SOIL HABITABILITY
Student Lab Procedures

Mars Education Program

Arizona State University

The University of Arizona
Lunar and Planetary Laboratory

version 3.1

SOIL HABITABILITY

Student Lab Procedures

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INTRODUCTION

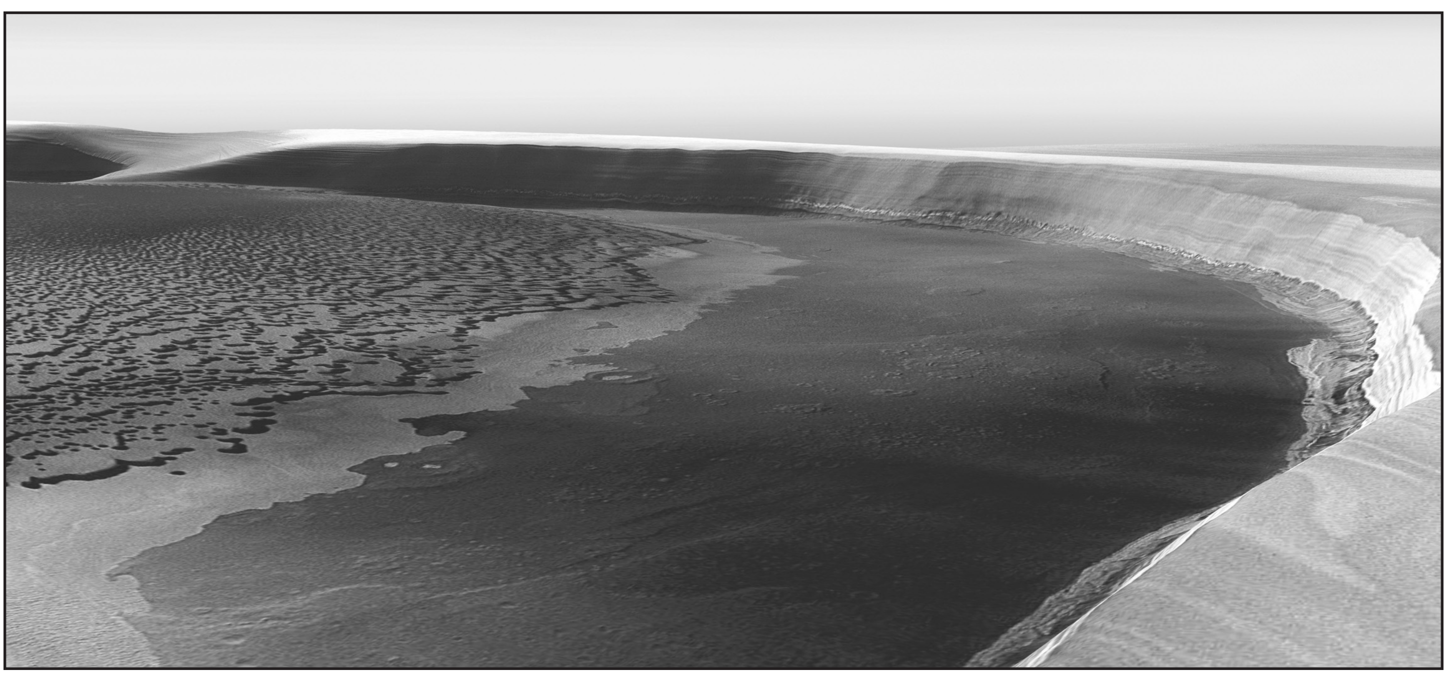
Soil habitability

Recent discoveries have shown that life on Earth can exist in the most extreme conditions. Indeed, bacterial ***spores*** can lie dormant in bitterly cold, dry, and airless conditions for tens of thousands of years or more and become activated once conditions are favorable. Such ***dormant microbe*** colonies may exist in the Martian arctic. A periodic wobbling of Mars' axis could allow liquid water to exist in the arctic for brief periods of time, occurring about every 100,000 years, perhaps making a ***habitable*** soil environment.

Even with the proper ingredients to sustain life, however, lander missions since the 1970s have found the Martian soil is exposed to hazards such as harmful ***solar ultraviolet radiation***, which could prevent biological growth. In looking for organic bio-signatures and potential habitability, the Phoenix Mars Lander will dig deep enough to analyze soil that is protected from this solar ultraviolet radiation.

The Phoenix Mars Lander experiments will assess the habitability of the Martian polar environment by measuring the soil's ***pH*** and its content of life-essential ingredients, including carbon, nitrogen, phosphorus, hydrogen, and salts.

Testing the soil to determine if it can sustain life is an important experiment. While you won't be testing your soil sample for the same essential ingredients that the Phoenix Mars Lander will, you can test your sample to see if life can grow in it. This experiment will simulate conditions that may be found at specific latitudes on Mars. Using fast-growing seeds that you will place in your sample, you will gather data about the "habitability" of the soil you collected. Will the conditions be favorable for the seeds to thrive and grow? This will be the question you are trying to answer.



Chasma Boreale, a huge canyon located in the northern polar cap (PHOTO CREDIT: NASA/JPL/ASU)

INTRODUCTION

Over the past three decades, spacecraft have shown us that Mars is rocky, cold, and sterile beneath its hazy, pink sky. We've also discovered that today's Martian wasteland hints at a onetime active world where volcanoes raged, meteorites plowed deep craters, and flash floods rushed over the land. And Mars continues to throw out new enticements with each landing or orbital pass made by our spacecraft.
After years of studying the Red Planet, NASA has developed a Mars exploration strategy: Follow the Water! Its goal is to discover the possibilities for Martian life — whether past, present, or even our own in the future.

Following the water begins with understanding the current environment on Mars. We want to explore features such as dry riverbeds, ice in the polar caps and rock types that form only when water is present. We want to look for hot springs, hydrothermal vents, or subsurface water reserves. We want to understand if ancient Mars once held a vast ocean in the northern hemisphere, as some scientists believe, and how Mars may have shifted from a wetter climate to the dry and dusty one it has now. Searching for these answers means delving into the planet's geologic and climatic history to find out how, when, and why Mars became the forbidding, yet promising, planet we observe today.

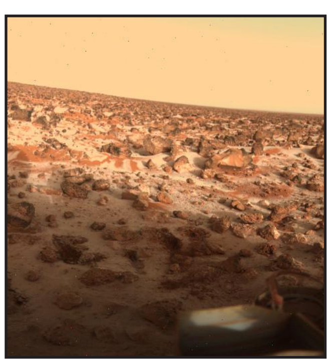
KWL Pre-Activity:

Understanding why life can exist on a planet such as Earth is an important step to help us understand under what conditions can life survive. Habitability is the term scientists use to determine how easy it is for an organism to survive given a particular environment. The habitiability of a planet is dependent upon many factors: planet location in reference to the sun, atmospheric conditions, climate conditions, and temperature, just to name a few. Temperature is one of the most basic conditions that we as humans adjust on Earth.

1. Understanding what you already know will guide you as you progress through the assessment of the factors necessary for life to survive on a planet. Write what you know about habitability in the section "What I know."

2. Once you have completed the section on what you know, set some goals by writing what you wish to know about habitability by the end of the module. This might include the conditions on other planets that make habitability difficult. Or it could include information leading you to investigate data collected by the Viking, Mars Pathfinder, and the Mars Exploration Rovers. Put your goals in the section "What I want to know."

3. Finally, you will complete the **KWL** chart by describing what you have learned. This will guide you in preparing your report at the end of this module. Do not fill out the "What I learned" section until you have completed the module.



Carbon dioxide frost covers the ground in this Viking lander photo.

PHOTO CREDIT: NASA/JPL

4. For further investigation, make note of anything more you want to investigate by writing this in the last column called "What I want to explore further."

5. After doing the module and learning the material, go back to the K column and see if any of your prior knowledge was inaccurate. Check any entries that are inaccurate according to the text. Correct any inaccurate statements by rewriting them.

6. Then go to the W column and look for the questions that the text did not answer. Be prepared to bring these unanswered questions up in class, or tell how you will find answers to them and where you will look to get the answers.

Now, let's begin our habitability study with an activity to help us understand what habitability really is, and why it is important to study.

As you look at the following questions, fill in the appropriate spaces on the **KWL** chart.

What do you see in the pictures below?

Image courtesy of NASA and Carnegie-Mellon University

Photo Credit: NASA/JPL/CORNELL/USGS

- *How are these pictures similar? How do they differ?*
- *Looking at both pictures, which environment would be suitible for organisms to survive?*
- *Do you think all environments are alike?*
- *Share with the class what you know about environments from your own personal experiences and what you think organisms need to survive in any environment.*

HANDS ON:
Pour the contents of the soil container from your teacher onto a sheet of white paper. As you examine the soil, ask yourself the following questions:

(1) Have you ever looked closely at a handful of soil?

(2) What did you notice?

(3) Is the soil at the beach the same as the soil in your back yard or on the playground?

(4) How are they different?

(5) How do you think the soil gets there?

KWL

what I Know, what I Want to know, and what I Learned

KWL chart about Habitability
(Fill in the first 2 columns before you begin your research. Complete the last 2 columns after you have completed your research)

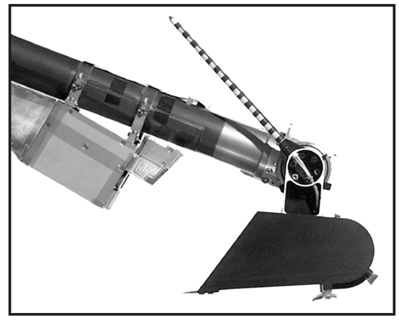
What I **K**now	What I **W**ant to Know	What I **L**earned	What I want to explore further
1.	***1.***	***1.***	***1.***
2.	***2.***	***2.***	***2.***
3.	***3.***	***3.***	***3.***
4.	***4.***	***4.***	***4.***
5.	***5.***	***5.***	***5.***
6.	***6.***	***6.***	***6.***
7.	***7.***	***7.***	***7.***
8.	***8.***	***8.***	***8.***
9.	***9.***	***9.***	***9.***
10.	***10.***	***10.***	***10.***
11.	***11.***	***11.***	***11.***

Additional questions to consider:

- What type of life needs dirt to survive?
- What's in the dirt that life needs to survive?
- How do we find out what's in the dirt?
- Why is it important to understand the properties of dirt?
- Who is interested in dirt properties besides scientists?
- How do scientists help these other folks that are interested in dirt?

FIELD WORK

Both Viking landers, the Pathfinder, and the Mars Exploration Rovers collected samples or measured soil using different instruments. Each Viking lander used a robotic arm to scoop up soil and place it into test chambers aboard the lander. The Pathfinder used an instrument called APXS (Alpha Proton X-ray Spectrometer) to measure elements in the soil and rocks near its landing site. The Mars Exploration Rovers carry a robotic arm similar to yours, with a shoulder, elbow, wrist, etc. The arm allows the rover to use specialized instruments to drill into rocks, take close-up soil pictures, and make measurements of the soil chemistry.



Close up of the scoop and other instruments at the end of the Robotic Arm (RA). (Photo courtesy of NASA, UA Phoenix website)

Each of the landers used different tools to collect data on rocks and soils. Likewise, the Phoenix Mars Lander will use a specialized tool to dig below the surface.

During this activity, you will simulate how the Phoenix lander collects soil samples.

Materials:

- 1 ziplock baggie
- sumulated robotic arm scoop (laundry scoop or other similar sized tool)

Sample Collection Procedures

The Phoenix lander has a robotic arm designed to trench the ground at the landing site, scoop up soil and water ice samples, and deliver them to onboard instruments for chemical analysis.

The robotic arm has four motions: (1) up, (2) down, (3) side to side and (4) rotation.

To simulate what Phoenix does on Mars, you'll collect your sample in a similar way.

1. Take a powdered laundry detergent scoop (or similar sized instrument) to the sampling site you have observed. Also bring a ziplock sandwich bag, marking it with the name of your team or a team member's initials and class period.

2. Scrape the ground five times with the scoop and put the contents from each scrape into the bag.

   (Do you find that five scrapes collect only a small sample? Well, it's too bad, but you can't make any more scrapes. This is the kind of real-life limit planetary scientists often face.)

3. Seal both so you don't lose any soil or moisture. With a marker, clearly label one bag with number 1 and the other with number 2.

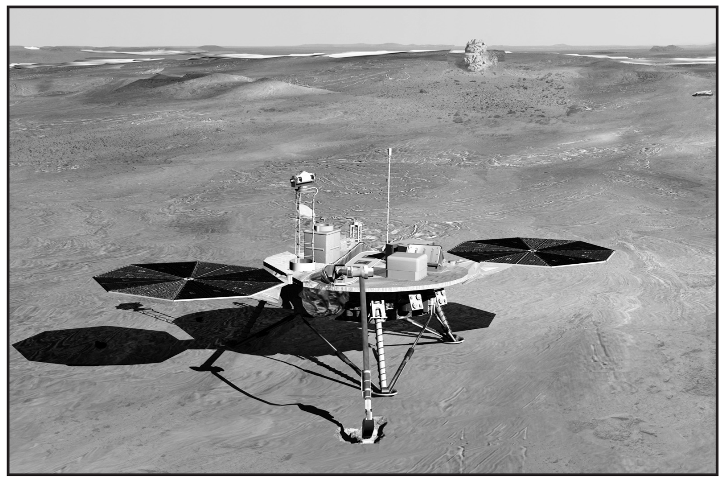
4. Before moving on to the lab work, wash your hands.

"Laundry Scoop"
simulated robotic arm scoop

LAB WORK

Both Viking landers housed specialized instruments to measure the chemistry of the soil, and to test for biological activity in it. While the experiments discovered chemical activity in the Martian soil, they provided no clear evidence for the presence of living microorganisms in the soil near the landing sites. In the decades since Viking, scientists have concluded that a combination of strong solar ultraviolet radiation, the soil's extreme dryness, and the oxidizing nature of the soil's chemistry make the Martian soil hostile to living organisms, especially microbes.

While the Phoenix lander will not be measuring biological activity in the soil, it will be measuring the soil's chemical composition. This will help us determine if the Martian soil can support life. One of the instruments is called the Microscopy, Electrochemistry, and Conductivity Analyzer (MECA). MECA characterizes the soil of Mars much like a gardener tests the soil in the backyard. By dissolving small amounts of soil in water, MECA determines the soil's pH and its abundance of minerals, as well as dissolved oxygen and carbon dioxide. Looking through its microscope, MECA examines soil grains to help determine their origin and mineralogy. Needles stuck into the soil determine its water and ice content, and the ability of both heat and water vapor to penetrate the soil.



Artist rendition of the Phoenix Mars Lander. Photo credit NASA/JPL

While you won't be measuring your soil sample's chemistry, you will be assessing its ability to support life by experimenting with fast-growing seeds.

Soil Sample Testing

Materials:

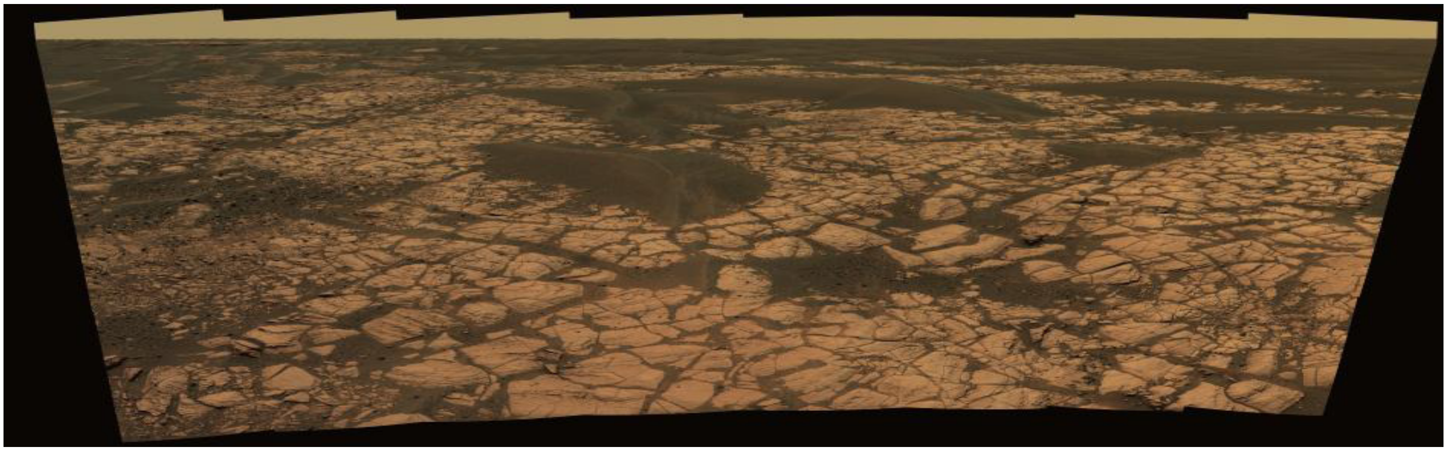
- 4 ziplock baggies
- Seeds (supplied by your teacher)
- Water to moisten the soil
- Pen, marker, or masking tape to label the baggies
- Themometer

LAB WORK

Procedure:

Using the soil sample you collected from the field:

1. Label the 4 baggies (including name, period, date, etc.):
    a. Bag 1: Control
    b. Bag 2: Room temp (simulates equatorial location conditions on Mars)
    c. Bag 3: Refrigerator (simulates mid-latitude location conditions on Mars)
    d. Bag 4: Freezer (simulates Phoenix lander conditions near the north pole of Mars)
2. Divide your soil sample into 4 approximately equal parts, putting one in each baggie—remember, try not to touch the samples.
3. Place 4 seeds into each baggie.
4. Moisten the soil in each baggie except the control (don't add water to the control bag). Don't put in a lot of water…you don't want mud.
5. Seal the bags tightly, and place them in the simulation locations (refrigerator, freezer, etc.). The control stays at room temperature, placed on a sunny window sill.
6. Using the Soil Habitability Tracking Chart, make some initial observations about what the soil looks like. At first, all the samples will probably look the same, but noting this will help you when you make future observations.
7. At first you may want to make observations every 1-2 days. After that, make your observations once a week. You can do this for as long as time allows for your class.
8. Finish filling out the Soil Habitability Chart.



Opportunity's 'Olympia' Panorama   PHOTO CREDIT: NASA/JPL-Caltech/Cornell

SOIL HABITABILITY CHART

Using the chart below, briefly describe any growth in the soil that may have occurred since the last observation. Be as detailed as possible. Be sure to measure the temperature (in Celsius) of the environment you have placed the seeds in. Temperature is a key factor for the life processes of organisms.

Date	Control	Refrigerator	Freezer	Room Temp
	Temp _____°C	**Temp _____°C**	**Temp _____°C**	**Temp _____°C**
	Temp _____°C	**Temp _____°C**	**Temp _____°C**	**Temp _____°C**
	Temp _____°C	**Temp _____°C**	**Temp _____°C**	**Temp _____°C**
	Temp _____°C	**Temp _____°C**	**Temp _____°C**	**Temp _____°C**

Conclusions

Habitability: Does your sample have the right ingredients that allow life to survive?
(Do the seeds grow)? ____

____

____

Do the other samples in the simulated environments (refrigerator, freezer) allow life to survive? ______

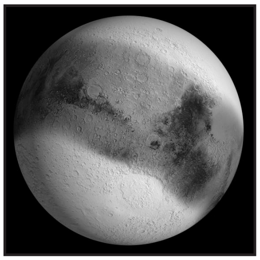
____

____

____

LAB WORK

Soil Habitability Extension:



Climate models suggest that snow could have periodically fallen on Mars at lower latitudes (Image: NASA/JPL/Brown University)

The axis of Mars slowly wobbles over 100,000-year cycles. As the axis tilts closer to the Martian orbit, the poles grow warm and the mid-latitudes get colder. When the planet's axis tips more upright again, the situation reverses and the poles grow colder while the mid-latitudes become warmer. During these cycles, water can migrate between the polar regions and the mid-latitudes. In addition to its axis wobbling, Mars has an orbit much more eccentric than the Earth's, and its perihelion cycle (which has a period of 51,000 years) does apparently have a significant effect on climate and prevailing wind direction there.

Because Mars' climate can vary over time, areas that may be too cold for life in one period may become warm in another. Thus, ice could melt and provide liquid water for a habitable environment.

In this extension activity, you will place the fridge and freezer soil samples at room temperature. Over a period of several days, record what happens to them.

Hypothesize (take an educated guess) what you think will happen to the samples and the seeds:

Using the chart below, describe what you see happening

Date	Refrigerator	Freezer

Conclusions

Do the seeds begin to grow once they are warmed sufficiently? Explain what you think is happening:

Keywords

Celsius degree:
The metric unit for temperature measurement; equals 1.8 Fahrenheit degrees.

Dormant:
A period of inactivity or biological rest; in living organisms, little or no growth occurs during this time and some biological functions be suspended

Habitable:
An environment is habitable when it can develop and sustain life.

Microbe:
A microscopic organism.

pH:
A measure of acidity, ranging from 1 (acid) to 14 (base).

Spores:
An inactive form of bacteria or other microorganisms containing material that can reproduce active bacteria. Bacterial spores are usually much more difficult to kill than active bacteria.

Solar ultraviolet radiation:
A portion of the electromagnetic spectrum with wavelengths shorted than visible light. The Sun produces ultraviolet (UV) radiation, which is commonly split into three bands (A, B, C) of decreasing wavelength. Shorter wavelength UV radiation (UVC) has a greater potential to cause biological damage. All three types reach the Martian surface almost unhindered.

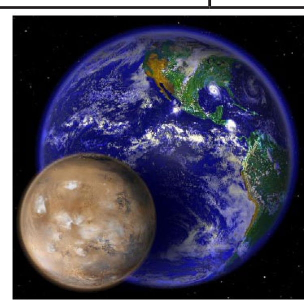
Additional Information

Factors Influencing Habitability

Many factors need to be considered when investigating the habitability of a planet. Our planet has just the right combination of factors that allow life to thrive. Mars on the other hand is a very hostile planet for life trying to survive on the surface. What about below the surface? That is what scientists and the Phoenix lander are trying to investigate. The chart below can help in understanding more about specific factors, and how they can influence the habitability of a planet.

Table adapted from the Lunar and Planetary Institue's "Making a Habitable World" activity.

Factors that influence a planets habitability	Decrease the factor	Ideal conditions	Increase the factor	Earth vs. Mars
Temperature: affects how molecules behave, such as whether water is found as a solid, liquid or gas.	Chemicals react more slowly together, this also interferes with reactions necessary for life. Low temperatures cause water to become unavailable.	Life as we know it on our planet seems to be limited to a range of -15°C to 115 °C. In this range, liquid water can still exist under certain conditions.	At about 125°C , protein and carbohydrate molecules and genetic material (DNA and RNA), start to break apart. Also, high temperatures quickly evaporate available water.	Earth: Only Earth's surface is in this temperature range. Mars: Temperatures range from -140°C to 20°C.
Water: Dissolves and transports chemicals within cells.	Chemicals a cell needs for energy and growth are not dissolved or transported to the cell.	Water is regularly available. Life can go dormant between wet periods, but, eventually, water needs to be available	Too much water is not a problem, as long as it is not so toxic that it interferes with the chemical balance	Earth: Only Earth's surface has water. Mars: Once had surface water, and still has water ice in its polar caps
Atmosphere: Traps heat, shields the surface from harmful radiation, and provides chemicals needed for life, such as nitrogen and carbon dioxide.	Small planets and moons have insufficient gravity to hold an atmosphere. The gas molecules escape to space, leaving the planet or moon without an insulating blanket or a protective shield.	If a planet is the right size to hold a sufficient-sized atmosphere, then It can keep the surface warm & protects it from radiation & small- to medium-sized meteorites.	If an atmosphere is too thick, heat rapidly builds up, and causes a planet to become too hot for life. Venus's atmosphere is 100 times thicker than Earth's. It is made almost entirely of greenhouse gasses, making the surface too hot for life. The four giant planets are completely made of gas.	Earth: The atmosphere is about 100 miles thick, shielding the surface from harmful radiation, and maintaining the proper temperature balance for water and life. Mars: The atmosphere is about 1/1000th the thickness of Earth's atmosphere, and composed of mainly carbon dioxide. Because of the thinness of the atmosphere, if there was any water on the surface, it would quickly boil off into the atmosphere.

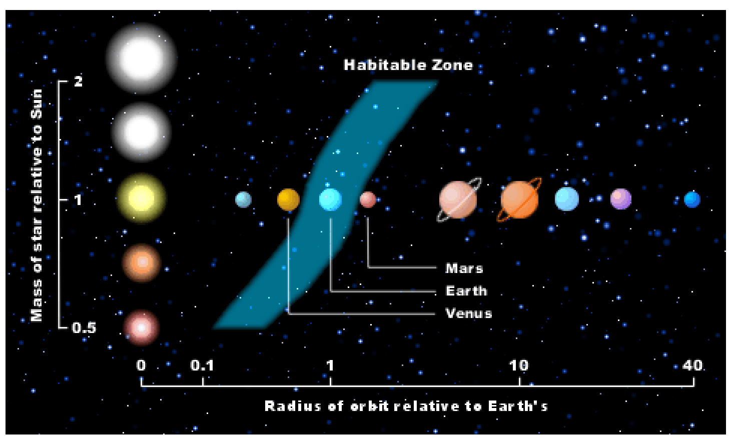


Earth/Mars Comparison picture
NASA/JPL

Additional Information

Factors Influencing Habitability cont.

Energy: Organisms use light or chemical energy to run their life processes.	When there is too little sunlight or too few of the chemicals that provide energy to cells, such as iron or sulfur, organisms die.	With a steady input of either light or chemical energy, cells can run the chemical reactions necessary for life.	Light energy is a problem if it makes a planet too hot or if there are too many harmful rays, such as ultraviolet. Too many energy-rich chemicals is not a problem	Earth: Just the right distance from the Sun for organisms and chemical processes. Mars: The surface of the planet receives only 44% of the sunlight Earth does because of its distance from the Sun. This factor, combined with a thin atmosphere, causes surface conditions to be extremely hostile for any organisms.
Nutrients: Used to build and maintain an organism's body.	Without chemicals to make proteins & carbohydrates, organisms cannot grow. Planets without systems to deliver nutrients to its organisms (e.g., a water cycle or volcanic activity) cannot support life. Also, when nutrients are spread so thin that they are hard to obtain, such as on a gas planet, life cannot exist.	All solid planets & moons have the same general chemical makeup, so nutrients are present. Those with a water cycle or volcanic activity can transport and replenish the chemicals required by living organisms.	Too many nutrients are not a problem. However, too active a circulation system, such as the constant volcanism on Jupiter's moon, Io, or the churning atmospheres of the gas planets, interferes with an organism's ability to get enough nutrients.	Earth: Earth has a water cycle, an atmosphere, and volcanoes to circulate nutrients. Mars: Although Mars has the largest volcanoes in the solar system, scientists believe they have been extinct for millions of years. In addition, because Mars no longer has surface water, or volcanic activity, there is no active method for transporting nutrients to organisms.



Habitable zone according to the size of the star

Helpful Links

Mars isn't the only planet that scientists are studying to gain an understanding of soils and how that relates to the search for life. The following resources are provided to help with your understanding of not only Mars, but additional planetary studies that are going on today.

Mars Websites

- ***http://phoenix.lpl.arizona.edu/*** The Phoenix Mars Mission official website
- ***http://mars.jpl.nasa.gov/*** This site focuses on the exploration that is being conducted not only in orbit around Mars, but on the surface as well, analyzing the composition of the soils on the surface.

Soil resources

- ***http://soils.usda.gov/*** This is the main website of the USDA's (United States Department of Agriculture) Natural Resources Conservation Service (NRCS). This site holds a wealth of information from printed publications, to online tools used to view soil survey maps and reports.
- ***http://visibleearth.nasa.gov/*** This is a collection of images and animations of Earth. It has a searchable index that will allow you to find images and animations of specific topics, such as soils.
- ***http://www.jpl.nasa.gov/solar_system/*** This site, through NASA's Jet Propulsion Lab, highlights missions that focus on exploration of the solar system.
- ***http://www.fs.fed.us/*** The main website for the USDA Forest Service

Biology resources

Habitability is an important factor when studying soils. Scientists today are studying locations on Earth that are very similar to Mars(called planetary analogs) to understand how life can survive in extreme environments. The following resources describe some of these environments, and what scientists are doing to study extreme life.

- ***http://nai.arc.nasa.gov/*** NASA Astrobiology Institute's (NAI) website. How does life begin and evolve? Is there life elsewhere in the Universe? What is the future of life on Earth and beyond? NAI carries out collaborative research and education in astrobiology, the interdisciplinary science that seeks answers to these fundamental questions. It supports investigation of these issues on Earth and serves as a portal to space for the scientific community.
- ***http://science.nasa.gov/PhysicalScience.htm*** The Science@NASA Web sites' stories feature such topics as astronomy, astrophysics, Earth science, physical science, biology, and living in space. From microscopic to astronomical scale, NASA science covers them all.
- **http://astroventure.arc.nasa.gov/:** At this interactive site, students in grades 5-8 role-play NASA occupations as they search for and build a planet for human habitation.

Additional resources

- ***http://www.dlese.org/library/index.jsp*** DLESE is the Digital Library for Earth System Education, a geoscience community resource that supports teaching and learning about the Earth system. It is funded by the National Science Foundation and is being built by a community of educators, students, and scientists to support Earth system education at all levels and in both formal and informal settings.

(Each of the links above are active as of March 2007)