DETECTING LIFE UNIVERSALLY IN WATER: MARTIAN LAGOONS, JUPITER'S MOONS, AND ENCELADUS' PLUMES. S. A. Benner. Foundation for Applied Molecular Evolution, 13709 Progress Blvd., Alachua, FL 32615 USA

Introduction. Our understanding of what kinds of biopolymers might support Darwinism is assisted by synthetic biologists who generate alternative genetic molecules that store information, transmit information, and evolve like DNA and RNA, but on different molecular platforms. These have generated many alternative molecules that perform at least as well as terran DNA/RNA. However, synthesis also has taught us that two structural features are universal to any biopolymer operating in water to support Darwinism, believed to be the only way matter can self organize to give properties valued in life. These features are universal for life and water, whether that water comes from Enceladus geysers, Europa oceans, or Martian aquifers.

The aperiodic crystal structure. In 1943, Erwin Schrödinger knew nothing about DNA. However, he knew that simple binding cannot guarantee fidelity of information transfer needed for biology, at the level needed to avoid “error catastrophe”. For that, Schrödinger needed the physics of phase transitions. For *that*, Schrödinger recognized that the exchangeable informational building blocks that were exchangeable during evolution must all have the same size/shape. They must all fit in an "aperiodic crystal" structure.

The polyelectrolyte theory of the gene [1][2]. As a second requirement, an informational biopolymer must be able to change sequence to change information without changing its physical properties sufficient to impact its performance in processes involved in inheritance. These properties include, its solubility, its molecular recognition behavior, and its reactivity. We know from synthetic biology that such systems are scarce. However, one way to get mutation free of significant changing in physical properties is with a biopolymer which has a repeating backbone charge (positive or negative) it. In DNA, the repeating backbone charge carried by the phosphates so dominates its properties that nucleobase replacement is only a minor perturbation.

The polyelectrolyte also determines Watson-Crick pairing rules. As part of our effort to try to create alternative genetic systems that might operate in the liquid methane oceans on Titan, we sought to create DNA analogs that lack the backbone charge. A surprising discovery emerged: These molecules no longer followed Watson-Crick rules. This discovery forced us to recognize that backbone-backbone repulsion forced to DNA strands to contact each other as far as possible from the backbone, to the Watson-Crick edges of the nucleobases. Thus, the polyelectrolyte backbone also is responsible for the rule-based molecular recognition that is valued in DNA.

The polyelectrolyte also prevents folding, to allow templating. A further discovery made as we attempted to make charge neutral genetic molecules was the recognition of the role of intra-strand columbic repulsion. This, it turns out, is required to prevent the DNA strand from folding on itself, like a protein does. This, in turn, is responsible for allowing DNA molecules to template the formation of their replicas.

The remaining features of DNA are mutable. This includes the nucleobase pairs to a large extent, and the carbohydrate in the backbone, as long as the Schrödinger principle is followed. This, in turn, is insured by having hydrogen bonds directing base-base interactions. Purely hydrophobic interactions have failed so far to allow the molecule to generally fit the Schrödinger principle.

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References: [1] Benner, S. A., Hutter, D. (2002) Phosphates, DNA, and the search for nonterrean life: A second generation model for genetic molecules. *Bioorg. Chem.* **30**, 62-80. [2]Benner, S. A. (2017) Detecting Darwinism from molecules in the Enceladus plumes, Jupiter's moons, and other planetary water lagoons. *Astrobiol.* **17**, 840-851.