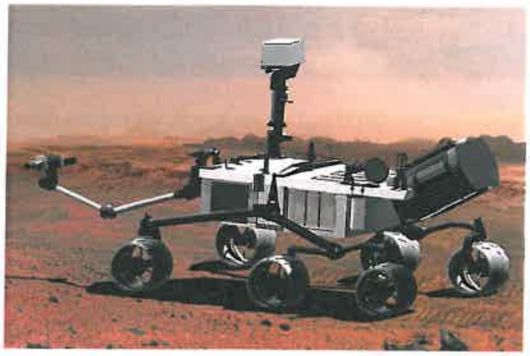
Earth-Mars Comparison Fact Sheet

	Earth	Mars
Average Distance from Sun	150 million kilometers (93 million miles)	229 million kilometers (142 million miles)
Average Speed in orbiting Sun	29.8 km per second (18.5 miles per second)	23.3 km per second (14,5 miles per second)
Diameter	12,755 kilometers (7,926 miles)	6791 kilometers (4,220 miles)
Tilt of Axis	23.5 degrees	25 degrees
Length of Year	365.25 days	687 days
Length of Day	23 hours 56 minutes	24 hours 37 minutes
Gravity	2.66 times greater than Mars	37.5% of Earth's (Less)
Average Temperature	14 degrees Celsius (57 degrees Fahrenheit)	-63 degrees Celsius (-81 degrees Fahrenheit)
Atmosphere	Nitrogen, oxygen, argon, others	Mostly Carbon dioxide, some water vapor
Number of Moons	1	2
Tallest Mountain	Mauna Kea, Hawaii: 10,203 meters (33,476 feet) high; height from ocean floor	Olympus Mons: 21,171 meters (69,459 feet) high

National Aeronautics and Space Administration

NASA facts

Mars Science Laboratory



NASA's Mars Science Laboratory mission is preparing to set down a large, mobile laboratory — the rover Curiosity — using precision landing technology that makes many of Mars' most intriguing regions viable destinations for the first time. During the 23 months after landing, Curiosity will analyze dozens of samples drilled from rocks or scooped from the ground as it explores with greater range than any previous Mars rover.

Curiosity will carry the most advanced payload of scientific gear ever used on Mars' surface, a payload more than 10 times as massive as those of earlier Mars rovers. Its assignment: Investigate whether conditions have been favorable for microbial life and for preserving clues in the rocks about possible past life.

Mission Overview

Plans for the Mars Science Laboratory call for launch from Cape Canaveral Air Force Station, Florida, between Nov. 25 and Dec.18, 2011, and arrival at Mars in August 2012.

The spacecraft has been designed to steer itself during descent through Mars' atmosphere with a series of S-curve maneuvers similar to those used by astronauts piloting NASA space shuttles. During the three minutes before touchdown, the spacecraft slows its descent with a parachute, then uses retro rockets mounted around the rim of an upper stage. In the final seconds, the upper stage acts as a sky crane, lowering the upright rover on a tether to the surface.

Curiosity is about twice as long (about 3 meters or 10 feet) and five times as heavy as NASA's twin Mars Exploration Rovers, Spirit and Opportunity, launched in 2003. It inherited many design elements from them, including six-wheel drive, a rocker-bogie suspension system and cameras mounted on a mast to help the mission's team on Earth select exploration targets and driving routes. Unlike earlier rovers, Curiosity carries equipment to gather samples of rocks and soil, process them and distribute them to onboard test chambers inside analytical instruments.

NASA's Jet Propulsion Laboratory, Pasadena, Calif., builder of the Mars Science Laboratory, has engineered Curiosity to roll over obstacles up to 65 centimeters (25 inches) high and to travel up to about 200 meters (660 feet) per day on Martian terrain.

The rover's electrical power will be supplied by a U.S. Department of Energy radioisotope power generator. The multi-mission radioisotope thermoelectric generator produces electricity from the heat of plutonium-238's radioactive decay. This long-lived power supply gives the mission an operating lifespan on Mars' surface of a full Mars year (687 Earth days) or more. At launch, the generator will provide about 110 watts of electrical power to operate the rover's instruments, robotic arm, wheels, computers and radio. Warm fluids heated by the generator's excess heat are plumbed throughout the rover to keep electronics and other systems at acceptable operating temperatures.

The mission has been designed to use radio relays via Mars orbiters as the principal means of communication between Curiosity and the Deep Space Network of antennas on Earth.

The overarching science goal of the mission is to assess whether the landing area has ever had or still has environmental conditions favorable to microbial life, both its habitability and its preservation.

Curiosity will land near the foot of a layered mountain inside Gale crater. Layers of this mountain contain minerals that form in water. The portion of the crater floor where Curiosity will land has an alluvial fan likely formed by water-carried sediments. Selection of Gale followed consideration of more than 30 Martian locations by more than 100 scientists participating in a series of open workshops.

Selection of a landing site of prime scientific interest has benefited from examining candidate sites with NASA's Mars Reconnaissance Orbiter since 2006, from earlier orbiters' observations, and from a capability of landing within a target area only about 20 kilometers (12 miles) long. That precision, about a five-fold improvement on earlier Mars landings, makes feasible sites that would otherwise be excluded for encompassing nearby unsuitable terrain. The Gale landing site is so close to the crater wall, it would not have been considered safe if the mission were not using this improved precision.

Advancing the technologies for precision landing of a heavy payload will yield research benefits beyond the returns from Mars Science Laboratory itself. Those same capabilities would be important for later missions both to pick up rocks on Mars and bring them back to Earth, and conduct extensive surface exploration for Martian life.

Science Payload

In April 2004, NASA solicited proposals for specific instruments and investigations to be carried by Mars Science Laboratory. The agency selected eight of the proposals later that year and also reached agreements with Russia and Spain for carrying instruments those nations will provide.

A suite of instruments named Sample Analysis at Mars will analyze samples of material collected and delivered by the rover's arm, plus atmospheric samples. It includes a gas chromatograph, a mass spectrometer, and a tunable laser spectrometer with combined capabilities to identify a wide range of organic (carbon-containing) compounds and determine the ratios of different isotopes of key elements. Isotope ratios are clues to understanding the history of Mars' atmosphere and water. The principal investigator is Paul Mahaffy of NASA's Goddard Space Flight Center, Greenbelt, Md.

An X-ray diffraction and fluorescence instrument called CheMin will also examine samples gathered by the robotic arm. It is designed to identify and quantify the minerals in rocks and soils, and to measure bulk composition. The principal investigator is David Blake of NASA's Ames Research Center, Moffett Field, Calif.

Mounted on the arm, the Mars Hand Lens Imager will take extreme close-up pictures of rocks, soil and, if present, ice, revealing details smaller than the width of a human hair. It will also be able to focus on hard-to-reach objects more than an arm's length away. The principal investigator is Kenneth Edgett of Malin Space Science Systems, San Diego.

Also on the arm, the Alpha Particle X-ray Spectrometer for Mars Science Laboratory will determine the relative abundances of different elements in rocks and soils. Dr. Ralf Gellert of the University of Guelph, Ontario, Canada, is principal investigator for this instrument, which will be provided by the Canadian Space Agency.

The Mars Science Laboratory Mast Camera, mounted at about human-eye height, will image the rover's surroundings in high-resolution stereo and color, with the capability to take and store high-definition video sequences. It will also be used for viewing materials collected or treated by the arm. The principal investigator is Michael Malin of Malin Space Science Systems.

An instrument named ChemCam will use laser pulses to vaporize thin layers of material from Martian rocks or soil targets up to 7 meters (23 feet) away. It will include both a spectrometer to identify the types of atoms excited by the beam, and a telescope to capture detailed images of the area illuminated by the beam. The laser and telescope sit on the rover's mast and share with the Mast Camera the role of informing researchers' choices about which objects in the area make the best targets for approaching to examine with other instruments. Roger Wiens of Los Alamos National Laboratory, Los Alamos, N.M., is the principal investigator.

The rover's Radiation Assessment Detector will characterize the radiation environment at the surface of Mars. This information is necessary for planning human exploration of Mars and is relevant to assessing the planet's ability to harbor life. The principal investigator is Donald Hassler of Southwest Research Institute, Boulder, Colo.

In the two minutes before landing, the Mars Descent Imager will capture color, high-definition video of the landing region to provide geological context for the investigations on the ground and to aid precise determination of the landing site. Michael Malin is principal investigator.

Spain's Ministry of Education and Science is providing the Rover Environmental Monitoring Station to measure atmospheric pressure, temperature, humidity, winds, plus ultraviolet radiation levels. The principal investigator is Javier Gómez-Elvira of the Center for Astrobiology, Madrid, an international partner of the NASA Astrobiology Institute.

Russia's Federal Space Agency is providing the Dynamic Albedo of Neutrons instrument to measure subsurface hydrogen up to one meter (three feet) below the surface. Detections of hydrogen may indicate the presence of water in the form of ice or bound in minerals. Igor Mitrofanov of the Space Research Institute, Moscow, is the principal investigator.

In addition to the science payload, equipment of the rover's engineering infrastructure will contribute to scientific observations. Like the Mars Exploration Rovers, Curiosity will have a stereo navigation camera on its mast and low-slung, stereo hazard-avoidance cameras. Equipment called the Sample Acquisition/Sample Preparation and Handling System includes tools to remove dust from rock surfaces, scoop up soil, drill into rocks and collect powdered samples from rocks' interiors, sort samples by particle size with sieves, and deliver samples to laboratory instruments.

The Mars Science Laboratory Entry, Descent and Landing Instrument Suite is a set of engineering sensors designed to measure atmospheric conditions and performance of the spacecraft during the arrival-day plunge through the atmosphere, to aid in design of future missions.

Program/Project Management

The Mars Science Laboratory is managed for NASA's Science Mission Directorate, Washington, D.C., by JPL, a division of the California Institute of Technology in Pasadena. At NASA Headquarters, David Lavery is the Mars Science Laboratory program executive and Michael Meyer is program scientist. In Pasadena, Peter Theisinger of JPL is project manager and John Grotzinger of Caltech is project scientist.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

For more information about MSL, go to:
http://www.nasa.gov/msl

ChemCam (Chemistry and Camera) Instrument

ChemCam is a rapid chemical and microscopic reconnaissance instrument onboard NASA's Curiosity rover. ChemCam will tell scientists what the rocks and soils are made of in the region surrounding the Curiosity rover's landing site. ChemCam, short for chemistry and camera, uses a technique called Laser-Induced Breakdown Spectroscopy (LIBS) to determine the compositions of rocks and soils. The Remote Micro Imager (RMI) will give ChemCam scientists high-resolution images of the rocks and soils that LIBS targets.

ChemCam vaporizes a point on a target in Gale Crater, Mars.

LIBS Analysis

- Pulsed laser vaporizes target rocks and soils up to 7 meters (23 ft) away.

- The spectrum of light from the laser-induced plasma reveals the chemical composition of the target in seconds.

- ChemCam can detect most elements, including the building blocks of life (C, H, N, O).

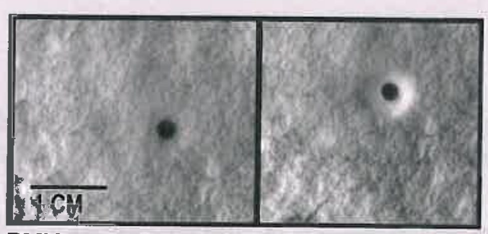
LIBS spark on a piece of iron pyrite. [1]

Remote Microscopy

- Provides images of target sites before and after laser analysis.

- Same resolution as the best cameras on Mars.

- Can see a human hair 2 meters (7 ft) away.



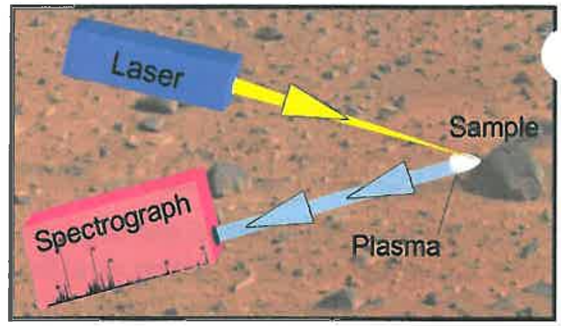
RMI image of an analysis pit formed on loose soil after 50 laser shots (left) and after 150 shots (right) at the same location. [2]

How does ChemCam work?

1. ChemCam fires a series of powerful, but invisible, nanosecond laser pulses at the target rock or soil. (The yellow color of the laser to the right is for illustrative purposes.)

2. Surface material is strongly heated by the laser light causing the material's atoms to emit ultraviolet, visible, and infrared light.

3. ChemCam collects this light (pale blue) with a telescope and sends it down an optical fiber to a spectrometer in the body of the rover. The spectrometer acts like a prism, separating the light into a rainbow of colors. ChemCam will be able to distinguish different elements because each chemical element has its own unique "fingerprint" in the form of characteristic emission lines.



A schematic representation of the LIBS technique ChemCam uses to determine the composition of rocks and soil on Mars. [1]

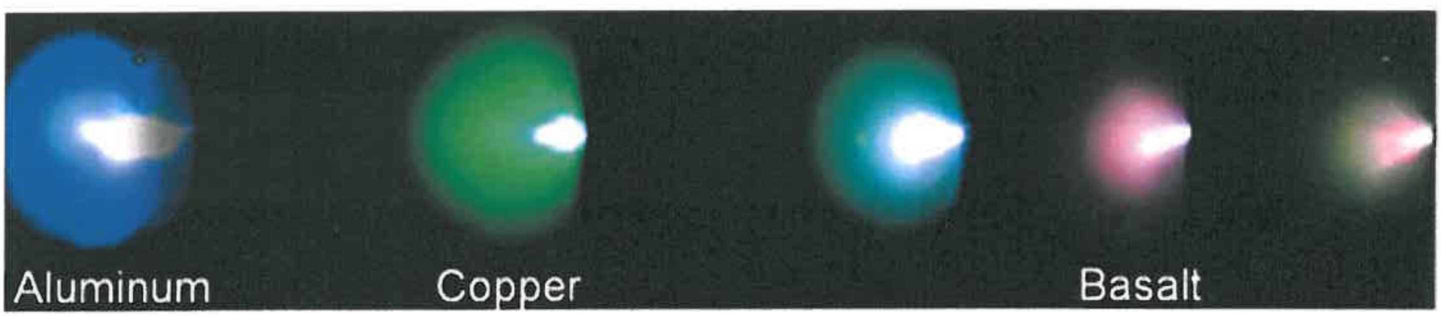
How does ChemCam fit into the MSL mission?

ChemCam will address the Mars Science Lab mission objectives relating to the habitability of Mars:

1. Characterize the geology and geochemistry of the landing site.
2. Investigate planetary processes relevant to past habitability.
3. Assess the biological potential of a target environment.
4. Look for materials that are hazardous to humans.

As a remote sensing instrument, ChemCam's primary objective is to rapidly characterize rocks and soils, and to identify samples of greatest interest for further investigation by contact and analytical laboratory instruments onboard the Curiosity rover.

ChemCam's laser can clear away dust from the surface of its target and can drill through layers of alteration to analyze the pristine interior.



Different elements, such as aluminum and copper, and rock types like basalt give off characteristic colors of light when zapped by the ChemCam laser. [3]

The ChemCam instument is an international collaboration led by Los Alamos National Laboratory in the United States and the Institut de Recherche en Astrophysique et Planetologie in France.

For more information on ChemCam, including interviews with instrument scientists and engineers, please visit the ChemCam website at www.msl-chemcam.com.

Image Credits:
[1] The ChemCam Team and Los Alamos National Laboratory
[2] The ChemCam Team, Los Alamos National Laboratory, Institut de Recherche en Astrophysique et Planetologie, and Centre National d'Etudes Spatiales
[3] Sirven et al., JAAS, December 2007, Cover

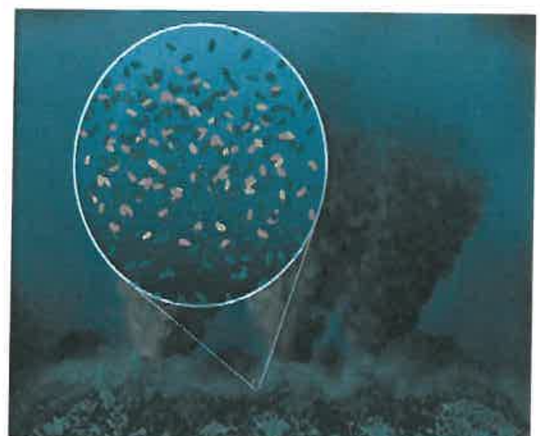
Life on Mars: Are we alone?

This profound question has captured our imaginations for many years. Only now are we gaining the knowledge and technology to attempt a scientific answer to it. We know more today than at any other time in the past about the qualities that a planet must possess in order to potentially support life. Within our solar system, Mars has always been in the forefront of this search. From little green men to alien–made canals, our imaginations have sometimes gotten the better of us, but as missions shed new light on the Red Planet, our hopes for uncovering the building blocks of life have been renewed. As a result of this interest in the search for life beyond our home planet over the past century, a new and exciting field of science has emerged to help examine these questions and more.

What is Astrobiology?

Astrobiology is the study of life in the universe. It investigates the origins, evolution, distribution, and future of life on Earth and beyond. This branch of biology requires an understanding of biological, planetary, and cosmic phenomena. By viewing biology as a planetary phenomenon, astrobiologists strive to address three questions:

- How does life begin and evolve?
- Is there life elsewhere in the universe?
- What is the future of life on Earth and beyond?



Origin of Life?
Scientists believe that life on Earth may have begun as microscopic organisms in extreme underwater hydrothermal environments such as depicted here.
Credit: Lunar and Planetary Institute.

Through our efforts to understand how life began and evolved on Earth, we hope to determine where and how to best look for it elsewhere. The scientific field of Astrobiology embraces the search for life both close to home (Earth) and far beyond. From laboratory and field investigations on Earth – to the exploration of Mars and the outer planets – to the search for potentially inhabited planets beyond our Solar System, scientists are studying the potential for life to adapt and thrive beyond our home planet. This research, like other space related science programs, involves a broad range of research interests, and requires partnerships among many fields of science, including (but not limited to) molecular biology, ecology, planetary science, astronomy, information science, and space technologies.

How is NASA searching for life?

In 1998, in a concerted effort to address the challenges in finding life beyond Earth, the National Aeronautics and Space Administration (NASA) established the NASA Astrobiology Institute (NAI). As an innovative way to develop the field of astrobiology and provide a scientific framework for flight missions, the NAI is composed of competitively–selected teams across the country that incorporate astrobiology research and training programs in concert with the national and international science communities.

Community and collaboration are essential to achieving the NAI's mission and to effectively answering the fundamental questions of astrobiology. During its first decade, NAI had many significant research accomplishments, as well as contributions to NASA missions. It was influential in defining the landing sites for the Mars Exploration Rovers (Spirit and Opportunity), which ultimately provided evidence of past liquid water on the Martian surface. NAI scientists may have also detected methane gas in the Martian atmosphere, which would suggest that the planet is at least geologically alive, if not biologically as well.

Here on Earth, NAI scientists have discovered microorganisms living completely independently of the Sun, almost 2 miles (3km) beneath the Earth's surface. They have also expanded their search to planets around other stars, detecting both water vapor and carbon dioxide in the atmospheres of some of these newly discovered planets. As NAI continues in its mission, scientists will continue to explore the limits of life on Earth, developing new ways to search for life elsewhere in the Universe, and advancing our understanding of how life originated on our own planet.

For more information about the NAI and its teams, please visit:
http://astrobiology.nasa.gov/nai/

What is Life?

Identifying the characteristics of life is necessary to astrobiologists because they need a working definition of life – a set of criteria for something to be considered alive – to use in their work. Would you be able to identify life if you saw it? You probably have a set of criteria, whether you think about them specifically or not. Given the broad range of life, some of the characteristics of living things may be more obvious than others.

Defining life is not easy. Part of the complexity of is caused by the fact that there are nonliving examples that display one or more of these same characteristics. How, then, do we design instruments, sensors, probes, and missions to seek out life, if we cannot even define it in a way that satisfies everyone in the scientific community? Despite these differences in opinion, scientists have worked together to developed a set of general characteristics of life.

Based upon the examples on Earth, there are several characteristics that can be agreed upon:

1) Life stores and uses energy
2) Life engenders more life (reproduces and/or grows)
3) Life responds to its environment (external stimuli)
4) Life changes (evolves and adapts) over time

All Earth life, life as we know it, is organized in essentially the same way: it is all based on the chemistry of the element carbon; it requires liquid water; it engenders further life via DNA and/or RNA; it uses phosphate molecules to store energy, and it uses protein molecules to respond to and affect (influence) its environment. Despite differences in preferred environment or complexity of body structure, all life on this planet adheres to these basic principles and, as far as we can tell, this has been the case for billions of years.

What Does Life Need?

There are four main requirements that have been the focus of our search for life in the universe. Life as we know it needs an energy source, nutrients (something to eat or consume), protection from the elements, and liquid water. Scientists are looking for places in our solar system – and beyond – that have all the things that we know life needs.

Of the four identified necessities for life, the presence of **liquid water** is considered to be one of the most important and perhaps useful to scientists. Liquid water has been a focus in the search for life beyond Earth because, to date, we have only found living organisms where liquid water exists. Pure water is a liquid over a fairly wide range of temperatures – between 0°C (32°F) and 100°C (212°F). Under special circumstances, however, water can remain a liquid beyond this range. For example, at high pressures (like at the bottom of the ocean or deep in the Earth's crust), water can remain a liquid to higher temperatures. Similarly, saline water (water containing salt like our ocean water) has a lower freezing temperature, allowing it to remain a liquid at temperatures that are colder than the normal freezing point. Temperatures much above or below this normal range for liquid water though, negatively affect the cellular structures of living organisms – potentially destroying them. The presence of water on a planetary body is one requirement for life to exist there (past or present), thus scientists are interested in identifying locations in the universe that possess water – especially liquid water – to better narrow their search for life beyond Earth!

The unique properties of water are also important as a component of life as we understand it. Water participates in many chemical reactions that are essential to life, both as a nutrient and as an energy source. Water also is an excellent solvent; it can dissolve many important chemicals and molecules, and so help transport nutrients, waste products, and chemicals, whether within cells or across oceans. Water has another unusual trait, it expands when it freezes. This means that solid water (ice) is less dense than liquid water, and thus it floats. As a result, water freezes at the top first, keeping bodies of water from freezing solid during times of global cooling. Water is a common component of planets as they form and is released readily by volcanic activity. This means that although liquid water may not be present at a planet's surface, it may still exist below the surface. Because water has so many essential functions in life (as we know it), identifying its presence will continue to be a focus for astrobiologists; however the other requirements of life must be met as well.

Early microscopic life, such as cyanobacteria, may have thrived in shallow water environments similar to this artist depiction.
Credit: Lunar and Planetary Institute

All organisms require some form of **energy** to run their life processes (like growing, moving, and reproducing). The organisms that we are familiar with primarily use either light energy or chemical energy. Plants get their energy from light. Microbes at deep–sea vents do not have access to light and instead get their energy by breaking down chemical compounds dissolved in water circulating from Earth's interior. Light energy available to a planet diminishes with distance from the sun, and it also diminishes with distance from a planet's surface. On Earth, an example of this could be the ocean bottom or deep within caves. If light energy is absent, then there must be an alternate energy source that can be utilized by organisms.

All organisms also require **nutrients**, the minerals and other chemicals used to maintain and grow their bodies and structures. Plants get nutrients from soils and the atmosphere. Animals get their nutrients as food by eating plants or other animals. Life must have a continuing source of nutrients, not only for an individual plant or animal, but over long times so that the plant–animal communities can continue.

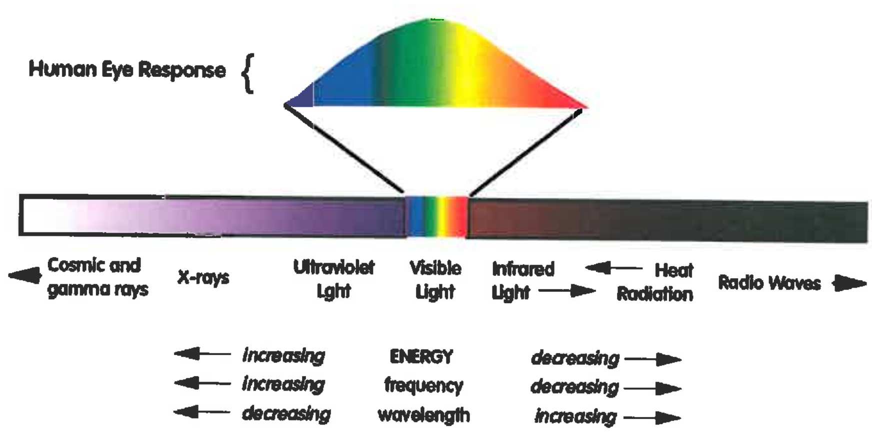
Finally, all organisms require **protection** from the extremes of the space environment in which the planets reside. This protection may provide the environmental stability necessary for the development and continuation of life. Otherwise, life would fall victim to high–energy processes in solar systems, like asteroid/comet impacts and ultraviolet radiation from the Sun. Rock layers and deep water can provide this protection, and many organisms on Earth live underground or deep in the ocean. A planet's atmosphere can provide some protection from hazards (like ultraviolet radiation, extreme temperature variations, and small to medium–sized meteorite impacts) and allows access to sunlight as a major source of energy. Atmospheres also help to moderate day to night temperature changes, helping to maintain a habitable temperature range. However, to serve as an effective shield or insulator, an atmosphere has to be fairly substantial, such as those on Earth, Venus, or Saturn's moon Titan. A planet or moon depends upon its own interior processes, such as volcanic activity, to create an atmosphere and its gravity (of adequate strength) to hold onto the atmosphere (keep it there). A small–sized body such as Pluto or Earth's Moon has too weak of a gravitational field to hold onto a significant atmosphere, making life on or near the surface difficult.

Radiation and the Electromagnetic Spectrum

Light and heat are part of the spectrum of energy – or radiation – our Sun provides. We can "see" light and we can feel heat. But there are other types of energy that our Sun produces. Much of this energy makes up the electromagnetic spectrum. Light is part of the visible section of the spectrum and heat is part of the infrared section of the spectrum. Radio waves, microwaves, ultraviolet rays, X–rays, and gamma–rays all are parts of the spectrum of electromagnetic energy – or radiation – from the Sun.

Radiation is energy that travels in waves or as particles. Radio waves, microwaves, visible light, and infrared radiation have relatively long wavelengths and low energy. But ultraviolet rays, X–rays, and gamma–rays have shorter wavelengths and higher energy. This shorter wavelength is so small that these wavelengths interact with human skin, and cells, and even parts of cells – for good or for bad!

Our Sun also produces cosmic radiation. Cosmic rays are very high energy, fast moving particles (protons, electrons, and neutrinos) that can damage DNA, increasing the risk of cancer and causing other health issues. Cosmic rays have such high energy that it is difficult to design shielding that blocks them; Cosmic rays do not only come from our Sun, but from other places in our galaxy and universe.



Electromagnetic spectrum

The subject of this activity is ultraviolet – UV – radiation. Humans need UV radiation because our skin uses it to manufacture vitamin D, which is vital to maintaining healthy bones. About 10 minutes of Sun each day allows our skin to make the recommended amount of vitamin D. However, too much exposure to UV causes the skin to burn and leads to wrinkled and patchy skin, skin cancer, and cataracts.

On Earth, we are protected by our atmosphere from most UV radiation coming from the Sun. The Ozone layer absorbs much of the UV portion of the spectrum (UVB and UVC). Some still gets through (UVA and a bit of UVB). We can protect ourselves completely by covering ourselves with clothing and using sun block. Our atmosphere protects us from most of the X–, gamma–, and cosmic radiation as well.

On Mars there is very little atmosphere to protect living things from UV radiation – or from X–rays and gamma–rays or even more dangerous cosmic rays. Organisms would have to provide their own protection in the form of body changes (adaptations) or sheltered environments (such as underground). These measures would work fairly well for protecting against UV radiation.

How Did Life Begin on the Earth?

According to our current understanding, the origin of life on Earth was dependent upon the geological processes that are driven by the heat from the Earth's interior. These interior processes have played an important role in shaping the surface. The surface of the Earth is a dynamic place, changing over time due to the influences of plate tectonics and volcanism (interior processes), external events such as impacts, an active water cycle, and weathering of various forms (wind, water, etc.). These early geologic processes helped in the formation of Earth's atmosphere and liquid water at the surface.

Over the past few decades, our view of the origin of life on Earth has advanced substantially. Life on Earth has been shown to be much more robust and adaptive than previously imagined, and has been found in places where no one had previously thought to look for it. Our current understanding of Earth life suggests that it may have originated very quickly in geologic terms, developing from inorganic matter in much less than one billion years. Scientists are working hard to understand the specific set of processes that led to the origin of life and the amount of time required; this search is especially difficult as we know of only life on Earth, and have not figured out how to make life in the laboratory. Despite this, we do have some basic understanding of the processes involved.

The raw materials from which life arose are now known to be relatively common throughout the universe. The most important of the major biogenic elements are carbon (C), hydrogen (H), oxygen (O), and nitrogen (N). Comets and some asteroids are rich in these elements (and their compounds, like water), and an early influx of comets and asteroids may have provided additional amounts of these elements to Earth. It is significant that these compounds have been shown to come from a far larger and more ancient process, one which operates in vast clouds from which the stars themselves are formed. Life, then, appears to be a natural outgrowth of the universe's basic structure and organization.

What can life tolerate?

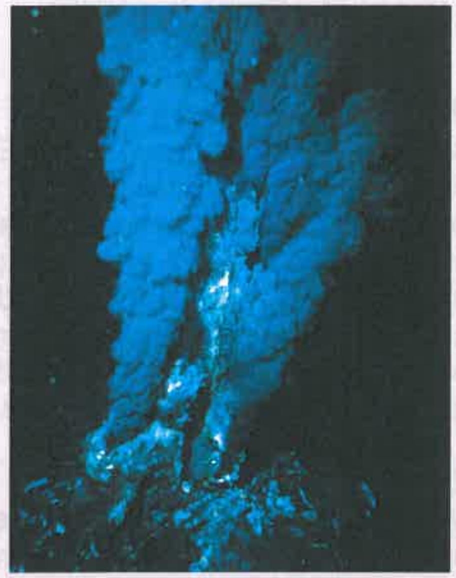
Based on what we know, life on Earth exists in nearly every environment that includes liquid water, even those that only experience water occasionally. Most of Earth's life lives in the range of temperatures between 30°C (86°F) and 45°C (113°F), averaging around 37°C (98.6°F). However, particular varieties of life – extremophiles – can thrive in conditions far below freezing (down to –15°C, 5°F) and far above the boiling point of pure water at surface pressure (up to +121°C, 250°F). Temperatures above this range break down cellular materials and lower temperatures cause chemical reactions to be too slow to maintain life functions.

Extremophiles

Much of the research taking place in Astrobiology emphasizes the environment and habits of extremophiles – organisms that thrive in conditions that we would consider "extreme" and life–threatening (e.g., very high or low temperatures, very salty or acidic water). Extremophiles can live where most organisms cannot because they have adapted special mechanisms for survival. Any life that may exist beyond Earth in our solar system would likely be found to exist in these types of harsh conditions. By studying analog sites on Earth – places that have similar environmental conditions to those currently found or that may have existed in the past beyond Earth (such as Mars) – scientists are working to understand the processes that allow these resilient organisms to live and thrive despite the unfriendly environment.

One such analog environment that may be of use in the search for signs of life on Mars is hydrothermal vents. A *hydrothermal vent* is a hot spring on the seafloor. It continuously spews super–hot, mineral–rich water that helps support a diverse community of organisms. Although most of the deep sea is sparsely populated, vent sites abound with a fascinating array of life. The first hydrothermal vent was discovered in 1977. They occur along mid–ocean ridges (spreading seafloor) in all of the Earth's oceans, at an average depth of about 7,000 feet (2,100 meters). The creatures that live in darkness, from bacteria to tubeworms, may light the way to the development of new drugs to improve human health, industrial processes, and help us in identifying life beyond Earth.

Deep Sea Hydrothermal Vent: Black Smoker



Black Smokers are an interesting type of hydrothermal vent found deep within the ocean at about 7,000 feet below the surface.

The plumes of super–heated water from within the Earth's crust are laden with minerals, which are responsible for the black appearance of these features.

Despite the seemingly inhospitable location, scientists have discovered thriving communities of organisms living within the hydrothermal vents.

Image Courtesy: NOAA (National Oceanic and Atmospheric Administration)

Extreme environments may also include extreme depths, pressures, alkaline or saline waters, or severe radiation conditions. The majority of these extremophiles are microbes, and they belong to an ancient group of life called Archaea (the other two groups are bacteria and eukaryotes). Astrobiologists are interested in these microbes because they closely resemble fossilized remains of earliest discovered fossils on Earth and thrive in environments very similar to the conditions that scientists think fostered the origin of life as we know it.

Earth contains an interesting menagerie of extremophiles, such as *Pyrolobus fumarii*, the hydrothermal vent dweller that lives at temperatures of 113°C (235°F), or the *Cryptoendoliths* that live at temperatures of –15°C (5°F) inside sandstone rocks in the Antarctic. Anaerobic extremophiles can exist without oxygen, similar to the early Earth, which lacked oxygen in the atmosphere. Many of these microbes have remained nearly unchanged for the past 3 billion years. The microscopic *Menthanococcus jannaschii* lives in hydrothermal vents on the floor of the Pacific Ocean. Thriving under pressures that would crush a conventional submarine, this heat–loving microbe lives without sunlight or oxygen and gives us hints about conditions and life on early Earth.

Might There be Life on Mars?

All life as we know it requires liquid water, hence the strong interest in finding evidence of past liquid water on Mars, and understanding the history of this water. There is good evidence that liquid water once flowed and ponded on the surface of Mars, so it is possible that life could have become established there. The first evidence for life on Earth, in the form of *fossil bacteria,* is in rocks that formed about 3.5 billion years ago – at approximately the time that the Martian environment was changing from warmer and wetter to colder and drier. Microbial life on Earth probably existed before this time period, possibly becoming established after the period of intense asteroid bombardment was over, but there is no record of it. In short, life may have taken up to a billion years to become established on Earth, although it may have happened more quickly, and so scientists consider this to be a reasonable timeline for Mars as well.

Given this start, and using Earth as a model, conditions on much of Mars would have been suitable for life for about a half billion years, before the climate deteriorated. However, the features recording flooding events suggest that there were occasional warmer and wetter periods, and there may have been refuges for life, such as moist areas near warm volcanic regions. Given the harsh conditions, and lack of evidence, it is improbable that life evolved into complex multi–cellular forms, like it did on Earth between one billion years and 500 million years ago. Life on Mars – if it exists or existed in the past – would most likely have been in the form of microbes.

In the 1990's NASA scientists announced the presence of organic molecules, mineral features that could have been formed by biological activity, and possible microscopic fossils of primitive, bacteria–like organisms in a Martian meteorite recovered in Antarctica. They interpreted the features to have formed on Mars more than 3.6 billion years ago, and to be evidence that life existed on Mars. The results have been hotly debated in the scientific community. Many scientists believe the structures could have been formed by chemical processes, rather than biologic; such chemically formed features are known to exist. Others suggest that the organic signature is contamination from Earth. At present, few scientists are convinced that the features are evidence of life. Debate is a healthy part of the scientific process – and it has served an additional purpose – it has helped scientists better identify the "signals of life" and to develop more tools in the identification process being used by astrobiologists today.

Losing the Atmosphere

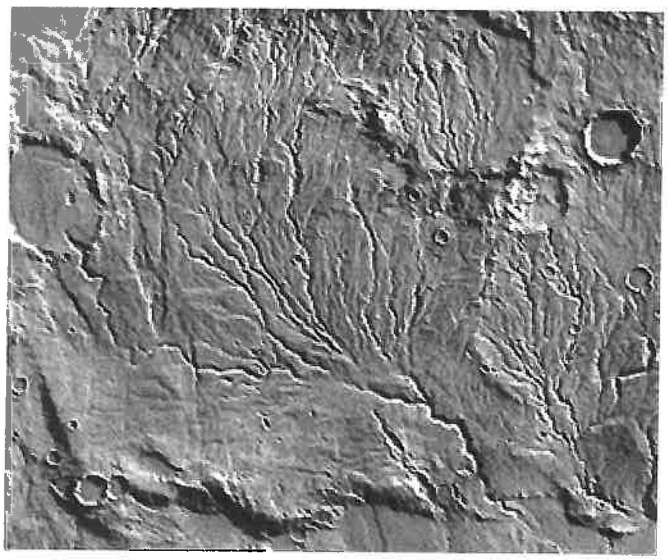
Early Mars probably had a thicker atmosphere with more carbon dioxide and water vapor, provided by vigorous volcanic activity. As mentioned previously, volcanic activity (i.e., a geologically active environment) is believed to be important for the development of life. The young Mars' magnetic field shielded the surface from the charged particles of the solar wind and dangerous cosmic radiation. This Mars was warmer and wetter, and the higher atmospheric pressure permitted flowing water at the surface. However, by about 4 billion years ago, Mars' environment became cold and dry, as it is now. As Mars' interior cooled, the gases and water vapor from the volcanism gradually dwindled and the magnetic field disappeared. Left unprotected, the atmosphere was worn away by the solar wind, and the Martian surface was bathed in radiation.

This image looks obliquely at part of the southern hemisphere of Mars.
The numerous circular structures are impact craters, indicating that this is an old part of the Martian surface. The thin Martian atmosphere can be seen as a layer between the rock surface of the planet and the black of space.
Image courtesy of NASA.

An image of the cold, dry Mars of today, taken by Mars Exploration Rover, Spirit.
Image courtesy of NASA, JPL, and Cornell

Disappearing Water

Early Mars was wetter and warmer. Several lines of scientific evidence support this claim. Images obtained by Mars orbiters have revealed that the ancient Southern Highlands are covered by dendritic drainage patterns – networks of stream channels, or "valley networks" that erode into the highland craters. While there are some differences, these features are generally similar to gently meandering river channels on Earth. The valley networks on Mars are interpreted to have formed at a slow rate, and thus they require a time in Martian history when flowing liquid water was stable at or near the surface of the planet. Chemical measurements made from orbit reveal the presence of clay associated with some of these channels; the formation of clay requires that water was present at some time. Additional evidence for liquid water was found by the Mars Exploration Rovers. They documented structures in the rocks that are created by flowing water, and minerals formed in salty, acidic water. Several meteorites from Mars contain mineral deposits – carbonate and clay minerals – that formed when the rocks were soaked in water on Mars.

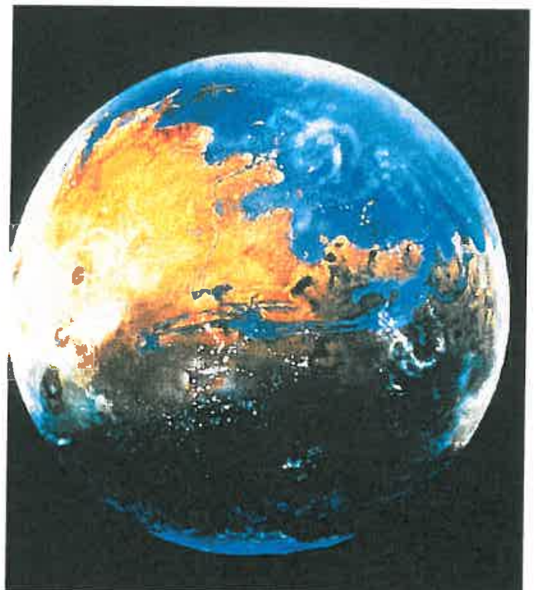


Stream drainage across the Southern Highlands of Mars.
The streams erode the edges of some of the older, larger craters. This pattern is similar to stream drainage patterns – dendritic drainage – seen on Earth that is caused by flowing water. The image is 200 kilometers across (125 miles); Viking Orbiter image 606A56
Image courtesy of NASA.

Features that look like the Mississippi River Delta (minus the water) are found on Mars' surface, suggesting that water flowed across the surface for a long period of time, gradually creating a delta in a body of water. The feature is 11 kilometers wide (7 miles) and 13 kilometers from top to bottom (8 miles) in the image.
http://www.msss.com/mars_images/moc/2003/11/13/
Image courtesy of NASA / JPL / Malin Space Science Systems

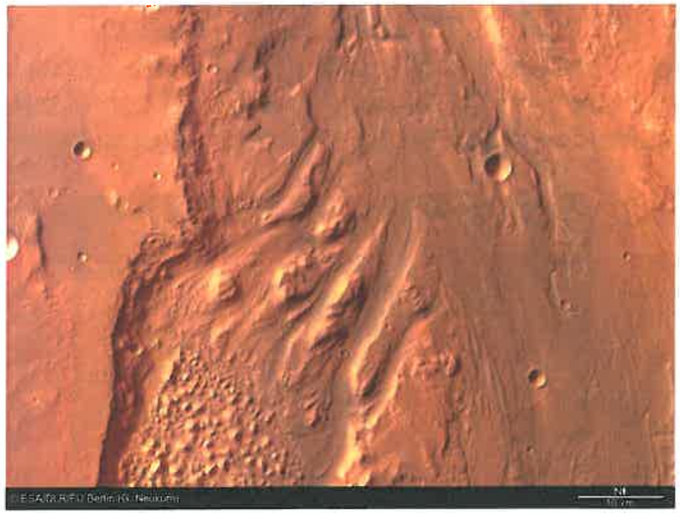
Rover images of layers in the rocks at the Martian surface. The thin layers are interpreted to be sediment deposited by flowing water. The "blueberries" are small, BB–sized deposits of hematite. Hematite is a mineral that typically, though not always, forms in water. Image courtesy of NASA.

Some scientists have calculated that Mars may have had a global layer of water that was about 394 feet (120 meters) thick. Imagine Mars with an ocean at its northern hemisphere, and streams flowing across the landscape, draining into it.



An artistic rendering of what an ancient ocean might have looked like on Mars.
http://www.lpi.usra.edu/publications/slidesets/redplanet2/slide_28.html

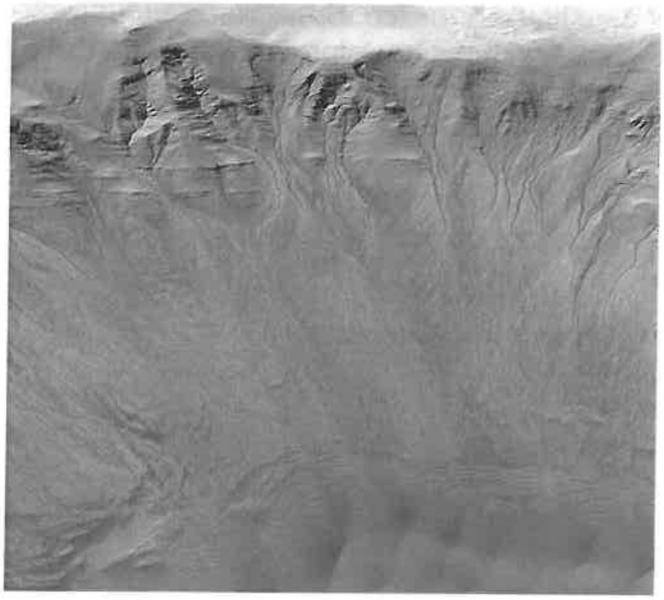
About 4 billion years ago, things changed. Mars became cooler and drier, because of changes in its atmosphere. The thin atmosphere and low air pressure no longer permitted liquid water to exist at the surface. Under these conditions, water turns directly from ice into gas – it sublimes – when it is exposed and warmed at the surface. As Mars cooled and the conditions became unstable for liquid water to exist at the surface, the water may have been sequestered underground, either as a liquid or as ice. Occasional warm periods in Mars' history resulted in melting of the subsurface ice and gigantic floods. The floods are recorded by outflow channels that feed into the Northern Lowlands. These features are much more chaotic than the orderly drainage patterns of the Southern Highlands. Outflow channels, similar in features to braided streams on Earth, form from catastrophic floods of water. Multiple wide channels "braid" together, transporting gigantic blocks of the underlying rocks.



Outflow channels cut by flood waters in Ares Vallis. The blocky "chunks" in the broad channel at the bottom of the image are displaced blocks of material pulled from the walls of the channel as the water rushed along.
Image courtesy of ESA / DLR / FU Berlin (G. Neukum)

Tear–drop shaped islands formed as flood waters rushed through this area. The circular depressions are impact craters. The region shown is 475 kilometers (295 miles across). Mosaic of images from NASA's Viking mission. Image courtesy of NASA.

Recent images of gullies on the slopes of Martian craters, compared to older images of the same crater, show a new flow of material down the crater slopes. Some scientists interpret these flows to suggest that water occasionally flows on the surface of Mars today. Ice below the surface may melt and carry material down slope, before the water evaporates or refreezes. The cause of these features continues to be debated by scientists. However, some scientists suggest that these gullies are created by the flow of dry sand, with no water present at all. Another Martian mystery!



Martian Gullies
This image shows several gullies on the wall of Newton crater on Mars. Some scientists believe that the gullies are evidence of the recent flow of liquid water at the surface of Mars. The image is 3 kilometers (2 miles across). NASA Mars Global Surveyor image. Image courtesy of NASA.

In 2011, on the heels of the launch of the next rover to Mars, Curiosity, NASA scientists announced the discovery of bright veins of a mineral deposited by water, apparently gypsum, by the Mars Exploration Rover, Opportunity. The discovery helped to support the idea that liquid water flowed through underground fractures in the rock.

The vein examined most closely by Opportunity is about the width of a human thumb (0.4 to 0.8 inch), 16 to 20 inches long, and protrudes slightly higher than the bedrock on either side of it within the Endeavour Crater. The vein, which is informally named "Homestake," contains plentiful calcium and sulfur, in a ratio pointing to relatively pure calcium sulfate. Calcium sulfate can exist in many forms, varying by how much water is bound into the minerals' crystalline structure. Image data from Opportunity's camera suggest that the vein is of the mineral gypsum, a hydrated calcium sulfate (Gypsum is common on Earth and is used to make drywall and plaster of Paris).

Observations from orbit have detected gypsum on Mars previously. A dune field of windblown gypsum on far northern Mars resembles the glistening gypsum dunes in White Sands National Monument in New Mexico. The Homestake deposit, whether gypsum or another form of calcium sulfate, likely formed from water dissolving calcium out of volcanic rocks. The minerals combined with sulfur either leached from the rocks or introduced as volcanic gas, and was deposited as calcium sulfate into an underground fracture that later became exposed at the surface.

Throughout Opportunity's long journey across Mars' Meridiani plain, the rover has discovered bedrock composed of magnesium, iron and calcium sulfate minerals that also indicate a wet environment billions of years ago. This suggests that veins such as

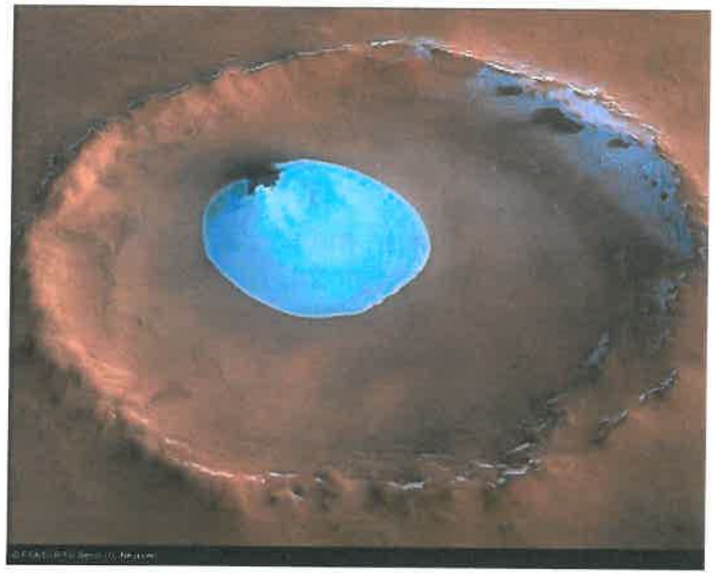
"Homestake" could have formed in a different type of water environment – one more hospitable for a larger variety of living organisms.

Where is the water now?

Much of Mars' water is underground, either as a liquid or as ice. Subsurface water is common on Earth, too! Much of our drinking water comes from "groundwater." NASA's Mars Reconnaissance Orbiter and the European Space Agency's Mars Express have instruments aboard designed to detect evidence of subsurface water on Mars.

And do not forget the polar *ice* caps! Mars' northern and southern ice caps contain water ice, as well as carbon–dioxide ice – like the dry ice you can get in supermarkets. Mars' northern ice cap is mostly water ice.

Water and carbon–dioxide ice ("dry ice") occur in the Southern Polar Ice Cap. Image courtesy of NASA.



Residual water ice in Vastitas Borealis Crater.
Image courtesy of ESA/DLR/FU Berlin (G. Neukum).

There is no evidence that life exists on Mars right now – but finding life – or evidence of past life – is challenging when you are examining an entire planet! You need to be in the right place. Scientists will continue to work to identify where the conditions might be right for life, as we understand it, on Mars.

In 2011, a new NASA study suggested that if life ever existed on Mars, the longest lasting habitats for life were most likely below the surface. A new interpretation of years of mineral–mapping data, suggests Martian environments with abundant liquid water on the surface existed only during short episodes. These episodes occurred toward the end of hundreds of millions of years during which warm water interacted with subsurface rocks. This has implications about whether life existed on Mars and how its atmosphere has changed.

While the types of clay minerals that formed just below the surface are all over Mars, the types that formed on the surface are present only in very limited locations and are quite rare. The discovery of clay minerals on Mars in 2005 indicated the planet once hosted warm, wet conditions. If those conditions existed on the surface for a long period of time, the planet would have needed a much thicker atmosphere than it has now to keep the water from evaporating or freezing. Researchers have sought evidence of processes that could cause a thick atmosphere to be lost over time.

These new findings support an alternative hypothesis that persistent warm water was confined to the subsurface and many erosional features were carved during brief periods when liquid water was stable at the surface.

"If surface habitats were short–term, that doesn't mean we should be glum about prospects for life on Mars, but it says something about what type of environment we might want to look in," said the report's lead author, Bethany Ehlmann, assistant professor at the California Institute of Technology and scientist at NASA's Jet Propulsion Laboratory in Pasadena.

One of the exceptions may be Gale Crater, the site targeted by NASA's Mars Science Laboratory mission. Launched on November 26, 2011, the Curiosity rover landed safely and began investigating rock layers that contain clay and sulfate minerals starting in August 2012!

Missions to Mars: The Search for Signs of Life – Past and Present

While missions to Mars have faced significant adversity and setbacks at times, NASA has successfully conducted both orbital and lander missions to the Red Planet. The first successful missions, Mariner 4, 6, 7, and 9, launched over the course of the 1960's and early 1970's, were the first spacecraft to acquire and return close range images of Mars. These missions were also the first to take measurements of the Martian magnetic field, cosmic dust and cosmic rays, and the solar wind. Building upon the Mariner program, NASA has continued to explore Mars through several successful missions.

This image, taken by the Viking 1 lander shortly after it touched down on Mars July 20, 1976, is the first photograph ever taken from the surface of Mars.
Image Courtesy of NASA.

In the 1960's, while the Mariner missions were under way, a group of NASA scientists, engineers, and technicians came together to design and create an ambitious robotic mission to Mars, they named this mission Viking in honor of the fearless Nordic explorers of Earth. The Viking mission was composed of four spacecraft (two orbiters and two landers), whose primary objectives were the following:

1. Obtain high–resolution images of the Martian surface
2. Characterize the structure and composition of the atmosphere and surface
3. Search for evidence of life on Mars

Of these objectives, the principal reason for the mission was to look for evidence of life. The landers dug soil samples from the frozen surface and looked for signs of respiration — an indication of biological activity. Though the initial results were thought promising, Viking found no conclusive signs of life. However, it is important to note that these experiments were not very sensitive by modern standards. In fact, more recent discoveries by the Mars Phoenix Lander in 2008 have called into question the original conclusions that the Viking landers did not discover any organic compounds. Results of experiments from Phoenix suggest that soil examined by the Viking landers in 1976 may have contained carbon–based chemical building blocks of life. For more information about Mars Phoenix Lander, please visit:
http://www.nasa.gov/mission_pages/phoenix/main/index.html

Following the successes – and disappointments (no confirmed life) – of the Viking mission, NASA's Mars Exploration program sent a series of missions to explore the surface features and history of Mars, its geology and water, but these missions did not search for signs of life. These missions did serve an important role in helping scientists to characterize the environment on Mars and to identify promising locations for future scientific studies.

Mars Exploration Rovers: Spirit and Opportunity

Launched in mid–2003, the Mars Exploration Rovers, named Spirit and Opportunity, landed on the Red Planet in January 2004 as a part of three–month missions to look for signs of past water activity on Mars. However, both rovers far exceeded their mission goals and expectations, making important discoveries about wet environments on Mars in the past and possibly at the present. NASA ground controllers lost communication with Spirit in March 2010; after repeated unsuccessful attempts to awaken the rover, NASA sadly declared that Spirit was dead in May 2011. Opportunity on the other hand, is still going strong (as of 2012) and has logged more than 20 miles on the Red Planet!

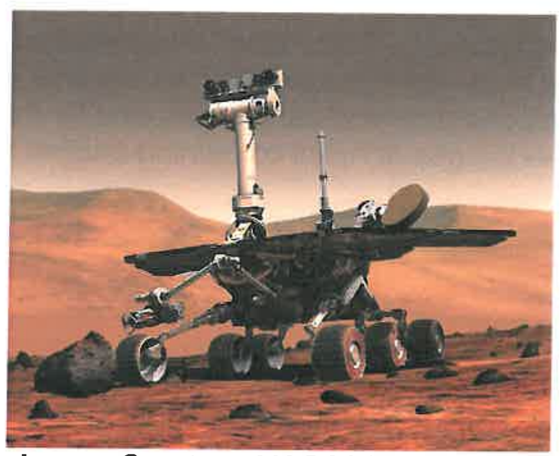
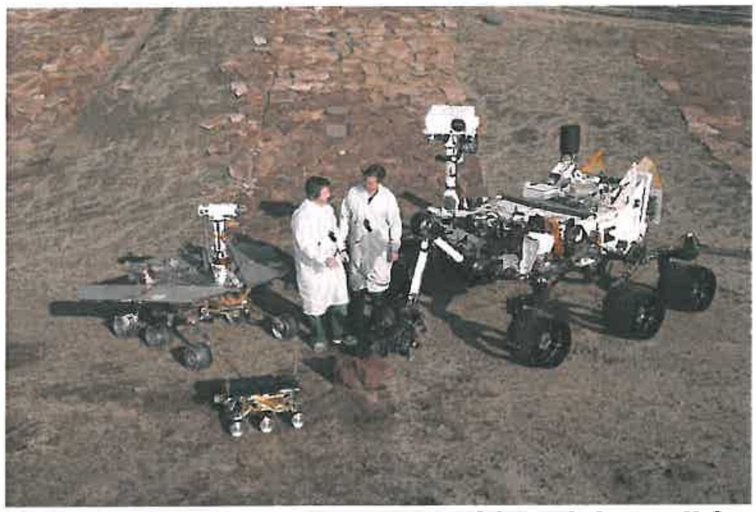


Image Courtesy NASA/JPL–Caltech

An artist's representation of the MER rovers, Spirit and Opportunity.

For more information about the Mars Exploration Rovers, please visit:
http://www.nasa.gov/rovers and http://marsrovers.jpl.nasa.gov.

The latest mission to Mars, Mars Science Laboratory (MSL), is looking for the precursors (building blocks) of life and evidence of past habitable environments, but not for life itself. MSL's Curiosity rover will study rocks, soils, and the local geologic setting in order to detect chemical building blocks of life (e.g., forms of carbon) on Mars and will assess what the Martian environment was like in the past. For more information about MSL, please visit: http://marsprogram.jpl.nasa.gov/msl/



Lessons learned from Viking technology have blazed the trail for Mars research. Scientists stand in the midst of three generations of NASA's Mars rovers (Pathfinder's Sojourner, MER's Opportunity/Spirit, and MSL's Curiosity). Curiosity is the largest and most technologically advanced rover to date.
Image Courtesy of NASA.

The Next Generation: Mars Science Laboratory

The Mars Science Laboratory rover, Curiosity, is continuing the exploration of Mars and is specifically searching for signs that habitable environments existed on Mars in the past. Within its first forty days on the Red Planet, Curiosity had already uncovered evidence of a stream that once ran vigorously across the area on Mars where the rover was driving. Previous missions provided earlier evidence for the presence of water on Mars, but this evidence — images of rocks containing ancient streambed gravels — was the first of its kind.

Image Courtesy NASA/JPL–Caltech
Image of the MSL "Curiosity" rover

Scientists are studying the images from the Curiosity rover of stones cemented into a layer of conglomerate rock. The sizes and shapes of stones offer clues to the speed and distance of a long–ago stream's flow. This was the first time scientists were actually seeing water–transported gravel on Mars, and was a transition from speculation about the size of streambed material to direct observation of it.

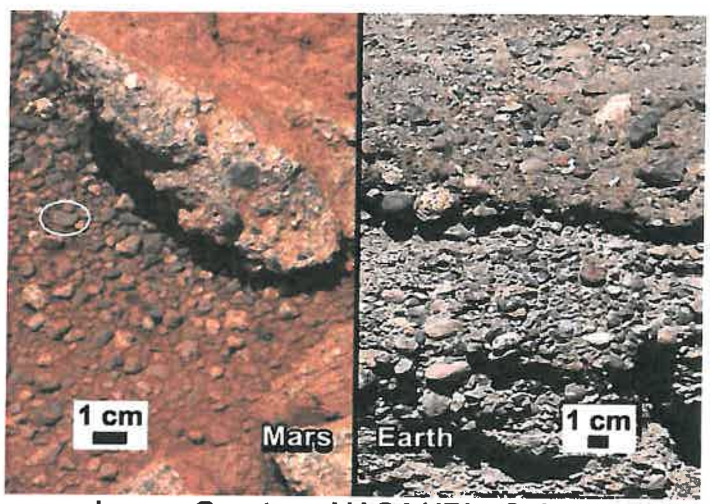
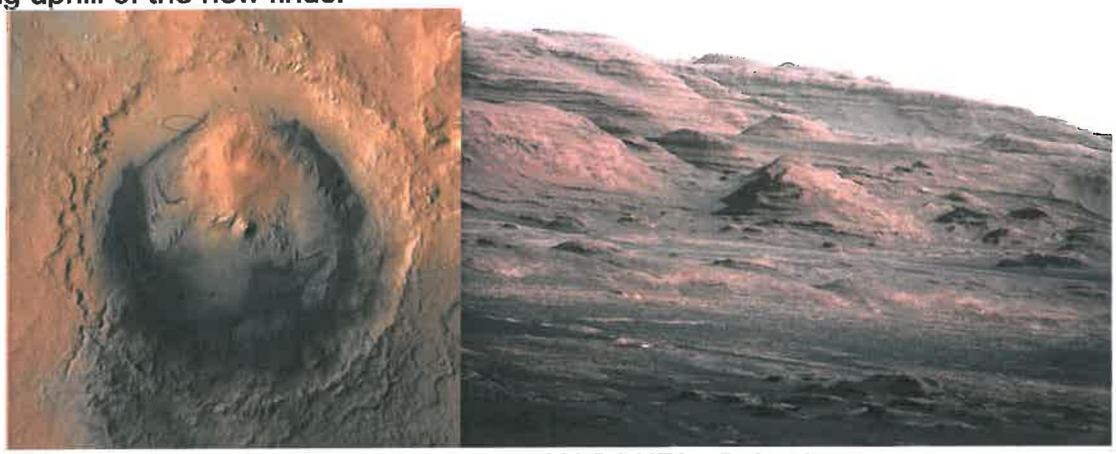


Image Courtesy NASA/JPL–Caltech

This set of images compares the "Link" outcrop of rocks on Mars (left) with similar rocks seen on Earth (right). The image of "Link," obtained by NASA's Curiosity rover, shows rounded gravel fragments up to a couple inches (few centimeters), within the rock outcrop.

The "Link" finding site lies between the north rim of Gale Crater and the base of Mount Sharp, a mountain inside the crater. Earlier imaging of the region from Mars orbit allows for additional interpretation of the gravel–bearing conglomerate. The imagery shows an alluvial fan of material washed down from the rim, streaked by many apparent channels, sitting uphill of the new finds.



Images Courtesy NASA/JPL–Caltech

This view of Gale Crater (on the left) is derived from a combination of data from three Mars orbiters. The view is looking straight down on the crater from orbit. Gale Crater is 96 miles (154 kilometers) in diameter. Mount Sharp (close up image on the right) rises about 3.4 miles (5.5 kilometers) above the floor of Gale Crater.

For more information about the history of NASA Mars Exploration, please refer to the following: WhyMars.pdf

A Little More About Mars

The Martian day, the time it takes Mars to spin once on its axis, is 24 hours and 40 minutes long, very similar in length to Earth's day. Its year is almost twice as long as Earth's, however. It takes Mars 687 Earth days to orbit the Sun. That path around the Sun is slightly more elliptical than Earth's, and the Sun is not exactly in the center of its orbital path.

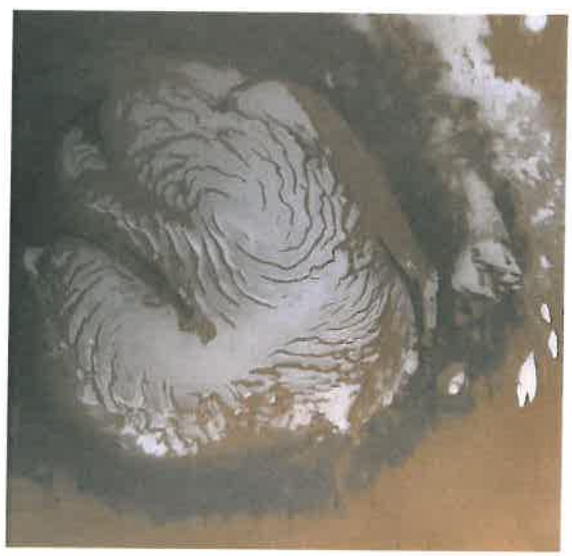
Like Earth, Mars is tilted on its axis. This tilt, combined with the elliptical orbit, contributes to seasons on Mars. Because Mars is closer to the Sun during its southern hemisphere summer, the summer in that hemisphere is warmer than the northern hemisphere summer.

Mar's surface is cold — a warm summer day might reach 27°C (80.6°F), and winter at the poles can be as cold as –125 °C (–193°F), and its atmosphere is very thin. The atmospheric pressure at the surface of the planet is about 1/100th of that of Earth's. Mars' atmosphere is mostly carbon dioxide (95%), with significant nitrogen (3%) and argon (2%), and trace amounts of other gases, like oxygen (<0.15%). In contrast, Earth's atmosphere is much thicker and is mostly nitrogen (77%) and oxygen (21%). The thin Martian atmosphere offers little protection from dangerous ultraviolet light and radiation (subatomic particles) from the sun; unlike the Earth, Mars does not have an ozone layer to protect the surface from solar ultraviolet radiation.

Mars has massive dust storms that can cover the entire planet! Wind speeds can reach 100 km / hour (62 miles / hour), stirring up the fine red dust. The Martian atmosphere always contains some of this reddish dust, so that the Martian sky is not blue like the Earth's but reddish–pink instead.

A dust storm obscures the surface features on Mars
Image Courtesy of: NASA/JPL/Malin Space Science Systems
http://www.msss.com/mars_images/moc/E01_E06_sampler2002/dust/2001duststorms50.jpg

The Martian atmosphere contains much less water vapor than Earth, making clouds a rarity – but not unheard of (especially near the poles) – on Mars. There is no liquid water present at the surface. There may be frozen water in the ground, and Mars has ice caps in its polar regions that are mixtures of carbon dioxide ice (dry ice) and water ice.



Northern ice cap of Mars. The polar cap is about 1100 kilometers (700 miles) across.
Image Courtesy of NASA
http://ai.jpl.nasa.gov/public/home/chien/spring–agu–images/MLS/Mars_Ice_Cap.jpg

Mars is about half the size of Earth. Because it has less mass, it has a smaller gravitational attraction. Surface gravity on Mars is less than 40% of Earth's. If you weighed 100 pounds on Earth, you would weigh 38 pounds on Mars.