Why Does Life Start, What Does It Do, Where Will It Be? M. J. Russell, Planetary Science, MS:183-301, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena CA 91109-8099, USA, mrussell@jpl.nasa.jpl

A theory of how life emerged, based on our knowledge of this planet, is couched in the context of the expected differentiation of all relatively large terraqueous globes. While differentiation to the various spheres of the early Earth—core, mantle, asthenosphere, lithosphere, hydrosphere and atmosphere—may be considered largely a response to radiogenic and gravitational heat production in the interior, an effect of these differentiations is to gather electrons in the core in native iron (Fe^0 with its full compliment). However, early core formation still left the upper mantle relatively electron-rich (in Fe^{II}-bearing minerals), compared to the exhaling and accreting oxidized volatiles (H_2O, CO_2, NO) that composed the early hydrosphere and atmosphere. The atoms comprising these oxidized molecules share electrons and are the potential electron acceptors for dissimilatory metabolism of the kind that led to the emergence of the biosphere.

Because CO_2 and NO could permeate into the ocean and because the ocean could percolate within the upper crust, there was a blurring of the redox states between these outer spheres—a blurring that led to the emergence of the last and most complex sphere to differentiate—the biosphere. First the crust became somewhat oxidized through the process of serpentinization while a small portion of the H_2O, CO_2 and NO was (and still is) reduced to H_2, $CH_4 > > C_2H_6 >> C_3H_8 >> C_4H_{10}$ and NH_3. These volatiles were returned to the ocean and atmosphere. However, in the early stages of development of our planet their egress was inhibited by the co-precipitated Fe, Ni, Co, Mo and W sulfides or oxides, set in porous mounds comprised of carbonates and hydroxysilicates, precipitated where alkaline hydrothermal springs interfaced the acidulous ocean.

Protons from this early ocean penetrated the outer boundaries of the mounds and pushed the electrochemical potential for formate production from CO_2 to well within the range accessible to the hydrothermal, electron-donating H_2. The catalytic activities of the transition metals precipitated in the mound were vital to such syntheses. More complex intermediates such as carboxylic, amino, and eventually nucleic acids and their polymers, were generated in this milieu by these same chemiosmotic forces. This compartment-based autogenesis evolved to autotrophic life as electrons looked for a place to rest (in Szent-Györgyi's famous phrase). Heterotrophy—a digestive process using pre-existing biotic molecules, had to await autotrophy. It involves eddies of these electrons prior (in the long run) to their detrital dumping or atmospheric or aqueous egress. The use of solar energy then kicks in to greatly increase production of the surface biosphere. Just as heat is radiated to cold space, so too electrons in geochemically, metabolically and photolytically produced H_2, are returned to the ether. The main early effluents from emergent life were methane and acetate. Acetate, being an overwhelmingly biotic product, would be a less ambiguous guide to microbial activity on other planets.

Reference: [1] Nitschke, W. and Russell, M.J. (2009) *J. Molec. Evol., 69,* DOI:10.1007/s00239-009-9289-3