Name: ___________________________ Period: ______ Date: __________

Extremophiles

Artist's concept of an astronaut examining a rock sample on Mars. Life has been found living inside rocks in the various extreme environments on Earth. Clues derived from finding life in such terrestrial locations will serve as a guide to understanding where we might find life on other worlds.

Life based on carbon (which includes humans, plants, bacteria, etc.) have to live within certain conditions. For instance, we need a specific amount of oxygen, energy from the sun, water, and other things to live. However in the last few decades we've learned about organisms that don't need to live within these limits, they can live outside the limits and we call them "extremophiles" from the Latin "extremus" (being on the outside) and the Greek "philos" for love. Organisms that can live in more than one extreme, for example *Sulfalobus acidocaldarius* (a member of the Archea - an ancient branch off the family tree of life) lives at pH 3 and 80°C, are called polyextremophiles.

What do humans need to survive?

What are polyextremophiles?

Who are the extremophiles?
Most scientists think of extremophiles are microbes (tiny, tiny bacteria), however extremophiles include many things. Some organisms live at extremely high temperature, low temperatures, extremes of pH (high acidity or alkalinity), pressure, water, and salt levels. However there are some vertebrates (organisms with back bones) that can live in extreme cold temperatures like penguins and polar bears. They could be considered extremophiles too.

Summarize this paragraph.

To qualify as an extremophile, does an organism have to be an extremophile during all life stages? Under all conditions? Not at all. Spores, seeds, and sometimes eggs or larval stages are all far more resistant to environmental extremes than adult forms. Yet some adult organisms - trees, frogs, insects, and fish - can endure remarkably low temperatures during the winter as a result of seasonal shifts in physiology such as hibernation.

A Scanning Electron Micrograph of a Tartigrade

One of the most resilient organisms known are tardigrades ("water bears"). Tardigrades can go into a hibernation mode - called the tun state - where it can survive temperatures from -253°C to 151°C, as well as exposure to x-rays, and vacuum conditions. When you place tardigrades in perfluorocarbon fluid (again while hibernating), at a pressure of 600 MPa, (that's almost 6,000 times atmospheric pressure at sea level) they emerge from the experience just fine . Even the bacterium *Deinococcus radiodurans*, the most radiation resistant organism known, only achieves this resistance under some conditions such as fast growth and in nutrient-rich medium.

Why are tardigrades extremophiles?

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Lynn Rothschild, Ph.D., NASA Ames Research Center Tuesday, June 18, 2002
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Classification and examples of extremophiles

Environmental parameter	Type	Definition	examples
temperature	hyperthermophile thermophile mesophile psychrophile	Grows best >80°C Grows best 60-80°C Grows best 15-60°C Grows best <15°C	*Pyrolobus fumarii*, 113°C *Synechococcus lividis* *Homo sapiens* *Psychrobacter*, some insects
radiation	(no specific name)	Able to withstand various types of radiation (remember the electromagnetic spectrum)	*Deinococcus radiodurans*
pressure	barophile piezophile	Weight loving Pressure loving	unknown For microbe, 130 MPa
vacuum	(no specific name)	tolerates vacuum (space without matter)	tardigrades, insects, microbes, seeds.
desiccation	xerophiles	Able to withstand environments without water (can handle drying out)	*Artemia salina*; nematodes, microbes, fungi, lichens
salinity	halophile	Salt loving	*Halobacteriacea, Dunaliella salina*
pH	alkaliphile acidophile	High pH loving (pH of 9-14 – basic environments) low pH loving (acidic environments)	*Natronobacterium, Bacillus firmus* OF4*, Spirulina spp.* (all pH 10.5) *Cyanidium caldarium*, *Ferroplasma sp.* (both pH 0)
oxygen tension	anaerobe microaerophil aerobe	cannot tolerate O_2 tolerates some O_2 requires O_2	*Methanococcus jannaschii* *Clostridium* *Homo sapiens*
chemical extremes	gases metals	Can tolerate high concentrations of metal (metalotolerant)	*Cyanidium caldarium* (pure CO_2) *Ferroplasma acidarmanus*(Cu, As, Cd, Zn); *Ralstonia* sp. CH34 (Zn, Co, Cd, Hg, Pb)

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Extremophiles and Astrobiology

The study of extremophiles holds far more than Guinness Book of World Records-like fascination. Seemingly bizarre organisms are central to our understanding of where life may exist and where our own terrestrial life may one day travel. Did life on Earth originate in a hydrothermal vent? Will extremophiles be the pioneers that make Mars habitable for our own more narrow-minded species?

Why are extremophiles researched so much?

Fortunately, extremophile research is very profitable. Industrial processes and laboratory experiments may be far more efficient at extremes of temperature, salinity and pH, and so on. Natural products made in response to high levels of radiation or salt have been sold commercially. Glory also goes to those working with extremophiles. At least one Nobel Prize, that for the invention of the polymerase chain reaction (PCR), would not have been possible without an enzyme from a thermophile. As the world of molecular biology has become increasingly reliant on products from extremophiles, they will continue be the silent partner in future awards.

Current work on extremophiles in space focuses on two major aspects: Mars and Europa because of the possibility of liquid water - and thus life, interplanetary space because of the possibility of life traveling between planets.

This Mars Global Surveyor spacecraft photo covers an area approximately 3 kilometers (1.9 miles) wide by 6.7 km (4.1 mi) high. The image shows gullies eroded into the wall of a meteor impact crater in Noachis Terra. Channels and associated aprons of debris that are thought to have been formed by groundwater seepage, surface runoff, and debris flow.

Mars: Habitable?

Mars is considered inhospitable. Temperatures are, for the most part, frigid, exposure to ultraviolet radiation is high, and the surface is highly oxidizing, and it does not have any organic compounds on the surface. The atmospheric pressure is very low (similar to that of Earth's uppermost atmosphere) so liquid water is unstable on the surface. Yet hydrogeological evidence from Mars Global Surveyor hints that there may be liquid water under the surface. Previous evidence seems to show that it once flowed much more freely on the surface in ancient times.

Inhospitable means that things cannot live on it. What are two reasons why Mars inhospitable?

Could Mars harbor life under the surface, similar to the subsurface or hydrothermal communities found on Earth? If so, it would be protected from surface radiation, damaging oxidants, and have access to liquid water. Mars is rich in carbon dioxide, the raw material used by plants to produce organic carbon. Life has been found at the depths of Earth's oceans and several kilometers below the surface inside of rocks. If it did arise during a warmer, wetter period in Mars' history, perhaps it managed to migrate into warmer, more mild areas of the planet's interior before the surface became uninhabitable.

Why might underground water suggest that life exists on Mars?

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The Large Moons of Jupiter: Underground Oceans

With evidence adding up that one or more of the large moons of Jupiter (Europa, Ganymede, Callisto) have ice-covered lakes, the possibility of life on these moons becomes a subject of scientific discourse. One of these moons, Europa, has an ice layer too thick to allow enough light to get through to allow photosynthesis, the process that drives much of earthly life including life under the continuously ice-covered lakes of Antarctica. However, Chris Chyba from the SETI Institute has suggested that a livable atmosphere can exist on Europa based on the chemistry in the ocean's ice cover and its interaction with Jupiter's magnetosphere. The Galileo spacecraft has detected a weak magnetic field on Callisto, suggesting that salt water may lie beneath an ice-covered surface. Supportive evidence exists as well for an ocean with Ganymede. Several of Saturn's moons and other outer solar system bodies may also hold the potential for having a subsurface ocean.

What evidences are there for life on the moons of Jupiter?

Naked in Space: The Ultimate Exposure

Panspermia ("seeds spread far"), the idea that life can travel through space from one hospitable location to another is no longer wild speculation. Space is extremely cold, vulnerable to unfiltered solar radiation, solar wind, galactic radiation, space vacuum, and to slight gravity. But this dangerous realm can be crossed by life.

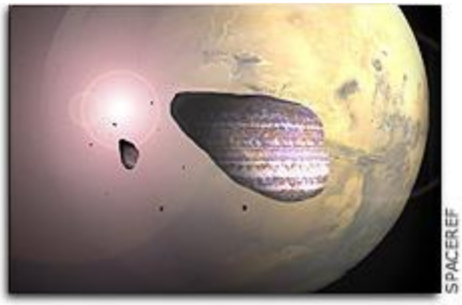
What is Panspermia?

We know from Mars meteorites, such as the (now) famous ALH84001 sample, that a natural vehicle exists for interplanetary transport. These meteorites contain organic compounds from Mars, showing that such compounds can survive the journey. Moreover, studies have shown that given a rock of sufficient size, conditions within a rock thrown off of Mars - and then later entering Earth's atmosphere - can remain cool enough organic material and also microbes contained within - could (theoretically) survive the trip.

What did we learn from the meteorites from Mars?

The criticism that life cannot endure extended periods in space is now being tested experimentally in space simulation facilities in the U.S. and Germany, and through unmanned flight experiments. NASA's Long Duration Exposure Facility and the European Space Agency's BioPan space experiments showed that microbes can survive direct exposure to the raw conditions of space. Survivors to date include spores of *Bacillus subtilis* and halophiles in the active (vegetative) state. Hopes for further experiments of this nature rest on both unmanned flights and the ESA Exposed Facility planned for the International Space Station.

Why is there research for how long microbes can survive in space?



Over the history of the solar large impact events may have served as a steady means of transporting rocks (which arrived as meteorites) between one world or another. Whether or not any of these rocks ever actually contained viable life forms is not known. However recent studies suggest that this is possible.

Summary

Earth provides us with a wondrous array of life's adaptations. Indeed, by studying the extremophiles here on Earth, we may get the first clear indication of what ET could be like - or at least the range of things they might eat and breathe.

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