Integrating Astrobiology Research for Exploration of Icy Bodies

I. Kanik and M. J. Russell
Jet Propulsion Laboratory, 4800 Oak Grove Dr. Pasadena CA, 91109

Introduction:

Astrobiology, a unifying, multidisciplinary scientific enterprise, has become the central theme to both NASA's and ESA's solar system exploration programs within the last decade by introducing some of the most exciting science questions of our time, such as the origin and nature of life, and does it exist elsewhere in our solar system and even beyond. If so, what are its signatures? Thus astrobiology not only includes the search for extant or extinct life, but also seeks to define the conditions that lead to habitable planetary environments and to discover whether the characteristics of our system that allow life to exist here are likely to be common or rare in the galaxy. One aspect we glean from the evolution of our planet is that the iron core was the first sphere to differentiate, leaving a ferrous iron-rich mantle from which a lithosphere separated along with the atmosphere and hydrosphere. The biosphere was the last sphere to differentiate, unless one counts the later occasional intense developments of icy shells across our terraqueous world (Kirschvink et al., 2000; Russell and Kanik, in review).

Astrobiology then, is multidisciplinary in terms of its content and transdisciplinary in its execution. Its success depends critically upon the close coordination and integration of diverse scientific disciplines and programs, including space missions. Astrobiology provides guidance for mission design and a framework for interpreting new discoveries by focusing on understanding both the geophysical and geochemical processes within icy bodies that may give rise to—and may sustain or even destroy—life. Such knowledge will inform the development of new analytical protocols and techniques most ideally suited for detection of life's chemical signatures. This initiative will create an opportunity to develop comprehensive steps for advanced mission concepts. Exploration of the solar system can reveal how likely we are to find life elsewhere in the universe and how it might be recognized. Just as studies of extreme but rarely visited terrestrial environments have revealed novel microbial species and unanticipated microbial ecosystems, so the detailed exploration of the solar system might also revolutionize our ideas about the diversity of life and the range of conditions in which it might originate and/or survive. For example, could metabolic pathways and cycles differ from those simple ones—those axial distributors of the simple biochemical molecules that lie embedded in the metabolic charts covering biochemistry's pin boards (Roche, 2006); are the chiralities of proteins and nucleic acids always the same as here on Earth or could they be the opposite; indeed, are DNA and RNA universal or are there variants; are the rarer transition metals that form the active sites of many proteins—molybdenum and tungsten—limiting for certain types of basic metabolisms (Nitschke and Russell, 2009)?

From what we know of our own planet, we might expect that a carbon dioxide atmosphere, or at least a carbonic hydrosphere beneath an icy exterior, along with moderate temperature hydrothermal delivery of hydrogen, to be a *conditio sine qua non* for life's emergence and evolution, at least in the absence of photosynthesis (Martin and Russell, 2007). But perhaps other forms of radiation could energise metabolism, though presumably, carbon dioxide (or at least carbon monoxide) would be one vital electron acceptor as well as the source of carbon.

The goal of this abstract is to facilitate transdisciplinary collaborations across the astrobiology community, with other science communities not currently engaged in astrobiology research in exploration of Icy Bodies. An early example of such a collaboration born of the NASA Astrobiology Institute is entitled "Minerals to Enzymes: The Path to CO Dehydrogenase/Acetyl CoA Synthase". This particular project involves Pennsylvania State Astrobiology Research Center, Montana State University Astrobiology Biogeocatalysis Research Center, JPL Icy Worlds Team and Stony Brook University Astrobiology Biogeocatalysis Research Center (Ferry, 1995; Schoonen et al., 2004; Milner-White and Russell, 2008; McGlynn et al., 2009).

When we discuss life in the context of solar system exploration, it must be clearly understood that success or failure is not measured according to whether or not we actually find life beyond planet Earth. It is just as important to know that life does not exist in a particular locale, because this may lead to the development of an understanding of the environmental conditions necessary for life's existence. This suggests that life-related studies must be intimately connected to studies of the origin and evolution of planetary environments. Therefore, to assess the habitability of a planet requires a thorough understanding of that planet's geochemical, tectonic, magnetic, magmatic, convective, hydrologic, and climatic evolution, including geochemical cycles of biological relevance, the development of potential habitats, and the processes responsible for the preservation and destruction of biomarkers. The study of the solar system as a whole, and of the mineral evolution of individual bodies within it (Hazen et al. 2008), helps us understand how the entire family of planets formed and how planetary systems might develop around other comparable stars. It therefore leads us to wonder whether other Earth-like planets can sustain life.

References:

Ferry, J.G. (1995) *Ann. Rev. Microbiol*. 49, 305-333.
Hazen, R.M. et al. (2008) *Am. Mineral.* 93, 1693-1720.
Kirschvink et al. (2000) *PNAS,* 97, 1400-1405.
Martin, W., Russell M.J. (2007) *Phil.Trans. Roy.Soc. London* (Ser.B) 362, 1887-1925.
McGlynn, S.E., et al. (2009) *Dalton Trans*. 4274-4285.
Milner-White, E.J., Russell, M.J. (2008) *Biology Direct* 3, 3: doi:10.1186/1745-6150-3-3
Nitschke, W., Russell, M.J. (2009) *J. Molec. Evol*., 69, DOI:10.1007/s00239-009-9289-3
Roche (2006) *Biochemical Pathways*, 4th edition.
Russell, M.J., Kanik, I. (in review) *J. Cosmol.*
Schoonen et al. (2004) *Ambio*, 33, 539-551.

ACKNOWLEDGMENT: This work was performed at the Jet Propulsion Laboratory (JPL), California Institute of Technology, under a contract with the National Aeronautics and Space Administration (NASA) under the NASA Astrobiology Institute (NAI) funding.