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EDITORIAL

Special Issue on the Early Evolution of Life

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About a year ago, in late 2013, one of us (MDG) had the idea to put together a Special Issue of the *Journal of Molecular Evolution* dedicated to the Early Evolution of Life. At the time, the journal was receiving an increased number of submissions on this topic and in fact in recent months has been increasing its focus on very early molecular evolutionary events. Thus we decided to move forward with this idea, and the current issue (November/December 2014) is the result of this current effort.

Research into life's earliest periods is very dynamic, interdisciplinary, and at times highly speculative, given the antiquity of the events under study. Our best guess places the origins of life itself from chemical beginnings at roughly 4 billion years ago, with no physical evidence of life surviving that long. The earliest cells may have evolved on the Earth in the 3.5–4.0 Gya time frame, and evidence of these, although possible, is scarce at best. At some point prior to roughly 3.0 Gya, the last common universal ancestor (LUCA), which was a single "species" or, more probably, a highly reticulated network of genomic entities, came into being from whom all terrestrial life today is descended.

Efforts to understand the events of the first billion years or so of life can be focused on a number of perspectives, including theoretical simulations, analyses of molecular "fossils" and/or phylogenetic clues, and empirical experiments in the laboratory. The articles in this Special Issue span all of these approaches. We start first with two Review papers, one by Ostrovskii and Kadyshevich (pp. 155–178, 10.1007/s00239-014-9641-0) and the second by de Sauza et al. (pp. 179–192, 10.1007/s00239-014-9655-7). The first of these reviews the LOH Theory (or life origination hydrate theory), which considers the origination of key biological molecular precursors such as the nucleobases themselves. Here, the thermodynamic potential of a suspected abiotic inorganic structure, methane hydrates, is invoked to provide a means for the production of adenine, guanine, uracil, and cytidine, along with some amino acids. The second review steps up to one of the next logical questions: where do cells come from? Pasquale Stano and colleagues review mechanisms of liposome formation and describe laboratory studies that indicate that under certain circumstances such liposomes can lead to the encapsulation of solutes at unexpectedly high concentrations. The advent of cell-like structures (protocells) was obviously a key step in the early evolution of life, and investigations into how this could have happened and into how it could have been coordinated with the enclosure of genetic material are hot areas of research today.

Following the Reviews, three original articles on very early events in the history of life appear. First, de Boer and Hogeweg (pp. 193–203, 10.1007/s00239-014-9648-6) tackle the problem of how protocells may have influenced the properties of the molecules that they encapsulate. Using a modeling approach, they consider the interaction of RNA folding and nucleotide mutation on the fitness of collections of molecules, and find that when some RNAs cooperate to help others fold, high fitness can be maintained even at high mutational error rates. Second, Poole et al. (pp. 204–213, 10.1007/s00239-014-9656-6) explore the relatively controversial idea that DNA may be as old, or even older, than RNA. While conventional wisdom under

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the "RNA World" hypothesis holds that RNA was the evolutionary precursor to DNA, reasoned in part because of the order and means by which nucleotides are made in contemporary cells, Poole and colleagues force us to re-examine the idea that there may have been abiotic routes to the more stable DNA molecule because some of these pathways are chemical plausible and biologically advantageous. And third, Herschy et al. (pp. 214–229, 10.1007/s00239-014-9658-4) reveal an origin-of-life reactor in the laboratory that may allow some experimental testing of early life hypotheses. These authors have constructed a reactor that contains thin Fe(S)Ni inorganic surfaces and that can demonstrate the in vitro synthesis of some key molecules for the advent of life such as formaldehyde and pentose sugars from H_2 and CO_2 starting materials. This reactor depends on thermophoresis (temperature gradients) to drive synthesis, and the importance of gradients such as these in early life is now unmistakable.

The last two papers in this Special Issue on the Early Evolution of Life move more into the biotic realm by examining the very deep phylogenetic history of life. To begin, Penny et al. (pp. 230–241, 10.1007/s00239-014-9643-y) ask what features the first eukaryotic cells may have had. Using comparative biochemistry and phylogenetic inference, they query the capabilities of the last eukaryote common ancestor (LECA), deducing that fundamentally new ways of viewing the early bacterial/archaeal relationships are needed for us to understand fully the advent of eukaryotes. And finally, Kim et al. (pp. 242–264, 10.1007/s00239-014-9637-9) consider the reconstruction of the entire tree of cellular life itself. By taking a new approach based on protein function rather than sequence per se, they can re-evaluate the relative branching orders of life's most basic groups, such as the Archaea, the Bacteria, and the Eukarya. They promote the use of "functionomic data" for deep phylogenetic reconstruction, and one representation of the Tree of Life based on this approach appears on the cover of this Special Issue. Although the papers in this issue touch on a tiny fraction of the molecular evolution of the early life on the Earth, we hope you enjoy them and can appreciate the broad range of exciting research that is being done in this field.

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