Fact or Fiction?

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Amazing Bacteria

Imagine diving into water that is boiling or near freezing. Better yet, what about jumping into a vat of vinegar, household ammonia, concentrated brine, or your copper sulfate plating solution? We wouldn't fare too well in such environments, yet many micro-organisms make their home in such forbidding brews.[1] Thriving in environments always thought to be off-limits for living things are organisms called extremophiles (liking extremes), because they not only tolerate, but even thrive in extreme conditions.

Extremophiles belong to a group of organisms called the Archaea or "Old Ones." Archaeans, like bacteria, are tiny, one-celled life forms that lack organized nuclei. They may be among the oldest organisms on Earth and perhaps the first living things to emerge from the primordial ooze. They include organisms that can tolerate heat (thermophiles), very cold climates (psychrophiles), high pressure (barophiles), low pH solutions (<1) (acidophiles), and high pH solutions (>9) (alkaliphiles).[2] A strain of mold has been reported that grows in a 270 g/L copper sulfate solution containing some sulfuric acid, as long as a little sugar was present.[3] Others have also reported on fungus growing in dilute sulfuric acid saturated with copper sulfate.[4,5] Rich, blue bacteria have been found in potassium ferricyanide solution.[6]

Lake Berkeley, which covers almost 700 acres of a former open-pit copper mine in Butte, MT, holds some 30 billion gallons of highly acidic, metal-laden water. It's the country's largest and most unusual body of contaminated water, with a pH of 2.6 and metals such as Al, As, Cd, Cu, Fe, Mn, Zn, and others.[7] In the past five years, more than 40 small organisms have been discovered in the lake, and these hold much potential for agriculture and medicine. It's even thought that some of these organisms can be employed to reclaim the lake and other similar contaminated waters by neutralizing acidity and absorbing dissolved metals.

Bacteria are found everywhere. Besides being present around sulfurous hot springs and volcanic vents, beneath glaciers or deep within the Earth where no physical contact with the outside world and its sunlight and atmosphere had ever taken place, they are found in the plaque of our teeth, our blood, our foodstuffs, and even our filtered beverages.[8] Some appear to be immortal, in that they remain dormant for long periods of time, yet are continually capable of resurrection. They gather together in stasis when all available water freezes or evaporates, and wait until it returns. It's not known how long they remain dormant, but the most conservative estimate is tens of thousands of years, while the upper estimate is hundreds of millions of years. A recent paper in *Nature* discussed 250 million-year-old bacterium that had survived in suspended animation until located two years ago.[9] In the same journal, Parkes[10] asks the question: If bacteria can survive for this length of time, why should they die at all?

Shrunken, dried microbes have been revived from ancient salt domes, from sub-Antarctic ice cores, and from NASA gear exposed to the cold vacuum of space.[11] And they've only recently been discovered. For example, more than 20 micro-organisms that grow at temperatures of +80°C have been found since 1980.[12] Michael Taylor, investigative journalist and spelunker, provides a fascinating tale of the discovery and scrutiny of nanobacteria in his book, *Dark Life*,[11] and Michael Gross in *Life on the Edge*[4] is equally fascinating in describing life on Earth—not by the rules, but by the exceptions to them. The study of these micro-organisms is quite new, and scientists are learning that examining them may provide hints about the possibility of extraterrestrial life.

Because some of these "extreme environments" may well pass for "normal" elsewhere in the solar system, the chances of finding life elsewhere start to become much more plausible.[11]

Some of the bacteria have been found to exhibit exciting new antibiotic and anticarcinogenic activities, which pharmaceutical companies are busy investigating. Because some of the bugs never have been in contact with the outside world, numerous diseases seemed to fall easy prey to certain strains of bacteria. This might even explain why hot springs and spas have gained their reputation for curative capabilities.

Think about this for a moment: You've just finished your hot tub soak at the spa and now you drink a glass of the foul smelling sulfur water, which we now know contains zillions of bugs, and your ailments are cured. Certain bacteria have shown the ability to kill cells associated with a particular type of breast cancer without harming healthy cells or other cancers. Why? The best guess, according to Taylor,[11] is that in order to protect their scant underground food sources from invading fungi, the organisms have evolved powerful toxins to attack an enzyme associated with a particular fungal growth phase.

Another issue relates to the fact that caves are oligotrophic environments (low available nutrients), and organisms that have adapted to this kind of lifestyle can't afford to waste energy wiggling around looking for something to eat. Therefore, they become adept at sticking tightly to surfaces in places where food will come to them via the slow trickle of water or other chemicals through rock. And it turns out that sticking tightly to surfaces is one of the attributes researchers look for in anti-cancer drugs.[11]

The thermophilic bacteria that live in Yellowstone hot springs have been the foundation of impressive developments in medicine and biotechnology.[13] The unique thermostable enzymes of these bacteria are finding wide industrial and medical use, and have become the basis of a multimillion dollar industry. How? In order to copy DNA and amplify it using the polymerase chain reaction (PCR), an enzyme (DNA polymerase) is needed that is active at high temperature. The DNA polymerase of Thermus Aquaticus (Taq polymerase), fills the bill. During the successive heating cycles of PCR, Taq polymerase is not destroyed, but continues to work. During each successive round of heating, the amount of DNA doubles. Progressive doubling leads to an exponential increase in DNA. From one original molecule, one can get millions! Taq polymerase finds wide use in medical diagnosis (AIDS, for instance) and forensics (DNA fingerprinting), and has become the basis of a $300,000,000 industry. Yellowstone may have a billion-dollar potential for the biotechnology industry.[13]

There are other opportunities under consideration.[12] Very-high-temperature proteases, amylases, and other hydrolases would be a boon in the food-processing industry. Fats could be hydrolyzed, proteins digested, and fiber modified enzymatically to make food more palatable and healthful. Another potential application of extremophiles involves the use of high-temperature glucose isomerases in the production of corn syrup, and high-temperature enzymes might be used to enhance the flow of oil or gas in drilling operations. Researchers speculate about possible roles for extremozymes in cleaning up abandoned military bases or other areas contaminated with solvents. Bacteria, especially members of the genus *Bacillus*, can concentrate a variety of metals on their anionic cell walls or, occasionally, within themselves.[14,15] This process, referred to as biosorption, has commercial applications such as metal removal from industrial process waters, contaminated groundwaters and surface waters, landfill and soil leachates, nuclear waste streams, and process streams.[16] Bio-organisms are currently used in our industry to continuously metabolize oils and greases in a soak cleaner that is operated at a temperature of 50°C and pH of 9–9.5. The organisms live in the cleaner and are recirculated through a maintenance module where pH is monitored/adjusted, and dead organisms are drawn off and new ones are added on a routine basis. According to AESF's Frank Altmayer,[17] folks using this system are quite pleased with it.

Substantial market opportunities exist for the use of biosorbents in the treatment of high-level radioactive wastes. However, little research has been done on the effect of high-level radiation on the long-term stability of biosorbent products.

Biobenefication of ores is a technology that has emerged relatively recently. It involves the removal by microbial leaching of ore constituents, which interfere with the winning of metal values from the ore. It is currently being practiced in dump and underground uranium and copper leaching operations, and the technology has taken on special significance in the processing of some gold ores.[18] A potential for bioleaching or biobeneficiation of some other ores—such as aluminosilicates, complex sulfides, Ag, Co, Cr, Ga, Mn, Mo, Ni, Pb, and Zn—also exists.[19] *P&SF*

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