two Plotting Paths of Spacecraft	X	X		X		X		X	X		X	X	X	X	X	X	X	X
Lesson Two Tricky Terrains	X	X	X	X	X	X		X				X	X	X		X		
Lesson Three Lava Layering	X	X	X	X	X	X		X	X	X	X	X	X	X	X			X
Lesson Four Mapping Mars	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Lesson Five *Activity One* Imaginary Martians	X			X			X	X	X	X				X				
Activity Two Looking for Life	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		
Activity Three Mars Critters	X	X			X	X	X	X	X	X	X	X	X	X	X		X	
Lesson Six Why Do We Explore?							X	X	X	X				X				

MARS RESOURCES

SCIENCE BOOKS

Mars (general)

J.N. Wilford (1990) *Mars Beckons*, Knopf, 244 pp.
H. Keiffer et al (1992) *Mars*, U. Arizona Press, 1498 pp.
W.Sheehan (1996) *The Planet Mars*, U. Arizona Press, 270 pp.
M.H. Carr (1996) *Water on Mars*, Oxford, 229 pp.
P. Moore (1998) *On Mars*, Seven Dials, 222 pp.
R Godwin (2000) *Mars, the NASA Mission Reports*, Apogee, 432 pp.

Mars (life)

D. Goldsmith (1997) *The Hunt for Life on Mars*, Plume, 286 pp.
B.E DiGregorio (1997) *Mars, the Living Planet*, Frog, LTD, 365 pp.
P. Bozorny (1997) *The Exploration of Mars*, Aurum, 200 pp.
M.R. Taylor (1998) *Dark Life*, Schribner, 287 pp.
M.Walter (1999) *The Search for Life on Mars*, Perseus, 170 pp.

Science Fiction

H.G. Wells (1900) *War of the Worlds*
E.R. Burroughs (1912-1940) *John Carter Series*
R. Bradbury (1951) *Martian Chronicles*
A.C. Clarke (1965) *The Sands of Mars*
F. Pohl (1976, 1990) *Man Plus*; *Mars Plus*
Ben Bova (1992, 1999) *Mars*; *Return to Mars*
Greg Bear (1993) *Moving Mars*
K.S. Robinson (1994, 1995, 1996, 1999) *Red Mars*; *Green Mars*; *Blue Mars*; *The Martians*

NASA EDUCATIONAL MATERIALS

See *Destination Mars* video information on page 2.
Mars Activities, K-12, http://mars.jpl.nasa.gov/classroom/
Exploring Mars curriculum, http://mars.jpl.nasa.gov/education/modules/
Exploring Mars education brief, EB-1999-02-128-HQ
Mars lithograph, LG-2000-10-481-HQ
Earth and Mars poster, EW-2001-02-009-JPL
NASA Mars slides at lpi.usra.edu or finley-holiday.com