

## Appendix A

# *Deinococcus radiodurans* as an Analogue to Extremophile Organisms That May Have Survived on Mars

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The only genetic systems within which the equivalent of millions of years' worth of background radiation accumulated as genetic damage have been studied in a living organism are those developed by the terrestrial bacterium *Deinococcus radiodurans*.<sup>1-7</sup> This bacterium is capable of repairing massive genetic damage without lethality or increasing mutation frequency. As such, *D. radiodurans* is an excellent organism in which to consider the potential for survival and biological evolution beyond its planet of origin, as well as the ability of life to survive extremely long periods of metabolic dormancy in high-radiation environments. Ultimately, the survival of any organism in such environments will be determined by its ability to repair, and recover from, accumulated genetic damage. *D. radiodurans* could likely survive extended periods of metabolic dormancy near the surface of Mars, periods of time in which the equivalent of Mrads of radiation damage would be accumulated in any genetic material.

It is likely that during the first 500 million years (0.5 Ga) of its existence, Mars had a warmer and wetter climate than it has now, and an active hydrologic cycle. This may slightly predate the time at which Earth first began to support water and life; evidence of chemically evolved life on Earth dates to ~0.6 Ga after its formation.

<sup>1</sup>Battista, J.R., Earl, A.M., and Park, M.-J. 1999. Why is *Deinococcus radiodurans* so resistant to ionizing radiation? Trends Microbiol. 7: 362.

<sup>2</sup>Minton, K.W. 1996. Repair of ionizing-radiation damage in the radiation resistant bacterium *Deinococcus radiodurans*. Mutat. Res. DNA Repair 362: 1.

<sup>3</sup>Mattimore, V., and Battista, J.R. 1996. Radioresistance of *Deinococcus radiodurans*: Functions necessary to survive ionizing radiation are also necessary to survive prolonged desiccation. J. Bacteriol. 177: 5232.

<sup>4</sup>Lange, C.C., Wackett, L.P., Minton, K.W., and Daly, M.J. 1998. Engineering a recombinant *Deinococcus radiodurans* for organopollutant degradation in radioactive mixed waste environments. Nat. Biotechnol. 16: 929.

<sup>5</sup>Brim, H., McFarlan, S.C., Fredrickson, J.K., Minton, K.W., Zhai, M., Wackett, L.P., and Daly, M.J. 2000. Engineering *Deinococcus radiodurans* for metal remediation in radioactive mixed waste environments. Nat. Biotechnol. 18: 85-90.

<sup>6</sup>Daly, M.J., Ouyang, L., Fuchs, P., and Minton, K.W. 1994. In vivo damage and rccA-dependent repair of plasmid and chromosomal DNA in the radioresistant bacterium *Deinococcus radiodurans*. J. Bacteriol. 176: 3508.

<sup>7</sup>White, O., Eisen, J.A., Heidelberg, J.F., Ilickey, E.K., Peterson, J.D., Dodson, R.J., Haft, D.H., Gwinn, M.L., Nelson, W.C., Richardson, D.L., Moffat, K.S., Qin, H., Jiang, L., Pamphile, W., Crosby, M., Shen, M., Vamathevan, J.J., Lam, P., McDonald, L., Utterback, T., Zalewski, C., Makarova, K.S., Aravind, L., Daly, M.J., Minton, K.W., Fleischmann, R.D., Ketchum, K.A., Nelson, K.E., Salzberg, S., Smith, H.O., Venter, J.C., and Fraser, Claire M. 1999. Genome sequence of the radioresistant bacterium *Deinococcus radiodurans* R1. Science 286: 1571-1577.