The role of the Australian Centre for Astrobiology (Centre of Research Excellence) in the Macquarie University Biotechnology Research Institute

While it may seem strange that the Australian Centre for Astrobiology (Centre of Research Excellence) is part of the Biotechnology Research Institute at Macquarie University, there are significant theoretical and technical links between the geologists and the microbiologists in the Institute.

It is widely recognised that there is a strong need to link microbiology more closely with geology in order to find explanations for many geological phenomena. Some of the organisms involved in geological processes are also of interest to the biotechnologist.

Although microbial and geochemical interactions are tightly interwoven within hydrothermal extreme environments, our knowledge of these interactions is limited. Research in the Centre is examining such interactions, concentrating on organisms involved in metal deposition and mineral formation.

Of particular interest are sulphate-reducing bacteria (SRB), a large and widespread group of anaerobic bacteria. SRB play an important role in geochemical sulphur cycling, such as the concentration of metals into sediment-hosted sulphide ore deposits. These investigations are providing insights into sulphur cycling in hydrothermal systems, and also providing clues about processes that were probably more widespread in the geological past. Increased knowledge of such geomicrobiological processes will contribute to a better understanding of the origin of life and the evolution of the biosphere.

In other studies, Labrenz *et al.*[1] have discovered sulphate-reducing bacteria that tolerate low levels of oxygen and can precipitate zinc sulphide minerals. These bacteria have a wide spatial and temporal distribution and a distinct preference for low oxygen or oxygen-free environments. They may be important players in geochemical cycling and in the concentration of metals into sediment-hosted sulphide ore deposits, and may provide clues to processes that may have been more widespread in the geologic past.

Peter L Bergquist

Biotechnology Research Institute
Macquarie University
North Ryde NSW 2109

Tel: (02) 9850 8614
Fax: (02) 9850 9748
E-mail: peter.bergquist@mq.edu.au

There is general consensus that the low oxygen conditions that dominated the planet's first 2000 million years favoured the proliferation of sulphate-reducing organisms and that they consequently controlled their environment. The implication is that bacterial sulphate reduction has been in operation from the early Archaean period until today (although geological evidence of this process is not seen until much later).

There is an obvious overlap of interest between the geologists and the microbiologists in determining the bacteria and archaea involved in mineral deposition in hydrothermal environments. The use of small subunit (SSU) primers and PCR is a key tool for these studies. Analysis of the SSU rRNA sequences of the microorganisms present within these hydrothermal environments will establish the extent of the diversity present.

Chemical analysis of air and water, as well as geochemical and meteorological readings, will allow a comprehensive description of environmental parameters. This will also clearly define each ecological niche from which samples are collected. Combination of these data will provide a comprehensive survey of the microbial ecology of the hydrothermal environments under study. An interdisciplinary approach makes the task simpler and both scientific specialities benefit from each other's particular expertise.

On Earth, living organisms inhabit a remarkable range of extreme environments, but our knowledge of the limitations for life is still incomplete. Future searches for extant or extinct life on neighbouring planetary bodies such as Mars and Europa will target terrestrial-like microorganisms[2]. Clearly, knowledge of terrestrial life would have little relevance for detecting organisms that had resulted from de novo genesis elsewhere in the solar system, but such an event is not the expectation of researchers in the new field of astrobiology[3].

It is now accepted that meteor-strikes could have resulted in cross-contamination of the planetary bodies soon after the time that life first emerged on Earth. There is increasingly compelling evidence for such a process[4, 5] and controlled experiments show that some species of bacteria have the longevity and radiation resistance necessary to survive the journey[6].

Furthermore, there is now empirical evidence that confirms what computer modelling has asserted for a number of years – heating of meteoric material both on ejection and re-entry would not be severe for sub-surface lithotrophs and ejected material reaching escape velocity. The journey after a large meteoric impact may take less than 100 years to cross the interplanetary space between Mars and Earth [5] – easily survivable by a deep-frozen microbe.

The commercial importance of exploring the metabolic and physiological diversity present within hydrothermal and deep earth systems cannot be overemphasised. The world market for industrial and research enzymes and reagents alone is expected to be in excess of US$10.5 billion per year in 2005. Extremozymes, isolated from extremophilic microorganisms, many of which are found in hydrothermal systems, contribute substantially to this annual figure. Only a very small percentage of this large and diverse group of organisms has yet been isolated and characterised in any detail. It is clear that a large number of extremozymes remain to be discovered, some of which will undoubtedly revolutionise whole areas of the biotechnology industry.

Two recent examples of how the study of bacteria from thermophilic environments can contribute to biotechnology are our recent findings of a xylan-degrading enzyme (xylanase) from an uncultured microorganism and the isolation of novel DNA polymerases with reverse transcriptase activity from extreme thermophiles isolated from high temperature anaerobic environments.

In many cases, thermophilic bacteria do not form conventional biofilms because of silica deposition; instead, they exist on granules of silica sand and the bacterial genomic DNA can be extracted from these sands. One study of such a pool sample showed a wide variety of bacteria and archaea as judged by rDNA analysis and allowed us to isolate the gene for a novel xylanase whose product retained activity at 110˚C [7]. Such an enzyme has advantages in the biological bleaching of paper pulp, where the kraft pulp is in large volumes at temperatures from 70-100˚C.

The second example relates to the isolation and cloning of a series of novel DNA polymerases unrelated to *Taq* polymerase that show substantial reverse transcriptase activity in buffer containing Mg^{2+}, allowing a one-tube reaction for the production of cDNAs [8].

These few examples show that investigations into geochemical cycling and looking for analogues for extra-terrestrial exploration on Earth can be closely linked to the interests of the applied microbiologists, providing mutually supportive research expertise that allows the discovery of unorthodox microorganisms and provides the possibility of exploiting their genes.

References

1. Labrenz M *et al.* Formation of Sphalerite (ZnS) deposits in natural biofilms of sulfate-reducing bacteria. *Science* 2000; 290:1744-174.
2. Walter M. *The Search for Life on Mars.* Allen and Unwin, St. Leonards, Australia, 1999, p170.
3. Pace NR. The universal nature of biochemistry. Proc. *Nat. Acad. Sci*. 2001; 98:805-808.
4. Nicholson WL, Munakata N, Horneck G, Melosh HJ & Setlow P. Resistance of *Bacillus* endospores to extreme terrestrial and extraterrestrial environments. *Microbiol. Mol. Biol. Revs.* 2000; 64:548-572.
5. Weiss BP, Kirschvink JL, Baudenbacher FJ, Vali H, Peters NT, MacDonald FA & Wikswo JP. A low temperature transfer of ALH4001 from Mars to Earth. *Science* 2000: 290:791-795.
6. Vreeland RH, Rosenzwieg,WD & Powers DW. Isolation of a 250 million-year-old halotolerant bacterium from a primary salt crystal. *Nature* 2000; 407:897-900.
7. Sunna A & Bergquist PL. A gene encoding a novel extremely thermostable 1,4-ß-xylanase isolated directly from an environmental DNA sample. *Extremophiles* 2003; 7:64-70.
8. Shandilya H, Flynn JK, Astatke MPJ, Shih PJ, Gerard GF, Lee JE, Griffiths K, Gibbs MD & Bergquist PL. Thermophilic bacterial DNA polymerases with Reverse Transcriptase activity. *Extremophiles. Accepted* 2003.