ENVIRONMENTAL ADAPTATION FROM THE ORIGIN OF LIFE TO THE LAST UNIVERSAL COMMON ANCESTOR. Marjorie Cantine[1] and Gregory P. Fournier[1], [1]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology , 77 Massachusetts Avenue Cambridge, MA 02139; mcantine@mit.edu

Introduction: Extensive fundamental molecular and biological evolution took place between the prebiotic origins of life and the state of the Last Universal Common Ancestor (LUCA). We assess current evidence on the origin of life and LUCA, identifying evolutionary developments and innovations between these two points. We consider these evolutionary innovations from the perspective of environmental adaptation, exploring the possibility that LUCA was both temporally and environmentally removed from life's earliest origins in the RNA world. Finally, we discuss the promise and potential of considering environmental adaptation in life's earliest evolution.

Evidence for environmental change: Between the origin of life and LUCA, life likely diversified into environments unlike the one where it emerged. Inferences based on the effects of and adaptations to temperature and UV radiation suggest these factors would have played critical roles [1, 2 3]. Our examination of available experimental and phylogenetic evidence indicates a cold, shielded environment for life's origin, and a mesophilic, surface-dwelling LUCA. We discuss evolutionary innovations between these two points as evidence for and drivers of adaptive radiation pre-LUCA.

This early environmental adaptation indicates the important role that cellular motility and cellularity played in early evolution. In order to diversify across environments and move away from their environment of origin, organisms would need to be able to contain their genetic code and important enzymes within a portable envelope. This is consistent with a pre-LUCA emergence of cellularity and compartmentation.

Early cellularity and membranes: The timing of cellular membranes' appearance remains controversial. Work focusing on early metabolism has suggested that life developed within mineral structures that sheltered self-replicating genetic molecules until membranes developed at a later point as a biological invention of this system [4]. Alternatively, "membrane-first" models propose that the first lipid membranes contributing to cellular biological systems arose abiotically and independently of heredity and metabolism. It has been suggested that these membranes pre-date the origin of life, and the compartmentation they allowed permitted the Darwinian evolution of early protocells [5]. We assess the experimental and phylogenetic evidence for early membrane emergence in light of environmental adaptation requiring cell motility and dispersal.

Conclusion: Examining the early evolution of life through an exploration of environmental adaptation is promising. Dispersal through adjacent environments can reconcile sets of both experimental "bottom up" and phylogenetic "top down" observations that support conflicting narratives of life's origins, if constrained to a singular primordial location. This scenario also supports LUCA's identity as one population of cells among many cellular/protocellular systems that likely coexisted across diverse ecologies. We highlight the importance of life's early diversification as a pre-adaptation to changing environmental conditions on a dynamic planet, as well as "Ecogenesis" or the emergence of ecosystems an early and important force in life's history.

References: [1] Heijde M, Zabulon G, Corellou F, Ishikawa T, Brazard J, Usman A, Todo T (2010) Characterization of two members of the cryptochrome/photolyase family from Ostreococcus tauri provides insights into the origin and evolution of cryptochromes. *Plant Cell Environ*, *33*(10). [2] Ravanat JL, Douki T (2016) UV and ionizing radiations induced DNA damage, differences and similarities. *Radiat Phys Chem*, *128*. [3] Forterre P, Confalonier F, Charbonnier F, Duguet M (1995) Speculations on the origin of life and thermophily: review of available information on reverse gyrase suggests that hyperthermophilic procaryotes are not so primitive. *Origins Life Evol B*, *25*(1-3), 235-249. [4] Martin W, Russell MJ (2003) On the origins of cells: a hypothesis for the evolutionary transitions from abiotic geochemistry to chemoautotrophic prokaryotes, and from prokaryotes to nucleated cells. *Philos T Roc Soc B*, *358*(1429). [5] Szostak JW, Bartel DP, Luisi PL (2001) Synthesizing life. *Nature*, *409*(6818).