Minimal catalytic and replicating systems.

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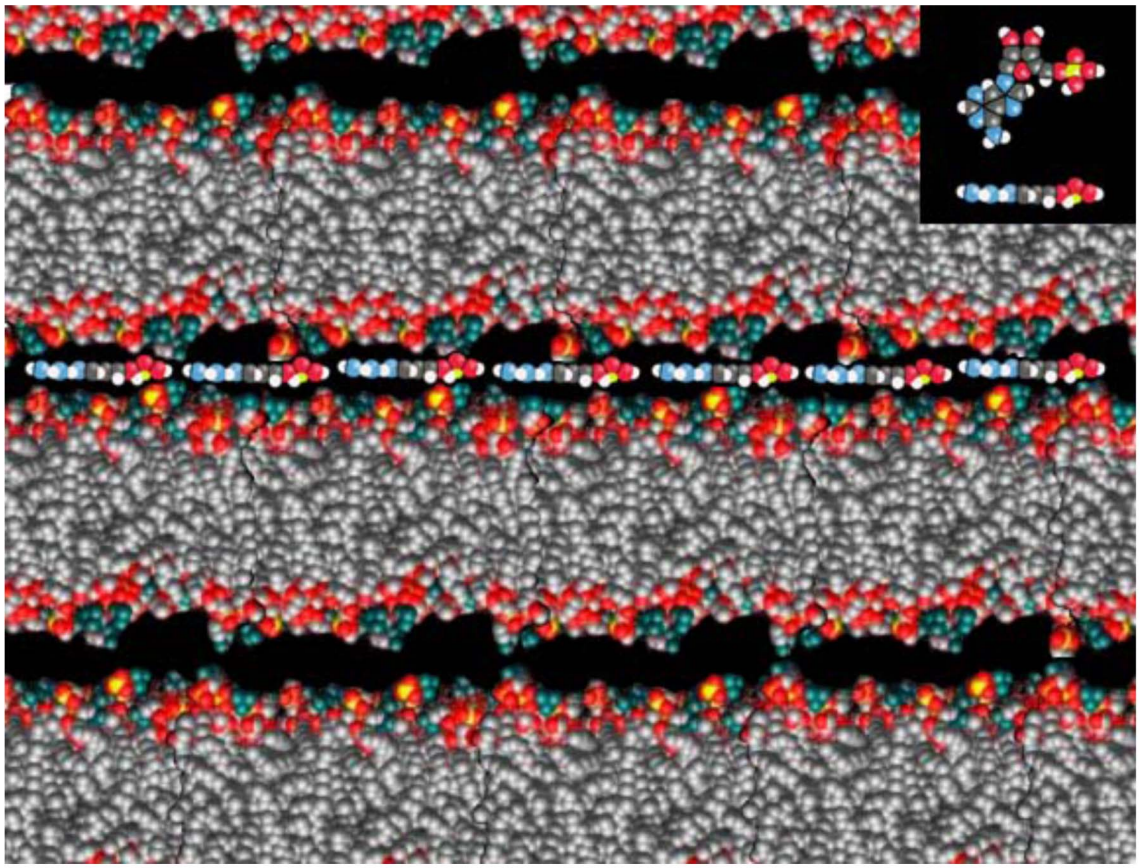
Inouye and Orgel (1982) showed that strands of synthetic RNA could act as templates for polymerization of activated monoribonucleotides. For instance, when a polyC template was incubated with imidazole esters of guanosine monophosphate for several days at 4 degrees C, strands of oligoG up to 30mers were products. Furthermore, if the templates were heteropolymers, sequence information could be transferred from the template to the product strands. However, a complete cycle of replication could not be demonstrated. For instance, activated cytosine mononucleotide could not use a polyG template to produce oligoC polymers.

Non-enzymatic polymerization of RNA and transfer of sequence information were ground-breaking discoveries, but two major hurdles remain: what is a plausible prebiotic mechanism for activating nucleotides, and how can the second half of the replication cycle be promoted?

We recently presented a possible solution by demonstrating non-enzymatic polymerization of ordinary 5'-mononucleotides by cycles of anhydrous and hydrated conditions in the presence of lipid matrices (Rajamani et al., 2008). The lipid served to concentrate and organize the mononucleotides in a multilamellar liquid crystal so that polymerization was promoted in the anhydrous phase by formation of phosphodiester bonds. Most recently, we showed that if ssDNA templates were present, dsDNA could be detected as a product, and sequence information was transferred to the product strands (Olasagasti et al., 2011).

These results have not yet been repeated by an independent laboratory, but they do bring up several important questions. In both cases, because catalysts and activated monomers are absent, the polymeric products are of random lengths and very low yields. It seems reasonable to consider that in the natural experiments leading up to the origin of life, polymers of varying lengths and composition would also be produced. If this is correct, what is the minimal length of oligonucleotide polymer that would be required for ribozyme activity to appear? Second, what is the minimal length of product at which transfer of sequence information becomes significant? Last, how could selection and amplification be introduced into the system so that evolution can begin? These are fundamental questions related to the origin of life, and state-of-the-art analytical approaches now available should make it possible to begin answering them.



Adenosine monophosphate (AMP) is one of the nucleotide monomers of nucleic acids, and a molecular model of AMP is shown as top and side views in the inset. The main figure illustrates how AMP can become organized within the two-dimensional plane between lipid bilayers in a multilamellar lipid matrix.

References:

T. Inoue and L. E. Orgel (1982) Oligomerization of (Guanosine 5'-phosphor)- 2-methylimidazolide on Poly(C): An RNA Polymerase Model. J Mol Biol 162: 201 – 17.

Rajamani S, Vlassov A, Benner S. Coombs A, Olasagasti F, Deamer D (2008) Lipid-assisted Synthesis of RNA-like Polymers from Mononucleotides. Orig Life Evol Biospheres 38: 57 – 74.

Olasagasti F, Kim HJ, Pourmand N, Deamer DW (2011) Non-enzymatic transfer of sequence information under plausible prebiotic conditions. Biochimie 93: 556-61.