The Universal Deconstructor and the Random Constructor

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Self-replication is a process by which the resources of the environment are transformed to generate more of the replicating system. A trivial example of such a replicator is a growing crystal, which cannot be considers as living. A more complex variant is von Neumann's Universal Constructor (UC) that through its ability to not only replicate itself but also construct any object of its underlying universality class is capable of evolving and therefore possesses an essential quality of a living system. The UC as model for a minimal living system, however, is already so complex that it becomes difficult to propose a pathway for its emergence in a prebiotic environment, let alone to devise a valid prebiotic model system for such a replicator.

Considering the evidence for prebiotic reactions that can produce molecules of considerable complexity, including long biopolymers [1,2], another solution for a non-trivial replicator can be hypothesized. This replicator is founded on the fact that the aforementioned prebiotic reactions create a statistical distribution of entities and can thereby be seen as a Random Constructor (RC). It is the coupling of the RC with a second system, which we refer to as the Universal Deconstructor (UD), that creates the replicating entity. This UD needs to possess three properties. Firstly, it needs to be capable of emerging from the pool of entities that the RC generates. Secondly, it needs to possess a functionality by which it can deconstruct all entities produced by the RC into the component resources upon which the RC acts. Thirdly, it needs to possess a functionality by which it protects its own entities, at least partially, from said deconstruction. Evolvability arises if the protection of what is considered as self to the UD is not perfect and thereby related entities are also protected. From here, several evolutionary pathways are conceivable, *e.g.* improved deconstruction or improved protection. Thereby, such a system consisting of an RC and a UD together is capable of non-trivial replication.

We propose a model system of chemical replicating peptides based on the RC/UD pair that can be plausibly set into a prebiotic environment. The random construction is a synthesis of peptides via carbonyl sulfide activation of amino acids or via activation of amino acids on iron-sulfur clusters with carbon monoxide [1,2]. The protection from deconstruction and the catalytic deconstructing activity (peptide hydrolysis) is achieved via the amyloid fold of the UD which arises from simple peptides made by the RC. The amyloid fold is a fibrillar supramolecular polymer of β-strands composed of the individual polypeptides. This fold has many properties, which make it interesting as a possible prebiotic entity [3]. In particular, it protects its constituents from a dilution in physical space and is capable of division into two fully functional daughter fibrils once it has grown to a sufficient length such that shearing forces can fragment it. The plausibility of such a system will be presented in light of the recent report of hydrolytically active amyloids [4].

References: [1] J. P. Ferris et al. (1996) *Nature, 381,* 59-61. [2] L. Leman et al. (2004) *Science, 306,* 283-286. [3] Greenwald J. and Riek R. (2012) *JMB, 421,* 417–426. [4] C. M. Rufo et al. (2014) *Nature Chemistry, 6*, 303-309.