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# Responsible Exploration: Protecting Earth and the worlds we explore from cross contamination

by Margaret Race, PhD



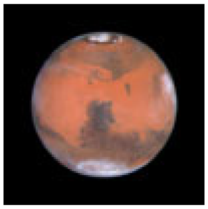
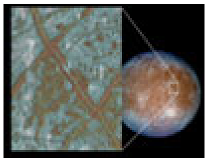
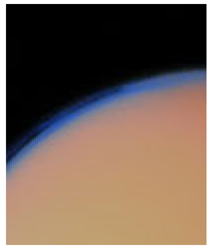
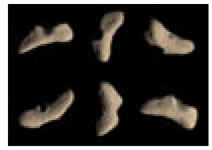
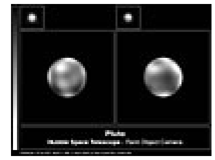
This image of Earth was taken on August 25, 1992 by NOAA GOES-7 satellite. It shows a planet teaming with life that we want to protect from contamination from alien life forms. At the same time as we explore beyond the boundaries of our home planet we must be careful not to carelessly spread even microbial life to other potentially fragile ecosystems.
Photo Credit: Image produced by F. Hasler, M. Jentoft-Nilsen, H. Pierce, K. Palaniappan, and M. Manyin. NASA Goddard Lab for Atmospheres - Data from National Oceanic and Atmospheric Administration (NOAA).

### What is Planetary Protection?

Since the beginning of the space program at the time of Sputnik, there has been concern about the need for planetary protection — the prevention of human-caused biological cross-contamination between the Earth and other solar system bodies. Although the probability is low because of the harshness of space environments, it's possible that "hitchhiker" bacteria and other organisms transported on spacecraft and equipment might cause irreversible changes in the environments of other planets or interfere with scientific exploration for life (forward contamination). In addition, until we know more about the prospect of extraterrestrial (ET) life, we have to be careful that spacecraft or extraterrestrial samples returned to Earth don't contain anything that could harm Earth's inhabitants and ecosystems (back contamination).

Planetary protection policies for space exploration are like environmental, health or safety policies on Earth. We want to prevent the transport of potentially harmful organisms or microbes from one place to another (either accidentally or deliberately) for two main reasons: 1) they could be infectious or pathogenic, or 2) they could cause ecological or environmental disruption. On Earth, there are regulations and control measures intended to prevent the spread of serious disease-causing microbes (for example, anthrax, HIV/AIDS, hoof and mouth disease, tuberculosis, or Dutch Elm disease), or to limit the movement of invasive pest species (for example, fire ants, gypsy moths, zebra mussels, kudzu vine or water hyacinth). In space exploration, the issues are basically the same, except for one important thing — we don't know if extraterrestrial life even exists, never mind whether it might harm Earth. Until we know for sure, we must follow strict domestic and international policies that apply to spacecraft and missions, prior to launch, on the planet during exploration, and upon return to Earth.

The task of planning effective planetary protection measures involves a combination of the latest scientific knowledge and some sophisticated guesswork. Even before a spacecraft arrives on a planet, there will have been tremendous thought about what kind of life might be there, how we would recognize it, and what kind of biohazard, if any, it might pose to Earth if it were returned in samples. Looking further into the future, we need to think about what precautions will be needed for human astronauts both when they visit new locations and when they return to our home planet. Planetary protection policies must take into account all these uncertainties — even while exploration continues to determine whether life exists elsewhere. Until we know for sure, we must be conservative to prevent the very act of exploring from disrupting or interfering with life, whether in extraterrestrial locations or on Earth.

|  |  |  |  |  |
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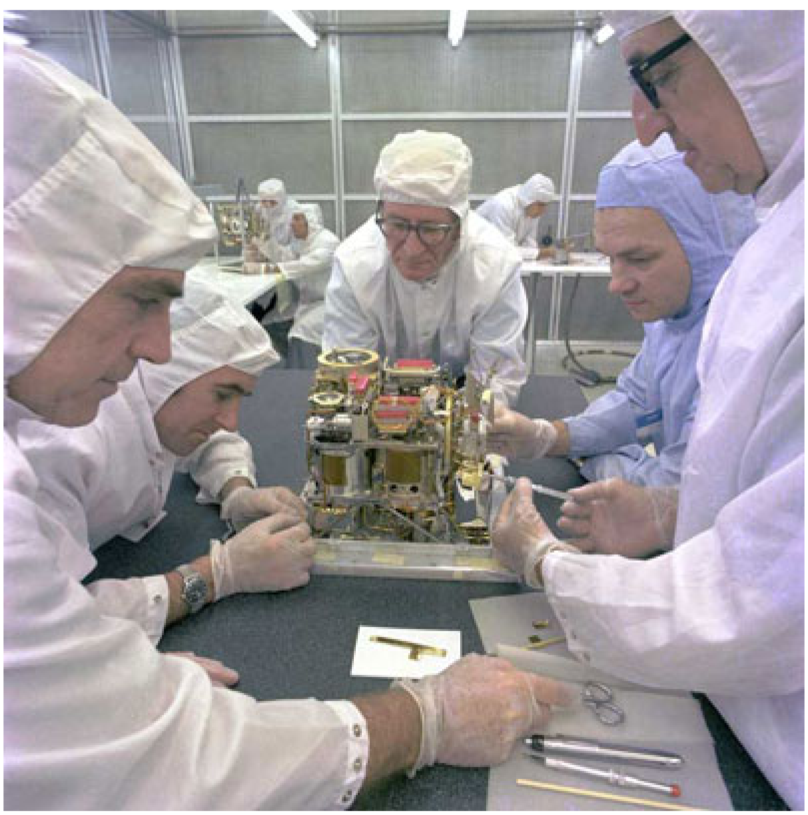
| Mars has long captured our imaginations and remains a serious target for human exploration. With evidence of water once being plentiful on this planet, we take the maximum precautions when exploring this world. Many of the new protocols being developed are for the near future as we plan sample return missions. | Europa is a moon of Jupiter. Its frozen surface is believed to have an ocean of liquid water beneath it heated by tidal forces. Water and heat make it another candidate for a possible abode of life. | Titan, Saturn's largest moon has a smoggy nitrogen atmosphere. Its make-up is similar to our own atmosphere, but much colder. Cassini will drop a probe through the smog to give us more detailed information about curious moon. | Eros, was the first asteroid to have a spacecraft put in orbit around it. Given its size and location, it is not a likely candidate to have life on it. Even though the spacecraft was eventually landed on the surface, the precautions to sanitize the spacecraft were much less rigorous than they are for a destination like Mars. | Pluto is the most distant planet in the solar system and is more like a comet than a planet. Because it always lurks at the frozen edges of the solar system, it is not a likely candidate for life. Any future spacecraft that may explore this distant icy world, will still be assembled in clean rooms but will not have to go through the same level of sanitizing that Mars rovers are subject to. |
| Click here to see larger versions of images with captions. | | | | |

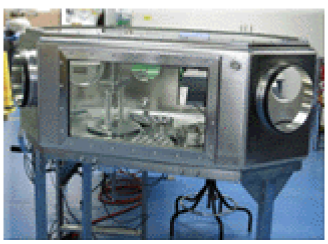
Depending on where in the solar system a spacecraft is going, a variety of different planetary protection procedures and controls may be used. If the environment is one where scientists think life could exist (for example Mars or Europa), strict controls are imposed, while missions to places with little or no potential for life require few, if any, special measures (for example Venus, Saturn, or our Moon). Planetary protection starts even before launch. For example, spacecraft are assembled in cleanrooms, and scientific instruments may be heat treated or specially packaged to further reduce the 'bioload' or the number of microbes before launch (similar to scrubbing and sterilizing equipment before surgery).

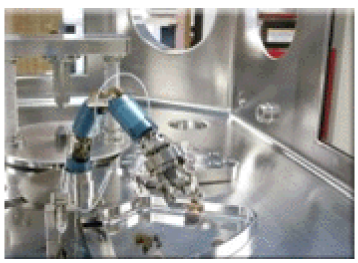


The TRW-built Mars viking biology experiment was prepared in a clean room. The equivalent of a university biology lab, it contained more than 40,000 components crammed into a space no larger than a car battery. Both Viking landers carried these devices. CREDIT: TRW Space & Electronics

If samples are returned from a place like Mars where scientists hope to find evidence of past or present life, sample materials will need to be sealed remotely inside special containers and monitored to ensure they don't leak during the return flight. If containment cannot be verified during the return flight to Earth, the sample and any spacecraft components that have been exposed to the extraterrestrial environment would either be sterilized in space or not returned to Earth. In addition, when they arrive on Earth, the returned samples will be transported to a special facility for testing and handling inside a quarantine laboratory equipped with biocontainment gloveboxes designed to simultaneously protect both workers and the samples from harmful contamination. No samples will be removed from containment until they are either sterilized or certified as non-hazardous, using a rigorous battery of life detection and biohazard tests. Although scientists agree that the likelihood of releasing and spreading a contained living organism is low, special equipment, personnel, and handling are warranted to minimize possible harmful effects, should a life form be discovered.

A similar approach to planetary protection and extraterrestrial quarantine was used during the Apollo Program when Moon rocks were returned to Earth. The rocks, along with lunar-exposed astronauts and the spacecraft itself, were quarantined at a special Lunar Receiving Laboratory until a comprehensive battery of tests proved there were no biohazards.





Until samples returned from other worlds can be determined to be free of biohazards they will not be touched by humans but will be handled carefully in sealed glove boxes and with robotic assistance.


After removing the isolation garments and freshening up, the three members of the Apollo 11 crew (Armstrong, Collins, and Aldrin, left to right) are greeted by President Nixon. Before we understood how sterile the lunar environment is, they were treated with the same care as the moon rocks to make sure they did not return with microbes that might have come from the Moon.

Future round-trip missions to Mars or other extraterrestrial locations will differ from Apollo in several ways. Because no astronauts will be involved in the initial sample-return missions, and because sample amounts are expected to be limited (less than 1 kilogram of rocks and soils from Mars compared to hundreds of kilograms of lunar rocks), quarantine procedures and flight operations will be less complex. Because of the distances involved, however, the missions will still be quite challenging. In addition, advances in microbiological and chemical techniques since Apollo have greatly increased our knowledge of life in extreme environments on Earth, while expanding abilities to detect life or life-related molecules in samples. Similarly, a heightened awareness has been developed about microbial capabilities and microbe-caused diseases — with corresponding public concerns about the potential risks of sample return missions.

As solar system exploration continues, so too will planetary protection policies. Revisions to those policies will depend on an improved understanding of extraterrestrial environments and our growing awareness of the tenacity of life in extreme environments on Earth. Increasingly, it appears likely there are extraterrestrial environments that could support Earth organisms. As importantly, future missions may find distant environments that support their own extraterrestrial life as well. Planetary protection provisions will be essential to the study and conservation of such environments. The Astrobiology Web has a section "Laws, Regulations, and Treaties Pertaining to Planetary Protection" if you'd like to study this more in depth.


# Responsible Exploration: Protecting Earth and the worlds we explore from cross contamination

### Where and how are we looking for evidence of life?

Astrobiology is a multidisciplinary scientific research program that studies the origin, evolution, distribution and fate of life in the universe. (See "The Universe in the Classroom," No. 51, Astrobiology: The Final Frontier of Science Education, by Jodi Asbell-Clarke and Jeff Lockwood.

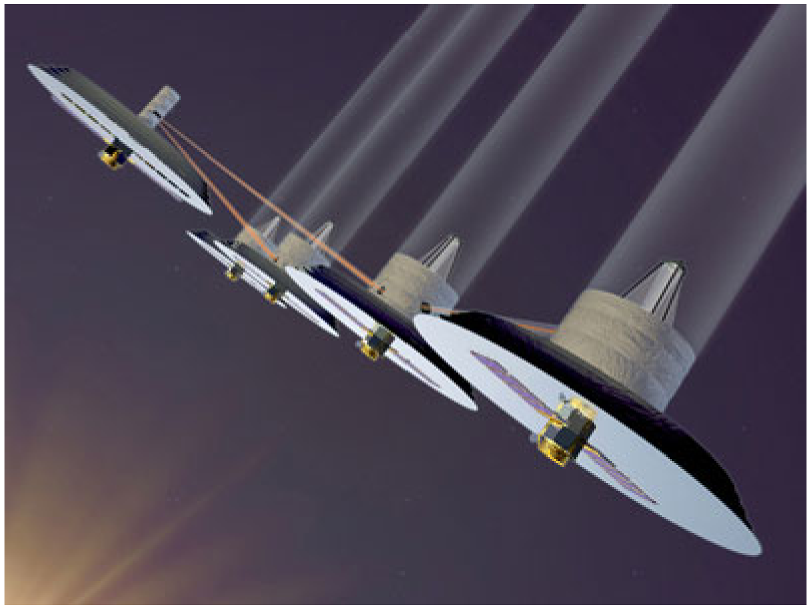
Scientifically, its cutting edge research is a synthesis of disciplines — from astronomy to zoology, from ecology to molecular biology, from geology to genomics — all focused on the common goal of discovering the thread of life in the universe. By using a variety of advanced technologies — both on Earth and in space — astrobiologists seek to discover the intricate chain of cause-and-effect that determines how life originates and evolves, and the resultant implications for the destiny of the worlds.

Because the universe is an immense place, it makes sense to search for evidence of life in more than one way. In addition to focusing on what we know about life on Earth, especially in extreme environments, astrobiology currently comprises three basic types of searches in space, each employing different technologies, looking in different places, and expecting to find different kinds of data:

1) The Search for Extraterrestrial Intelligence (SETI): the search within our galaxy using radiotelescopes to listen for electromagnetic signals from intelligent extraterrestrial civilizations,

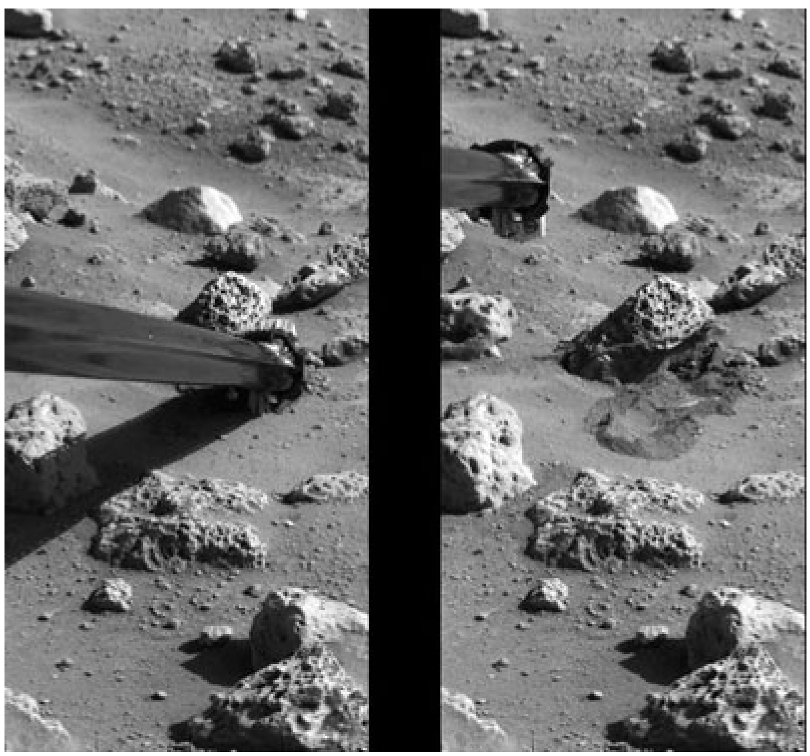
Aerial view of the Very Large Array, looking north-northeast. This set of large radio telescopes is used for a variety of astronomical observations including SETI searches. Here the antennas are in their closest configuration (D configuration). Photo by Dave Finley: Courtesy NRAO/AUI

2) The Search for Extrasolar Planets and Terrestrial-like Planets: This effort actually encompasses two types of searches: the first, using Doppler detection methods to look for evidence of stars that have nearby planets and solar systems of their own; and the second using a technique called 'interferometry' to translate optical data from far off terrestrial-sized planets into chemical 'fingerprints' to look for places that may have atmospheres indicative of habitability or even life's presence.



This is one of the designs for the proposed Terrestrial Planet Finder mission. Like the VLA, images from a collection of smaller telescopes are combined to give the same results that could be obtained from a much larger telescope.

3) Exobiology and Solar System Exploration: - the search within the solar system to detect evidence for the origin, evolution and existence of non-intelligent life, which would probably be microbial, although not necessarily simple (for example, anthrax and parasites may be small, but they reflect a long evolutionary history and are biologically quite complex).



The Viking 2 Lander was active on Mars in 1976. It had an arm that reached out to scoop up some soil and conducted three different experiments to determine if there was life on Mars. This pair of pictures shows the arm successfully pushing away a rock to take a soil sample. The results were disappointing so some. For a discussion of the results, go to: http://www.msss.com/http/ps/life/life.html

The search types — SETI vs. Extrasolar Planets vs. Exobiology — differ in many important ways. The search for extrasolar planets and terrestrial-like planets is really a search for locations or environments in the vastness of space. Is there land out there Columbus? Finding and mapping places helps us know more about what's out there, but without necessarily indicating anything about life, at least initially. This is in contrast with the other two search types. Positive findings in either SETI or exobiological searches would be interpreted as more indicative of some type of life or beings, either past or present. However, here again, the searches are distinctly different, especially from a planetary protection perspective.

In addition to searching vastly different locations and distances from Earth (within our galaxy vs. in the solar system), SETI and exobiological searchers each presumes distinctly different types of extraterrestrial life (intelligent and complex vs. microbial and biologically simpler). In addition, both searches employ different equipment and methods (radio telescopes vs. spacecraft and scientific instruments), and involve distinctly different data (incoming electromagnetic signals vs. biological, chemical and/or geological evidence). Searches for extraterrestrial intelligence (ETI) use non-intrusive, indirect methods, with no environmental impacts or potential planetary cross contamination concerns, either on Earth or in space. A positive finding would presumably be in the form of a signal or message. In contrast, the exobiological searches for life employ spacecraft, scientific equipment and experiments within the solar system, and raise questions about environmental impacts and planetary cross contamination both on Earth and the celestial bodies visited.

Taken together, all these differences have significant implications for activities during the period of exploration as well as for future actions if and when extraterrestrial life is discovered. The discovery of any type of extraterrestrial life, based on direct or indirect evidence, would have significant scientific, societal, practical and ethical implications.


# Responsible Exploration: Protecting Earth and the worlds we explore from cross contamination

### How do you recognize life?

Whether on Earth or in space, looking for living organisms–or evidence of life — can be a difficult task. Consider life on Earth. Large animals can be difficult to 'see' because they have adaptations like camouflage, hibernation, living underground or inhabiting extreme places like ocean depths. Microscopic organisms and some plants and fungi aren't visible with the naked eye, and other organisms — like viruses, parasites or symbiotic algae in corals — live some or all of their life cycles associated with other organisms. Finding life isn't easy.

The search for life in Astrobiology requires that we recognize life when we see it — and that's not a straightforward task. Spacecraft have already been to Mars, the moon and numerous other places in the solar system, but we haven't found life anywhere yet. So far, all the habitats we've visited have been extremely harsh places, with conditions that would be very stressful to living organisms (based on life as we know it). So what do we look for when we go to a place like Mars? And why do even continue to look when it seems to be so 'empty' of life?

Our interest in searching for life in far off places is driven in no small part by what we know about life on Earth. We've begun to recognize that Earth is much more 'alive' than we previously thought possible. In the past few decades, we've discovered microbial life, and in some cases, weird and different macroorganisms as well, in environments that were once thought to be totally incompatible with living organisms. For example, living organisms have been found in the darkness and extreme pressures of the deepest ocean, in thermal hot springs and dry deserts, as well as in Arctic and Antarctic permafrost. Microbial life has also been found inside of rocks kilometers beneath the Earth's surface, and in extremely inhospitable locations such as highly acidic waters or chemically toxic soils. In addition, we know that microbes can survive in dormant states for very long periods of time (consider for example anthrax spores, or dormant, yet viable microbes lodged inside salt crystals for nearly 250 million years!).

**PUNISHING ENVIRONMENTS**
are "home, sweet home" to extremophiles. The microbes shown are examples of the many found in the habitats depicted.

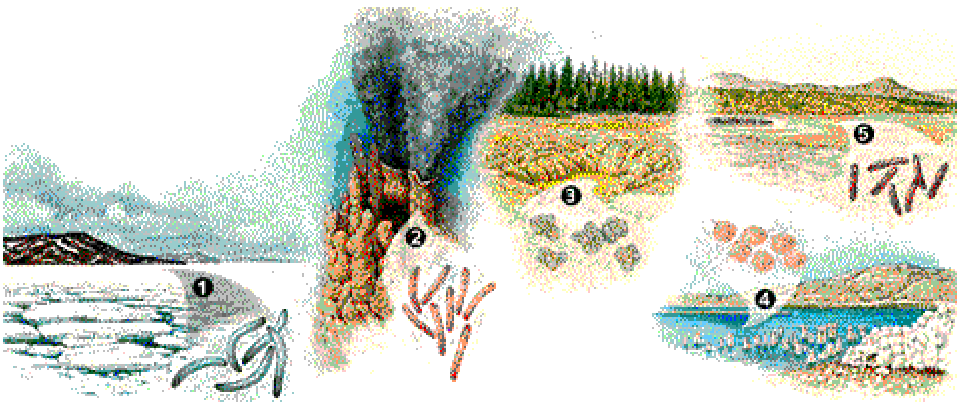


Image: Roberto Osti

| 1. SEA ICE | 2. DEEP-SEA VENT | 3. SULFURIC SPRING | 4. SALT LAKE | 5. SODA LAKE |
|---|---|---|---|---|
| cold–loving microbes (Psychrophiles) | heat–loving microbes (Thermophiles and Hyperthermophiles) | acid–loving microbes (Acidophiles) | salt–loving microbes (Halophiles) | alkali–loving microbes (Alkaliphiles) |
| *Polaromonas vacuolata* | *Methanopyrus kandleri* | *Sulfolobus acidocaldarius* | *Haloferax volcanii* | *Natronobacterium gregoryi* |

If life can be very small, and found in very unusual, extreme environments on Earth, why not in space? Take for example, Mars. If life did arise during a warmer, wetter period in Mars' history (as some scientists now believe), perhaps it managed to migrate into warmer, more clement regions of the planet before the surface became uninhabitable. Maybe if we look at martian rocks and soils, we might be able to find evidence indicative of that life–either live or dormant organisms, fossil evidence, 'biomaterials' or bits and pieces of living organisms, or even chemical cues in the form of molecular 'signatures' associated with life.

Thus, when we someday return samples from Mars (like we did from the Moon during the Apollo program), we will have a strategy that covers the waterfront, so to speak. We'll try to include a variety of rock types — and a variety of tests — to study for evidence of life in a variety of forms.

When Mars rocks and soils are returned to Earth (in about a decade from now if all goes as planned), the sample container will be opened inside a special containment and quarantine facility where three types of testing will be done: 1) physical and chemical testing 2) life detection analyses, and 3) biohazard tests. Because we do not know what martian life might look like, if it exists at all, information from all three categories will be essential to determine if there is any evidence of life. In general the tests will scan for the same types of evidence as we would look for to detect Earth microbial life:

- physical signs of life (size, shapes, structures etc);
- the presence of biologically associated chemical elements;
- structural chemistry (cellular components like cell walls, membranes, proteins, DNA, etc.);
- evidence of metabolism, growth, reproduction or chemical changes in the samples that might be caused by a living entity; and
- indications of biohazards — any changes or adverse effects on representative Earth species that could be caused by anything within the sample materials.

The first thing that will be done with samples is to 'look' for visual signs or chemical evidence of life. On Earth, all life has some shape or structure, regardless how small or simple. Highly sophisticated microscopes and instruments will *'look' for obvious signs of structures,* probing in cracks and fissures, or other obvious nonuniform parts of the rocks. The samples will also be *analyzed chemically to search for elements usually associated with biological systems* (the most obvious are carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur). For example, the biological element abundances in martian samples would be compared with those found on average in typical terrestrial microbes.

If no organic carbon is found in the samples, and no structures of any sort are detected (at scales as small or smaller than all known bacteria and microbes), the probability is be very low that there would be life in the samples. Even so, attention will focus on even finer detail.

Following the preliminary physical and chemical testing, a battery of life detection tests will also be conducted to search specific signs of life. For example portions of the samples will be scanned using a variety of instruments and laboratory techniques to look for *biochemical signs of 'life as we know it'* (for example, biological 'signatures' such as amino acids, DNA, peptides, lipids, enzymes, cell wall materials, etc). They will also attempt to culture extracts from the samples using standard microbiological plating procedures under a variety of laboratory conditions and growth media. *Cultures will be monitored over time to look for colony growth or chemical changes* that might indicate metabolism by some organism.

Even if all the tests above show no signs of life, or are inconclusive, there will be yet another set of biohazard tests done to determine whether there might be anything in the sample that could potentially harm either Earth life or its environment. These tests will use cell and tissue cultures with a variety of representative species to test for indications of hazards — toxic, pathogenic, life-cycle altering, capable of causing mutations, altering behavior or disrupting ecosystems, etc.)

If we verify that life exists in samples from Mars, it would be a profound and significant discovery in many ways. The obvious follow-up question would return us to yet another comparison with Earth life. All organisms that we have studied to date have the same biochemical and genetic makeup, sharing similar DNA and showing evolutionary relationships on the universal tree of life. Would martian life be related to Earth life, perhaps indicating that life had been carried between Earth and Mars — or vice versa — in meteorites? Or would extraterrestrial life be distinctly different, perhaps using some other 'alphabet' of amino acids for its genetic code, or different molecules altogether for its basic biochemistry. If life has happened at least twice in one solar system, would it mean we live in a universe that is 'biofriendly', and that life may be found in more places as well? All these questions — and all the potential answers and interpretations — depend on how carefully we are able to study samples from places like Mars, and whether we we'll be able to recognize life when we see it.


# Responsible Exploration: Protecting Earth and the worlds we explore from cross contamination

### What do we look for to 'see' Life?

**General Characteristics of Life on Earth:**

| Characteristic: | |
|---|---|
| Order | Has organization or structure that is recognizable at some level (body, cells, tissues, organs, biological molecules, etc.) |
| Uses Energy/Metabolizes | Able to take energy from the environment, transform it and 'use' it |
| Growth | Development or expansion of organism in size and complexity |
| Reproduction | Give rise to others of the same type |
| Mobility | Capable of using energy for self-propelled movement, however subtle |
| Responsiveness | Organisms can perceive the environment and react to it |
| Heredity | Have units of inheritance, a genetic code, that passes from parent to offspring — and that controls physical, chemical and behavioral traits |
| Adaptations | Organisms have structures, behavior, and abilities that suit their life form to their environment |
| Evolution | Populations of organisms change over time |

**What to Look For with Extraterrestrial Samples: Universal Properties of Life that are "Measurable"**

- Life builds and maintains order with obvious structural and molecular complexity
- Life has chemical distributions that are distinguishable from the background environment
- Life consumes energy/metabolizes
- Life creates waste products
- Life modifies its environment (which includes the capability to interact with other organisms)
- Life replicates (through a genetic code)
- Life evolves (not likely to be observable in single samples)

## About the Author

Dr. Margaret S. Race is an ecologist currently working with NASA through the SETI Institute in Mountain View, CA. Dr. Race's professional interests focus on the scientific and policy implications of large-scale projects involving science, technology and development. Her current work focuses on environmental impacts, legal and policy issues and risk communication related to solar system exploration and the search for extraterrestrial life. Recently, she has served as a member of two major National Research Council (NRC) studies: one on Issues in Mars Sample Return and the other on Sample Return from Small Solar System Bodies. For the last several years she has been an organizer and participant in NASA international workgroups developing containment and planetary protection protocols for the upcoming Mars Sample Return mission. Throughout her career she has also been actively involved in science education and outreach for K-12 schools, museums, mass media and the general public.

In addition to her appointment at SETI Institute, Dr. Race is a research affiliate with the Energy and Resources Group at University of California at Berkeley. Previously, she was Assistant Dean in the College of Natural Resources at UC Berkeley, and a faculty member in the Human Biology Program at Stanford University.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**Life Beyond Earth** by Joel Achenbach, excerpts from the January 2000 *NATIONAL GEOGRAPHIC*, http://www.nationalgeographic.com/ngm/0001/fngm/index.html

**Planetary Protection: Safeguarding Islands of Life** by multiple authors *The Planetary Report*. Vol XIV, number 4, July/August 1994, pages 3-23

**Astrobiology: Discovering New Worlds of Life** by Charles C. James and Cindy Lee Van Dover, *Science Scope*, Nov/Dec 2001, v 25(3) p42-45

*Ad Astra* feature issue on Astrobiology: www.astrobiology.com/adastra
All 8 articles on various aspects of the search for life, entire issue is available online, including an article about Planetary Protection, **Bring 'em Back Alive — or at Least Carefully!** by Race and Rummel

*Ad Astra* Special Issues: **Astrobiology Has Arrived** Jan/Feb 2002
6 articles and two full pages of astrobiology references and websites. (p 42-43) including: **A Sense of Place: Planetary Protections' Role in Astrobiological Exploration** by John Rummel and Margaret Race

### Activities

**1.** The very first issue of "The Universe in the Classroom" featured a section called "The Activity Corner" with an activity relevant to this latest issue about life on other worlds. With all the imaginative creatures in summer movie releases from Star Wars to Men in Black, "Invent an Alien" is an exercise that will challenge both your students' imaginations and their grounding in the environmental realities of other worlds: http://www.astrosociety.org/education/publications/tnl/01/01.html

**2.** Putting a different twist on the above activity Astro-Venutres is an educational, interactive, multimedia web environment highlighting NASA careers and astrobiology research. Designed for grades 5-8, students are transported to the future and become part of a team searching for habitable worlds and get a chance to "build a planet". http://astroventure.arc.nasa.gov

**3. Strange New Planet** http://athena.cornell.edu/educators/lp_05.html
ASU Mars K-12 Education Program 6/99. Adapted from NASA Education Brief "EB-112: How to Explore a Planet" 5/93. **Strange New Planet** brings insight into the processes involved in learning about planetary exploration. This activity demonstrates how planetary features are discovered by the use of remote sensing techniques. In this activity, the teacher gets to invent some interesting planets for the students to explore.

**4. Fingerprints of Life**
http://ares.jsc.nasa.gov/Education/websites/astrobiologyeducation/classact.htm

**5. Searching for Life**
http://ares.jsc.nasa.gov/Education/websites/astrobiologyeducation/lookforlife.htm
Science must have a working definition of life. These activities encourage students to think about the

characteristics of life and about the possibility of looking for life on Mars. The first three activities from **Destination: Mars** set up criteria for recognizing life. The other activities use the criteria for more advanced investigations.

**6. Destination Mars**
Lesson Five: Searching for Life on Mars
http://ares.jsc.nasa.gov/Education/activities/destmars/destmars.htm

**7. ExoQuest** is a multimedia educational product developed at NASA Classroom of the Future™. It creates links between students and scientists at NASA and other research organizations, integrating NASA's experience and expertise into the middle school and high school curricula. Several current and future NASA missions provide support for research in astrobiology; and, with the cooperation of the researchers involved, this project reflects and utilizes this wealth of information. For a full description, go to:
http://www.cotf.edu/ExoQuest/main.html


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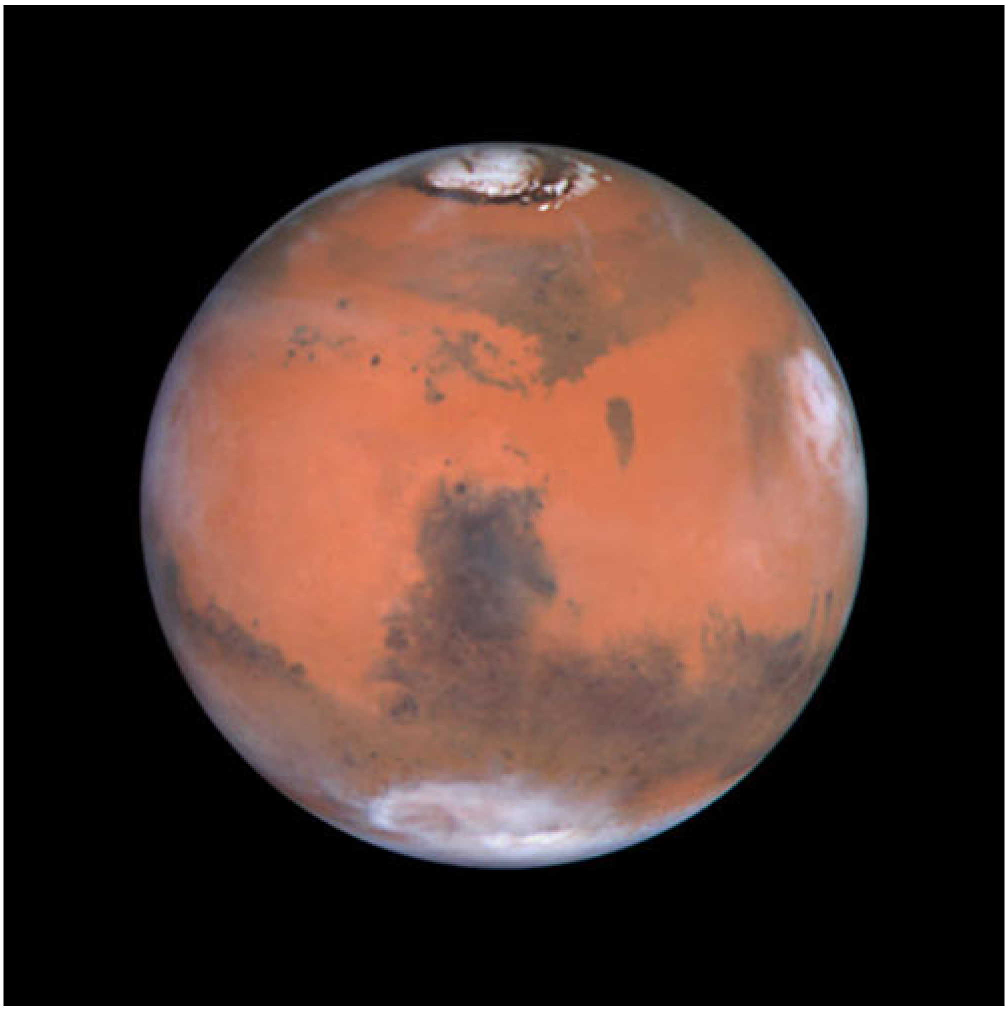
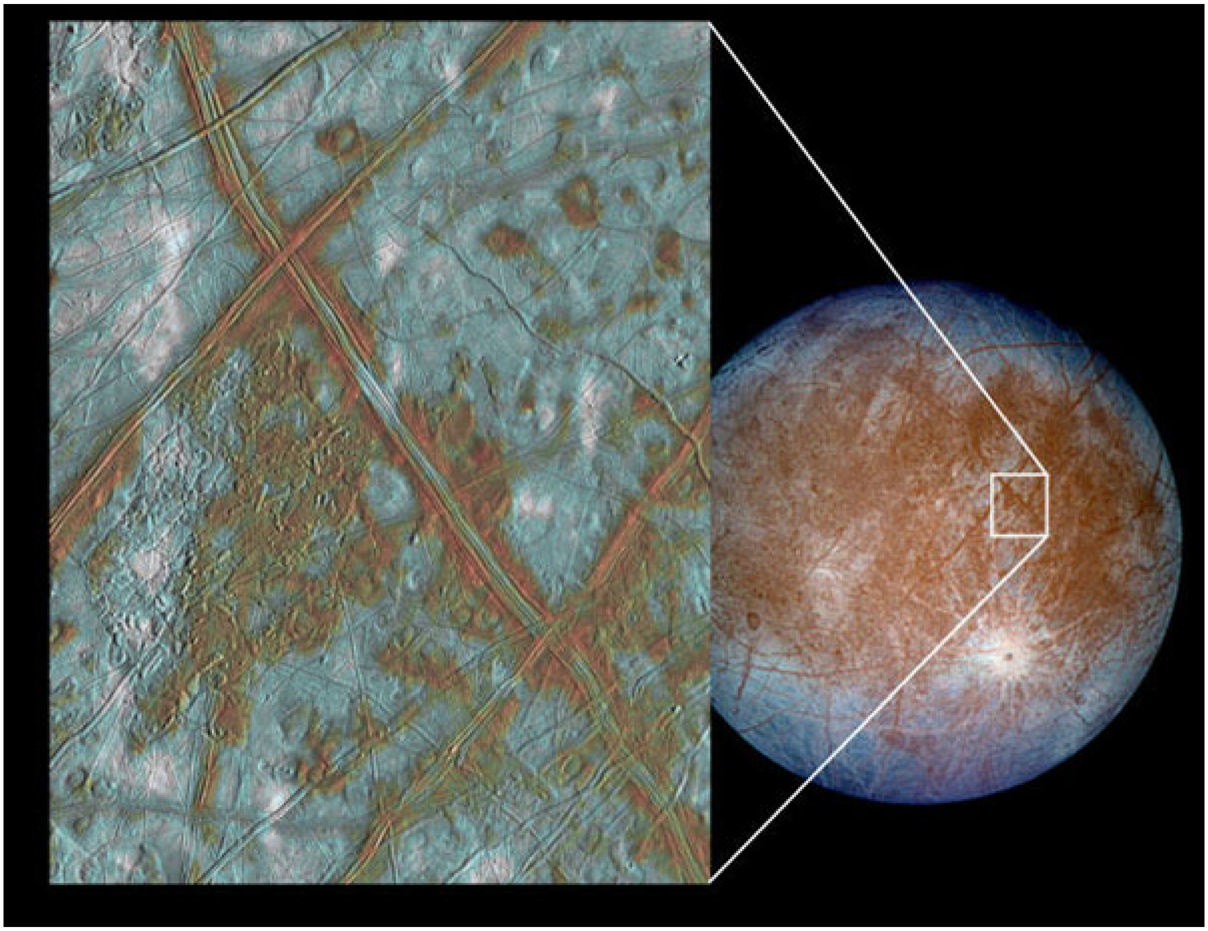
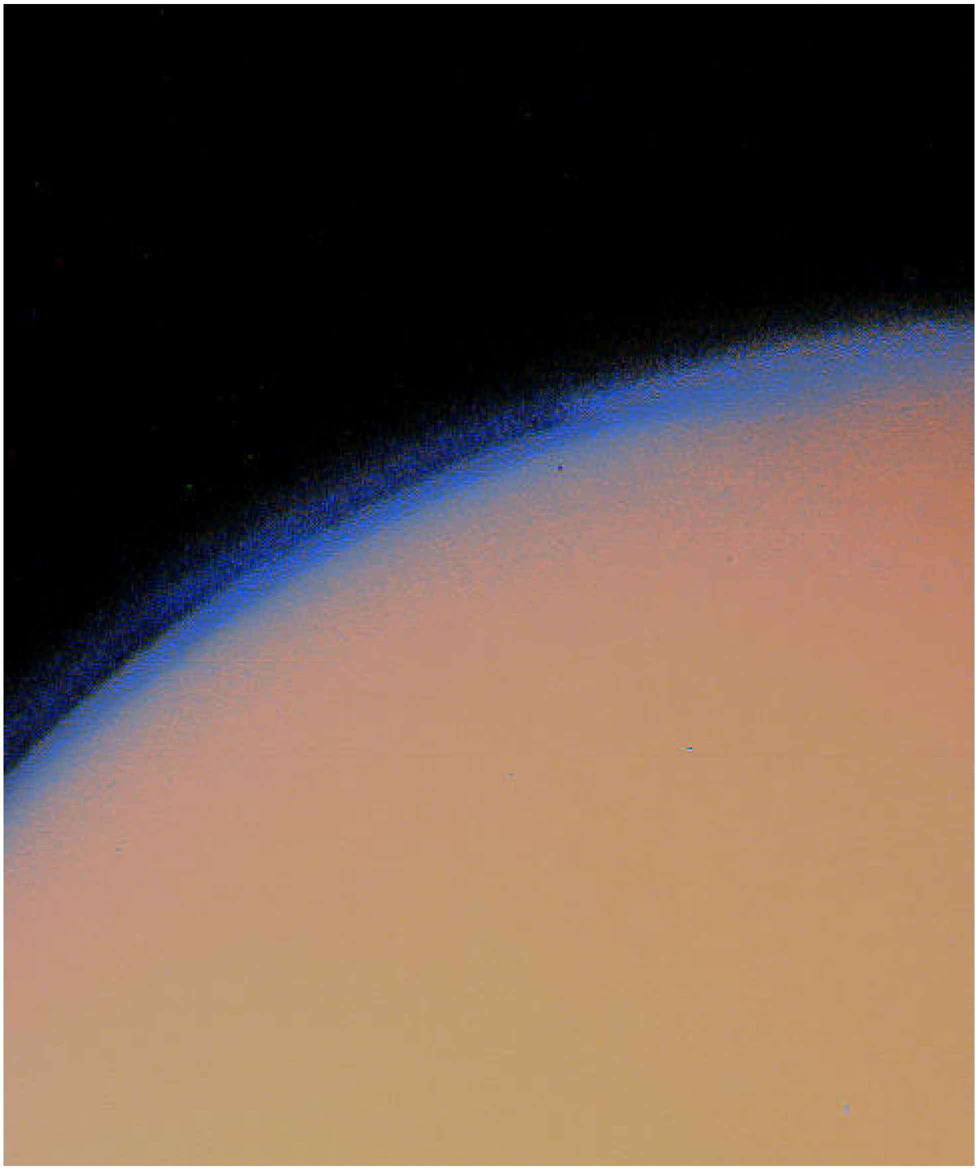


Mars has long captured our imaginations and remains a serious target for human exploration. With evidence of water once being plentiful on this planet, we take the maximum precautions when exploring this world. Many of the new protocols being developed are for the near future as we plan sample return missions.

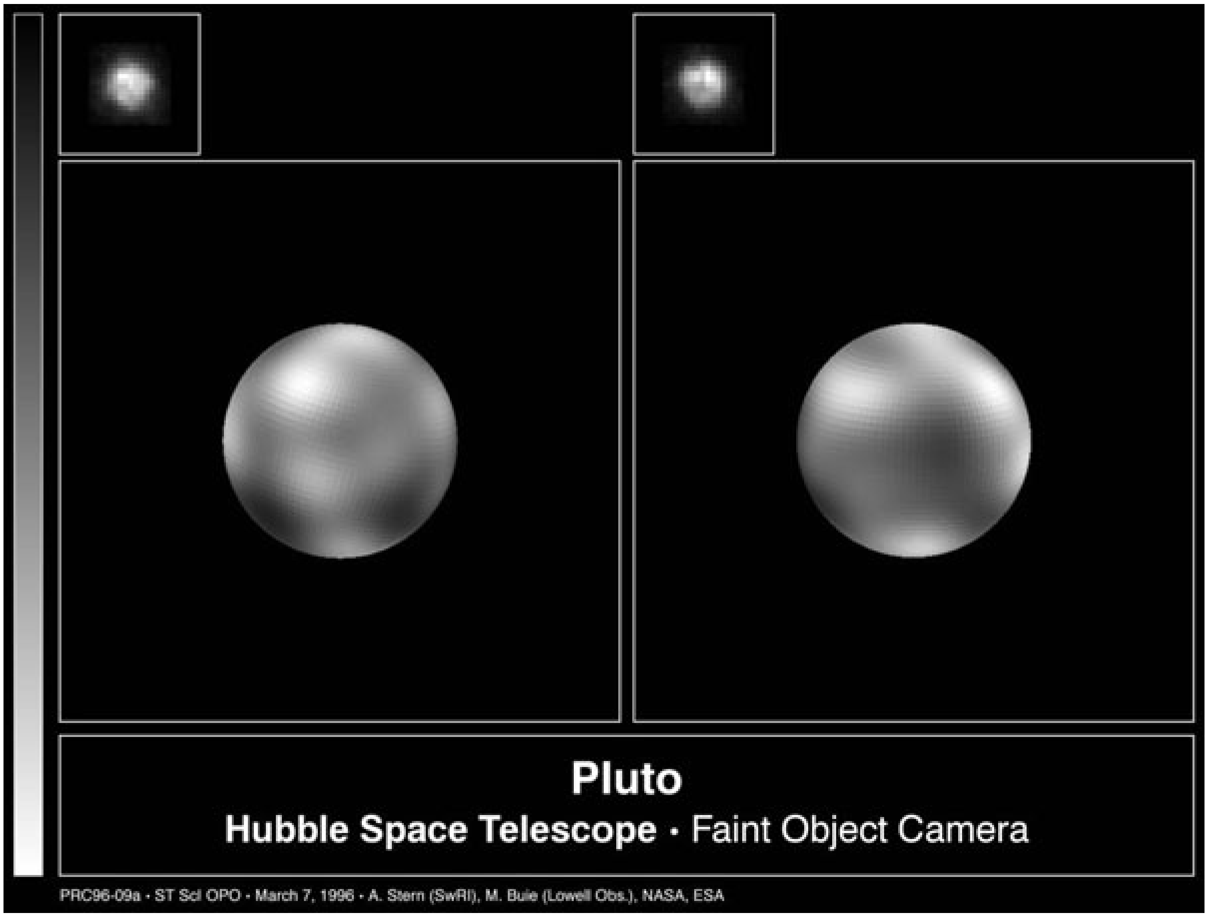


Europa is a moon of Jupiter. Its frozen surface is believed to have an ocean of liquid water beneath it heated by tidal forces. Water and heat make it another candidate for a possible abode of life.



Titan, Saturn's largest moon has a smoggy nitrogen atmosphere. Its make-up is similar to our own atmosphere, but much colder. Cassini will drop a probe through the smog to give us more detailed information about curious moon.

Eros, was the first asteroid to have a spacecraft put in orbit around it. Given its size and location, it is not a likely candidate to have life on it. Even though the spacecraft was eventually landed on the surface, the precautions to sanitize the spacecraft were much less rigorous than they are for a destination like Mars.




Pluto is the most distant planet in the solar system and is more like a comet than a planet. Because it always lurks at the frozen edges of the solar system, it is not a likely candidate for life. Any future spacecraft that may explore this distant icy world, will still be assembled in clean rooms but will not have to go through the same level of sanitizing that Mars rovers are subject to.