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Functional continuity: did field-induced oriented aperiodic constraints at Life's origin aid its sequence-based evolution?

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Abstract

A non-biological analog undergoing Darwinian-like evolution could have enhanced the probability of many crucial independent bottom-up emergent steps, engendered within its premises, and smoothen the inanimate-animate transition. Now, the higher-level environment-mutable DNA sequences influence the lower-level pattern of oriented templates (enzymes, lipid membranes, RNA) in the organized cell matrix and hence their associated substrate-dynamics; note how templates are akin to local fields, kinetically constraining reactant orientations. Since the lower-level is likely the more primitive of the two (rather than Cairns-Smith's "readily available" rigid clay crystal sequence-based replicators as a memory-like basis for slowly mutating predecessor-patterns en-route to complex RNA-based Darwinian evolution), a gradual thermodynamic-to-kinetic transition in an isotropic medium, is proposed as driven by some order-parameter --via "available" field-responsive dipolar colloid networks, as apart from bio-organics, mineral colloids also can display liquid crystal (LC) phases (see [1]). An access to solid-like orientational order in a fluid matrix suggests how aperiodic patterns can be influenced and sustained (a la homeostasis) via external inhomogeneous fields (e.g. magnetic rocks); this renders these cooperative networks with potential as confining host-media, whose environment-sensitivity can not only influence their sterically-coupled guest-substrates but also their network properties (the latter can enable 'functions' like spontaneous transport under non-equilibrium suggesting a natural basis for their selection by the environment). In turn LC systems could have been preceded by even simpler anisotropic fluid hosts, viz., external field-induced mineral magnetic nanoparticle (MNP) aggregates. Indeed, the capacity of an MNP to couple its magnetic and rotational d.o.f.s suggests how an environment-sensitive field-influenced network of interacting dipolar colloids close to equilibrium (eq) could have laid the foundation of a hierarchical organization with distributed control, enabling computations and the era of mutable gene-influenced dynamics (far from eq) via takeovers.

1. Introduction

Energy sources like gradients can bring about flows to be sure, but that is only one of the aspects required for overcoming the Second law towards sustained life-like organization. While such flows are crucial, (in the absence of organized bio-media) their impact needs to be understood not just in passive fluid media capable of merely responding by sustained mechanical motion but rather an active organized medium characterized by sustained localization and orientation of nano-scale components in the face of flows. This typically overlooked aspect needs to be explicitly incorporated in pre-biotic scenarios, such as via fields and their responsive materials. Moderate coherent-fields can ensure an entropy-rejection mechanism towards sustaining organization patterns of their responsive fluid-dispersed colloids (c.f. heat-protected conventional computing hardware). Since each solvent-dispersed field-responsive particle has infinite orientations and positions to choose from, imposition of an external field can drastically trim the dynamical phase space of each particle (individually), plus any (guest) organic bound to it. Being dynamically constrained, field-induced aggregates can be tuned (and hence influence its embedded dynamics), unlike non-reconfigurable constrained mineral surfaces (rocks, thermal gels). Indeed, such environment-tunable configurations--like 'thermodynamic lunches' in disequilibrium locations-- were also available for free, and could expand the potential of minerals in abiogenesis, as specific-affinity of a mineral colloid to an organic, complements its capacity to form complex patterns via field-responsiveness. Note that H-fields are invisible to small diamagnetic organics anchored to MNPs, (unlike electric-fields that can affect both). Such an environment-sensitive informational

medium hosting pre-biotic chemistry—like an associative memory-- could correlate the effect of environment fluctuations on its configuration (pattern) to the influence of its hosted dynamics on its embedded chemical events. And, pre-existing functional-informational systems—as higher-level predecessor-hosts--allowed successive takeovers of their memory mechanisms by efficient compatible lower-level organic guests (c.f. take-over of Cairns-Smith's crystal-organization by its invented RNA parasites), thus upholding functional continuity. We give some highlights of our thesis (see [1], plus cited references); some ideas are further developed here.

2. Discussion

Pure bottom-up approaches to life's origin assume formation and self-assembly of macromolecular units from simple organics all the way to evolving symbol-based hierarchical organizations, ignoring its engenderment from a parent-analog (c.f. evolution). So for enhanced continuity of life's origin to its evolution, the primitive ecosystem-like 'cell' is seen as a liquid-crystal (LC)-like medium hosting pre-biotic energy-matter flows, and whose environment-sensitive aperiodic oriented (domain-like) patterns are governed by heterogeneous external fields. It has isomorphic mapping to spatially organized (lower-level of) aperiodic oriented 'templates' (enzymes, rna, membranes, etc), encoded in environment-mutable genes, wherein these evolving parents/hosts not only constrain--but are also sustained by--energy-matter (guest) flows. So in continuity with evolution--via functional takeovers—the sustenance of such an environment-sensitive hierarchical matrix with long range stereochemical/ orientation-based order as predecessor enhances the probability of 'bottom-up' stepwise emergence to a metabolism-linked sequence-based reproducer, thus enhancing the very time scale for sustenance. For, besides catalysis, organic-affinity, etc., some minerals can form cooperative phases --magnetic, lyotropic LC, etc.-- needed to induce phase transitions in bound organics. So while bottom-up organic guest-processes require continued disequilibrium, their mineral host-systems--reconfigurable via fluctuations thanks to the availability of myriad closely-spaced states-- can be formed and sustained by constant action of moderate local fields (e.g. magnetic rocks) on their responsive colloids. For e.g. greigite particles (that also form magnetosomes) are negatively charged above pH 3; and the Wilkin and Barnes framboid-formation model (see [1]) may be extrapolated to nano-scales by invoking moderate fields; since, freely moving charged colloids can independently overcome thermal fluctuations in response to (distributed control of) external fields. And, in presence of short-range repulsion (presence of like-charges), non-specificity of induced dipolar-forces secures (top-down) influence of the field on resulting interaction patterns. The latter are (i) tunable via environment changes (field-parameters like intensity, direction, etc.; neighbour dipolar fields; medium parameters like temperature, ionic strength, etc.); (ii) can enable functions under varied disequilibrium conditions (transport, storage etc, crucial for their selection), via their tunable network properties; and (iii) can kinetically assist reactions (studied by Bibette's group, see [1]); thus can act as life-like scaffolds for enabling takeovers by engendered networks (e.g. weak H-fields can induce, sustain LC order in disordered soft-matter-- containing magnetic impurities--via the Brochard-de Gennes-effect; see [1]). Isothermal field-induced aggregates can host heat-transactions (template regeneration); encourage recognition- interactions between bound organics; lower side-reactions (reduce dynamical phase space of organics); transport charges, energy, etc. for reactions; provide diffusion-constrained medium (sustained low water activity) for enabling condensations, reaction-diffusion systems, co-localizing interdependent organics for auto-catalytic cycles, etc. (see [1] for references).

3. Summary and Conclusions

The above indicate how field-induced colloids can bootstrap requirements of a life-like scaffold medium. And, by virtue of being metastable and functional themselves under different dis-equilibrium conditions, such environment-responsive media can (await, assist and) enable selection of different types of energy-dissipating organic networks, forming by chance in its robust ecosystem-like premises, thus enabling adaptations, takeovers, etc.; this expands the scope of bottom-up approaches in various pre-biotic locations. Such coherent-field influenced networks could also have merged together –a la horizontal gene-transfers, -- owing to the complicity of coherent fields..

References

[1] Mitra-Delmotte, G., and Mitra, A.N.: Field-Control, Phase-Transitions, and Life's Emergence, Frontiers in Physiology, Vol. 3, p 366, 2012.