EMERGENCE OF LIFE ENERGIZED BY CYCLIC PHYSICOCHEMICAL PROCESSES OF ROTATING PLANETS. J. Spitzer, MCP Inc. (retired), Charlotte NC

Introduction: Many views about life's origins have been promulgated since the seminal work of Oparin, Haldane, Schrödinger and Stanley Miller. But they have remained controversial and mutually isolated. They do not add up to a convincing scenario of life's emergence for two reasons: (i) The proposed scenarios have not taken advantage of constraints offered by physical chemistry [1-3]. (ii) Many proposals of 'clean' chemical reactions neglect Stanley Miller's experimental fact that they create mixtures of organic tarry molecules [4]. Thus, the current 'complexification' paradigm—prebiotic syntheses of life's building blocks and their polymerizations and assembly into proto-cells—lacks clear foundational principles.

The origins problem is currently viewed as refractory to scientific inquiry, and its assumptions are being re-assessed [e.g., 5-8]. How to proceed? One possibility is to construct a physicochemical jigsaw puzzle of prebiotic processes to serve as a firm framework for further research [1-3]. The suggested jigsaw puzzle satisfies the diagnostic criteria of prebiotic plausibility: planetary *ubiquity*, evolutionary *continuity*, and physicochemical *robustness* [9].

The jigsaw puzzle of life's emergence: The jigsaw puzzle pieces described in Fig. 1 are underpinned by cyclic (evolutionary) chemical reactions and phase separations that are concurrently and continuously stoked by two planetary energies: (i) solar radiation impinging on the surfaces of rotating planets, and (ii) the concurrent hydration and dehydration cycles of tidal seawater [10]. Without a regular, periodic supply of energy, first cellular organisms could not have spontaneously self-assembled from prebiotic molecules. The stoking of the 'soup of chemicals' in prebiotic tidal environments created evolving patterns of chemical reactions and phase-separations, inevitably accompanied by purifications (compositional chemical simplifications) on colloidal nano- and micro- scales.

The jigsaw puzzle is based on the Pauling-Delbrück premise of 1940 [11], specifying that current physicochemical laws (chiefly quantum mechanics and chemical thermodynamics) are sufficient to understand life. This premise contradicts Schrödinger's 1944 call to look for new physical laws that could explain life. The jigsaw puzzle pieces—the evolutionary questions—identify research areas which can be tackled through new kinds of experiments with multicomponent compositions, using both 'bottom-up' and 'top-down' approaches. The bottom-up *prebiotic chemistry* can be investigated by means of large (chemical engineering) simulators of young Earth to demonstrate chemical evolution of multicomponent colloidal patterns at the gaseous(vapor)-liquid-solid boundaries of Hadean seashores [12]. The top-down *proto-microbiology* can be designed as cyclic 'resurrection' processes that re-assemble and evolve living prokaryotes from their dead biomolecules and biomacromolecules [13]. (Today's PCR protocols echo the cyclic evolution of nucleic acids during the Hadean eon.) The top-down and bottom-up approaches meet at the *crowding transition*, a key requirement for life to emerge. The crowding transition signifies the cyclic evolution of interacting proto-macromolecular surfaces at about 1 nm separations. This estimate reflects the range of commensurate interactions of the excluded volume effect (biomacromolecular crowding), hydrogen bonding and screened electrostatic forces.[1]

Conclusion: Single-cell microbial life, the cyclic transmission of genetic information, emerged *on the fly* from cyclic prebiotic tidal chemistry. Life did not spontaneously 'self-assemble' from a pool of prebiotic molecules—a physicochemical impossibility.

References: [1] Spitzer J. et al. (2015) *Biol. Direct.* doi: 101186/s13062-015-0060-y. [2] Spitzer J. (2017) *J Mol Evol.* doi 10.1007/s00239-016-9775-3. [3] Spitzer J. (2019) *Chapter 6.6. In "Handbook of Astrobiology"*, CRC Press. [4] Shapiro R. (1986) *Origins*, Schuster & Simon. [5] Sutherland J. D. (2017). *Nat Rev Chem.* doi: 10.1038/s41570-016-0012. [6] Walker S. I. et al. (2017) *Philos Trans A Math Phys Eng Sci.* doi: 10.1098/rsta.2016.0337. [7] Szostak J. W. (2017) *Angew Chem Int Ed.* doi: 10.1002/anie.201704048. [8] Luisi P. L. (2014) *Orig Life Evol Biosph.* doi: 10.1007/s11084-014-9386-1. [9] Deamer D. W. and Fleischaker G. R. (1994) *Origins of life.* Jones and Bartlett Publishers. [10] Bywater R. P. and Conde-Frieboes K. (2005) *Astrobiology* 5, 568–574. [11] Pauling L. and Delbrück M. (1940) *Science* 92, 77–79. [12] Spitzer J. (2013) *Astrobiology* 13, 404–413. [13] Spitzer J. (2014) *Res Microbiol* 165, 457–461.

[1] The same non-covalent forces (the Pauling Delbrück premise) also suggest a model of bacterial cytoplasm based on sol-gel transitions controlled by epigenetic biochemical reactions that attach 'tags' to biomacromolecules, e.g. phosphate or methyl groups. The transient gels are vectorially wired by aqueous electrolytic channels that distribute power and metabolites to molecular machines immobilized in the gels, while the disordered sol enables fast diffusion. Spitzer J. (2011) *Microbiol Mol Biol R* 75, 491–506. Spitzer J. and Poolman B. (2013) FEBS Letts 587, 2094–2098.

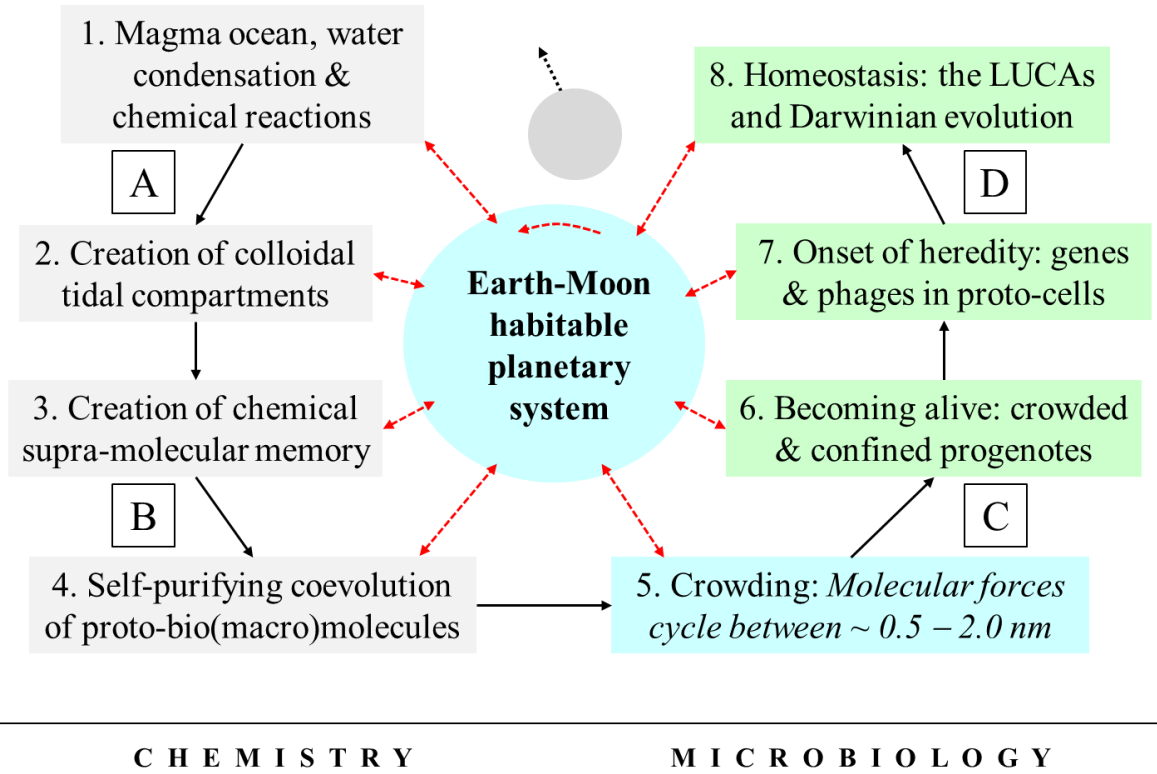

Fig. 1. Pieces of the jigsaw puzzle of the emergence of first single-cell organisms.

After the formation of the Moon, Earth's rotation slowed down and the Moon migrated away from Earth (black dotted arrow). Earth began to cool and the condensation of water initiated chemical evolution toward living states of matter **[A]**. Red arrows represent Earth's *daily* chemical evolution; black arrows represent Earth's chemical and microbiological evolution during the Hadean and Archaean eons (for one to two billion years).

[1] Earth cooled until water condensed and created the first seas. **[2]** Formation of colloidal compartments in tidal zones. **[3]** Persisting compartments begin to evolve, retaining chemical memory from previous cycles, a pre-condition for a potential evolution toward life **[B]**. **[4]** The principle of triple-coevolution of proto-proteins, proto-nucleic acids and proto-cell-envelopes through cyclic self-purifying processes toward phosphorus dominated carbon chemistry. **[5]** The crowding transition directs cyclic chemical evolution toward proto-microbiology and cellular life **[C]**. **[6]** Progenotes becoming alive through environmental cyclic energies **[7]** Progenotes becoming proto-cells with better enclosures and fast-evolving initial heredity. **[8]** Proto-cells become homeostatic, less dependent on cyclic environmental energies, with longer-term heredity, giving rise to LUCAs and Darwinian evolution **[D]**.

LUCAs lived in the deep phylogenetic roots of the Tree of Life, from which three domains of life emerged: Bacteria, Archaea and Eukaryota [Sapp J. (2009) *The New Foundations of Evolution. On the Tree of Life.* Oxford University Press].