Extreme organisms on Earth show us just how weird life elsewhere could be. by Chris Impey

How life could thrive on hostile worlds

Humans have left their mark all over Earth. We’re proud of our role as nature’s generalists — perhaps not as swift as the gazelle or as strong as the gorilla, but still pretty good at most things. Alone among all species, technology has given us dominion over the planet. Humans are endlessly plucky and adaptable; it seems we can do anything.

Yet in truth, we’re frail. From our safe living rooms, we may admire the people who conquer Everest or cross deserts. But without technology, we couldn’t live beyond Earth’s temperate zones. We cannot survive for long in temperatures below freezing or above 104° Fahrenheit (40° Celsius). We can stay underwater only as long as we can hold our breath. Without water to drink we’d die in 3 days.

Microbes, on the other hand, are hardy. And within the microbial world lies a band of extremists, organisms that thrive in conditions that would cook, crush, smother, and dissolve most other forms of life. Collectively, they are known as extremophiles, which means, literally, “lovers of extremes.”

Extremophiles are found at temperatures above the boiling point and below the freezing point of water, in high salinity, and in strongly acidic conditions. Some can live deep inside rock, and others can go into a freeze-dried “wait state” for tens of thousands of years. Some of these microbes harvest energy from methane, sulfur, and even iron.

The study of extremophiles has taught scientists that life has evolved on Earth to colonize even the most inhospitable environments. And if they can do it here, why can’t they do it out there — in the extremes of cold, pressure, and radiation beyond Earth?

As NASA prepares to spend billions on the search for life in the solar system, it’s worth recalling the exotic and weird life right under our noses. We have much to learn from extremophiles that could assist and inform the search for life elsewhere.

Extreme origins

Earth is a microbial planet, and the common ancestor of all life on Earth...
was probably a heat-loving extremophile. When scientists resurrected proteins from these ancient bacteria for study in the lab, the organisms performed best at aizzling temperature of 150° F (65° C).

Early Earth was as hostile and inhospitable as Dante’s hell. Visualize lightning, steam, a rain of meteorites, and a surface covered with magma and sulfur. This doesn’t exactly bring to mind Darwin’s “warm little pond.”

Think of extremophiles as stout-hearted little biological superheros, doing heroic jobs under nearly impossible conditions. If it helps, imagine them clad in tiny masks and capes and possible conditions. If it helps, imagine 

The names of extremophile catego-

As the temperature of water rises, conditions slow down and life gets sluggish. When water becomes superheated, it expands by 10 percent and causes cells to rupture. Yet there is a type of nematode — tiny, wormlike creatures — that can survive even boiling water.

Organisms ranging from microbial colonies to the tiny insect called a Himalayan midge remain active down to –0.4 F (–18° C). Biodiversity in the coldest parts of the world is amazing. In polar regions, although this is still unconfirmed.

The deep-sea tube worms in this image live on hydrothermal vents along the Pacific Ocean’s Galápagos Rift. The worms live symbiotically with bacteria in their guts. The bacteria use hydrogen sulfide gas spewing from the vents as a source of energy and, in the process, make carbohydrates for the worms. (Bruce W. Halsted, Woods Hole Oceanographic Institution)

The big chill

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But Ferroplasma acidarmanus likes it there just fine. This microbe is a member of the Archea, Earth’s earliest forms of life. It grows best at an acidic pH of 1 and a temperature of 240° F (115° C). For comparison, consider that lime juice has a pH of 2, similar to vinegar. But F. acidarmanus can even tolerate a pH of 0 — battery acid. It does this by using protons in an electrical balancing act that fends off the worst effects of acidity within the cell. Some organisms have adapted to multiple environmental extremes. Meet Bacillus infernus, the “bacillus from hell,” which withstands a combination of great heat, pressure, and acidity. This microbe resembles a tough customer in a can of meat that spoiled anyway.

The microorganism Chryseobacterium greenlandensis revived itself after lying dormant for 120,000 years in glacial ice at a depth of nearly 2 miles (3.2 kilometers). The existence of such a cold-hardened bacterium on Earth raises hopes of finding life in the solar system’s frigid fringes. One place that may harbor extraterrestrial extremophiles is the liquid ocean beneath the icy crust of Jupiter’s moon Europa (inset). Iceland’s Lonendal Center (PICO) (image: NASA/ESO/2012)

Microbial Godzilla

Last, consider a creature that’s like Godzilla compared to a normal extremophile. The remarkable tardigrade is no bigger than the dot above a capital A. But Ferostata radiodurans has the amazing adaptability of being able to withstand radiation levels that would quickly extinguish most other Earth life. Michael J. Daly (UHSUHS)

Water bears survive adversity by going into cryptobiosis, a truly deathlike state where metabolism plummets to 0.01 percent of its normal rate, or is undetectable. The organism’s water content falls to 1 percent of normal. It forms a hard, waxy exterior called a tun, which renders it impervious to the elements. Lightweight, desiccated tuns disperse on the wind and hitchhike on animals for long distances.

Alien extremists

Earth must shape our expectations for finding biology elsewhere in the universe. Extremophiles challenge fundamental assumptions about what life is and what normal is.

The term extremophile is anthropocentric. Their environments seem extreme only to us. To an extremophile, they’re normal. The range of adaptation of terrestrial life makes it more plausible that microbial life could exist in the martian permafrost, or on the frigid oceans of Europa, or in a half dozen other harsh and exotic environments in the outer solar system. Microbes might have hitchhiked on meteoritic debris between planets and moons. Extremophiles may even give us tips for our own travel in space, because cryptobiosis (suspended animation) is likely to be a requirement if we ever get to travel to the stars. At the very least, extremophiles expand the definition of a star’s habitable zone far beyond the slender range of distances at which liquid water can exist on a planet’s surface. Extremophiles show that life on Earth is like a liquid that has filled the full “shape” of the environmental conditions. On planets beyond the solar system, we have every reason to believe that microbial life will adapt to local conditions and so may be weirder than anything we’ve seen on Earth.

Heat is available in the crust of any large planet or any moon gravitationally flexed by the planet it orbits. If life can thrive under a planet’s crust or deep in its oceans, it may not need an atmosphere. If life can use hydrogen as a nutrient and get its energy from infrared radiation, it may be happy with any kind of host star — or may not need a star at all!

Across the cosmos, planets and moons covered by a web of extremophiles may be the norm. It’s hard to feel kinship with Bacillus infernus, but the fecundity of the universe and the prospect of microbial life on millions of planets beyond the solar system are thrilling developments in astronomy.