Was Mars the Cradle of Life?

Paul C. W. Davies
Australian Centre for Astrobiology, Macquarie University
NSW 2109
pdavies@els.mq.edu.au

The problem of life's origin remains one of the great outstanding challenges to science. Ever since Charles Darwin mused about a "warm little pond" incubating life beneath sunny primeval skies, scientists have speculated about the exact location of this transforming event. Nearly a century and a half later, we remain almost completely ignorant of the physical processes that led from a nonliving chemical mixture to the first autonomous organism. However, some progress at least has been made on tracking down *where* and *when* life first established itself on Earth. Fossil evidence suggests that the biological record extends back at least 3.5 billion years, pointing to a still earlier origin[1]. But this presents a problem. The cratering record of the moon implies that Earth was subjected to intense bombardment by large comets and asteroids over an extended duration until about 3.8 billion years ago. The largest of these impacts would have released enough energy to swathe the planet in incandescent rock vapour, boiling the oceans and sending sterilizing heat pulses a kilometre into the exposed crust[2]. This unpromising setting – hardly a secure one for warm little ponds – has prompted some astrobiologists to conjecture that life began somewhere else and came to Earth ready-made[3]. Favourite among extraterrestrial originating locations is the planet Mars[4].

Mars is the most Earth-like of our neighbouring planets and enjoyed a number of advantages during the early history of the solar system. Though a freeze-dried desert today, Mars was warm and wet before about 3.6 billion years ago[5]. Being a smaller planet, it cooled quicker, making it suitable for life sooner than Earth. Gene sequencing indicates that the oldest and deepest branches of the tree of life are occupied by hyperthermophilic archaea and bacteria[6], hinting that the earliest life forms dwelt deep beneath the oceans near volcanic vents, or even kilometres underground in the crust itself. The deep subsurface zone remains populated on Earth today, and probably offers the most promising location on Mars for finding any extant life. It would have become cool enough for hyperthermophilic microbial life on Mars perhaps as long ago as 4.5 billion years, when the Earth's crust was still sizzling. Ensconced in this Hadean niche, shielded by a kilometre of two or rock, Martian life could have withstood the ferocious early bombardment that afflicted Mars just as it did Earth.

Plausible though this exo-genesis theory may seem, it leaves the problem of how life spread from Mars to Earth. Fortunately a mechanism readily suggests itself. Earth and Mars are known to trade rocks on an ongoing basis: a couple of dozen Mars meteorites have so far been identified in terrestrial collections. The mode of delivery is the very same cosmic bombardment that so imperilled early life. Comets and asteroids can hit Mars hard enough to splatter rocks across the solar system, and computer simulations show that a few per cent end up on Earth eventually[7]. Cocooned within a rock a metre or two across, a microbe would be spared the worst hazards of outer space. The cold vacuum of space is not too problematic, and can even serve to preserve microbial spores. More importantly, the rock would shield the microbes therein from solar ultra-violet rays, solar flares and all but the highest energy cosmic rays. Studies by Curt Mileikowsky, Jay Melosh and their collaborators[8] indicate sojourn times of millions of years in such conditions before the accumulated radiation damage in any embedded microbes becomes irreversible. That is easily long enough for some fraction of ejected Mars rocks to land on Earth. Given a favourable trajectory, an incoming Mars rock would not burn up, or indeed even heat up much in the interior, on entry into Earth's atmosphere.

These considerations add up to a significant probability that, had life got going on Mars first, it would have been transported to Earth on a continuing basis over hundreds of millions of years, enabling it to become established as soon as terrestrial conditions permitted – say, 3.8 billion years ago. The same scenario could work in reverse, of course, though Earth's deeper gravity well and more torrid early history makes it less plausible. Calculations indicate that the transportation of viable microbes much farther afield than near-neighbour planets is exceedingly unlikely[9], so the above mechanism must not be regarded as giving support to the old panspermia theory of Arrhenius[10].

If Mars was indeed the cradle of terrestrial life, it adds urgency to the search for traces of life on the Red Planet today. Because Mars has not been subjected to severe tectonic processing, the record of the rocks there is likely to be much better preserved. On Earth, almost all traces of life's processes before 3.5 billion years ago have probably been obliterated. However, the fact that Earth and Mars are clearly not biologically isolated implies that the discovery of past or extant life on Mars will not provide us with a much sought-after second genesis. Rather, Martian and terrestrial organisms would occupy different branches on the same tree of life. Without a second sample of life – another bio-system that started from scratch independently of terrestrial biology – we will still not know the answer to the biggest question of all: whether life's origin was a freak chemical event, unique in the observable cosmos, or an automatic product of intrinsically bio-friendly laws of nature.

References

1. Schopf, J.W. *Cradle of Life: The Discovery of Earth's Oldest Fossils* (Princeton University Press, Princeton, N.J., 1999).
2. Sleep, N.H., Kahnle, K.J., Kasting, J.F. and Morowitz, H.J. (1989). Annihilation of ecosystems by large asteroid impacts on the early Earth. *Nature*, 342: 139-142.
3. Davies, P. *The Origin of Life* (Penguin, London 2003).
4. Kirschvink, J.L. and Weiss, B.P. (2002). Mars, panspermia, and the origin of life: where did it all begin? *Palaeolontogia Electronica*, 4 (2), 8-15. See also ref. 3.
5. Walter, M. *The Search for Life on Mars* (Allen & Unwin, Sydney, 1999.
6. See *Evolution of Hydrothermal Ecosystems on Earth (and Mars?)* by Gregory Brock and Jamie Goode, eds. (Wiley, New York 1996), Chapters 1 and 2.
7. Gladman, B. et. al. (1996). The exchange of impact ejecta between terrestrial planets. *Science* 271: 1387-8.

8. Mileikowsky, C. *et. al*. (2000). Natural transfer of viable microbes in space. *Icarus*, 145: 391-427.
9. Melosh, J. (2002). Exchange of meteorites (and life?) between stellar systems. Proceedings of the Rubey symposium, to be published.
10. Arrhenius, S. *Worlds in the Making* (Harper, London 1908).