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Organization of Nucleotides in Different Environments: Implications for the Formation of First RNA under Prebiotic Conditions

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How nucleic acids first assembled and then incorporated into the earliest forms of cellular life 4 billion years ago remains a fundamental question of biology. It is postulated that prior to today's DNA, RNA, and protein-dominated world, RNA was used for genetic storage and as a catalyst for reactions, such as polymerization. RNA is a polymer chain of nucleotides linked to a ribose-phosphate backbone. Polymerization of nucleotides occurs in a condensation reaction in which phosphodiester bonds are formed. However, in the absence of enzymes and metabolism there has been no obvious way for RNA-like molecules to be produced and then encapsulated in cellular compartments, an essential first step in the origin of cellular life.

To support the hypothesis that environmental conditions in the neighbourhood of volcanic hydrothermal springs could act to organize monomeric nucleotides through various noncovalent interactions and chemical reactions in the prebiotic era, we investigated 5'-adenosine monophosphate (AMP) and 5'-uridine monophosphate (UMP) molecules captured in different matrices that have been proposed to promote polymerization, namely multi-lamellar phospholipid bilayers, nanoscopic films, ammonium chloride salt crystals and Montmorillonite clay [1]. Two nucleotides signals were observed in our X-ray diffraction experiments, one corresponding to a nearest neighbour distance of around 4.6 Å and a second, smaller distance of 3.45 Å. While the 3.45 Å distance agrees well with the distance between stacked base pairs in the RNA backbone, the 4.6 Å distance can be attributed to un-polymerized nucleotides that form a disordered, liquid-like structure. From the relative strength of the two contributions, the effectiveness of the different environment for producing RNA-like polymers was determined.

[1] S Himbert, M Chapman, DW Deamer, Maikel C. Rheinstädter, submitted to PLOS ONE.

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