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The Diel Theory of Evolution: Shedding Light/Dark on Abiogenesis

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The possible role of photogenesis in the origin of life has been widely appreciated [1,2]. However, the day/night cycle has been all but ignored [3], which seems surprising considering the importance of circadian clocks in biology and of diel variation in geochemistry [4,5]. The diel theory of evolution raises the rotating earth to the level of primary tinkerer in the evolution of life's chemical complexity [6]. Cycles of solar radiation and darkness must have established a diel rhythm in the primordial soup early in Earth's history. Light-gathering molecules, plentiful in life's molecular arsenal, can be produced from precursors under plausible prebiotic conditions, especially with the aid of UV light [7]. Some chemical reaction cascades require light activation while others are inhibited by solar radiation. The prebiotic soup would have accumulated energy in the form of chemical bonds during the day, and some of that energy would have been available for other reactions in the evening and at night. Thus, as a starting point for experimental work, I suggest the use of cycling, full-spectrum solar radiation—as present on early Earth including UV-C and with a slowly lengthening period—to study the prebiotic chemical milieu.

It is possible that a primordial circadian clock emerged in a broth with a diel rhythm before Darwinian organisms [8,9], but a driving force seems obscure. Rather, organisms may have emerged as a kind of clock and gained separate, endogenous timekeeping as they evolved away from an autocatalytic cycle in the primordial soup. Research showing that metabolism influences endogenous clocks, as much as the other way around, lends support to this idea [e.g. 4].

An autocatalytic photosynthetic system may have been part of a primordial hypercycle that gave rise to life's metabolic complexity, for example, with different parts corresponding to morning, midday, evening, and night [10,11]. Daytime may have been a time for energy storage and synthesis of important precursor molecules. The evening could have been given to polymerization, repair from damage by UV light, and packaging for overnight storage. Nighttime may have been primarily a time to avoid dissolution, for example by proto-viruses, but could have also been an opportunity for primordial recombination. The morning may have been for repair from any overnight degradation and another opportunity for polymerization.

Over time these functions would have shifted within the cycle; for example, it seems likely that early on, most interesting chemistry would have happened by day. Indeed, the transition from daytime to other parts of the cycle may hold some secrets to life's origins; for example, energy storage to last through the night may have driven complex cell form. Packaging information overnight may have also been thermodynamically favorable compared to packaging complex structure, thus providing a driving force for the evolution of the central dogma. Life may have evolved multiple times in this context by short-circuiting or cheating this hypercycle, which may have existed until the great oxygenation event. Earliest life may have been phototrophic, but not necessarily so. Incorporating parts of the autocatalytic machinery may have allowed vesicular components to adopt an organoheterotrophic lifestyle, something like many modern protists.

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