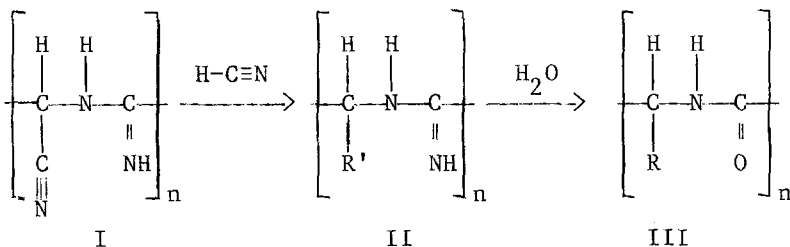


SIMULTANEOUS SYNTHESIS OF POLYPEPTIDES AND POLYNUCLEOTIDES?  
 HYDROGEN CYANIDE POLYMERS AS PREBIOTIC CONDENSING AGENTS.

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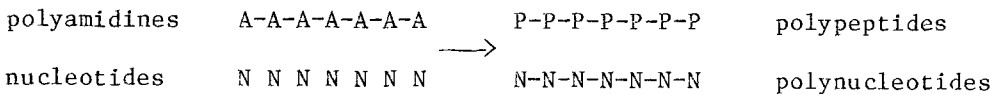
It is widely assumed that the prebiotic formation of primitive proteins occurred in two stages,  $\alpha$ -amino acid synthesis initiated by the action of natural high-energy sources on the components of a reducing atmosphere, followed somehow by condensation of the accumulated monomers in the oceans or on land. An alternative route for the origin of proteins considers instead the direct synthesis of heteropolypeptides from hydrogen cyanide and water without the intervening formation of  $\alpha$ -amino acids (Matthews and Moser, 1967). Following the initial production of hydrogen cyanide in the upper atmosphere by photolysis of methane and ammonia, a key step was the rapid vapor phase polymerization of clouds of HCN to polyaminomalnonitrile (I). Subsequent reactions of hydrogen cyanide with the activated nitrile groups of I then yielded heteropolyamidines (II) which settled in the oceans and became converted to heteropolypeptides (III) after a series of hydrolysis and decarboxylation steps.



Several kinds of experiments have provided results consistent with this route. In general, we find that water-soluble, yellow-brown solids can be extracted from the products of HCN polymerization or from electric discharge reactions yielding HCN from methane-ammonia mixtures. As predicted, acid hydrolysis of these yellow-brown polymers yields not just glycine but other  $\alpha$ -amino acids as well, such as alanine, aspartic acid, glutamic acid, serine, and leucine (GC-MS analysis). Also as predicted, the glycine is perdeuterated when  $\text{D}_2\text{O}/\text{DCl}$  is used for hydrolysis instead of  $\text{H}_2\text{O}/\text{HCl}$ . Non-destructive analysis of these polymer products became possible with the advent of cross-polarization magic-angle spinning solid state NMR spec-

trospectroscopy ( $^{15}\text{N}$ ,  $^{13}\text{C}$ ). In particular the unambiguous presence of secondary amide groups, as in peptides, has been established by double-cross-polarization studies on polymers synthesized from mixtures of  $\text{H}^{13}\text{CN}$  and  $\text{HC}^{15}\text{N}$  (Matthews et al, 1984).

The ready conversion by water of polyamidines to polypeptides demonstrated by these investigations suggests that the polyamidines I and II might have played a further essential role in chemical evolution. In the absence of water they could have been the original condensing agents of prebiotic chemistry. Their reactive amidine groups, eager to become amides, would have brought about the stepwise formation of nucleosides, nucleotides and polynucleotides from available sugars, phosphates and nitrogen bases. Most significant would have been the parallel synthesis of polypeptides and polynucleotides arising from the dehydrating action of polyamidines on nucleotides:



Optimum conditions might well have existed on a primitive Earth where prebiotic synthesis of organic molecules proceeded in the atmosphere in three overlapping stages defined by the relative volatility of methane, ammonia and water. First, hydrocarbon chains were formed following the photolysis of methane to acetylenes. Then, as ammonia became more involved in atmospheric photochemistry, hydrogen cyanide and cyanoacetylene became major reactants. Polymeric peptide precursors (I,II) and other nitriles were formed together with nitrogen heterocycles possessing the basic skeletons of purines, pyrimidines, pyridines and porphyrins. When most of the ammonia had been used up, photolysis of water vapor that had been confined to lower levels became possible, leading to the third stage when formaldehyde and sugars were synthesized, as well as phosphates from phosphine. Unlike the prevailing dilute soup picture of chemical evolution, this atmospheric model supplies an abundance of prebiotic compounds, fast, in the right place at the right time. As Earth's surface became covered with this organic shower, potential membrane material--carboxylic acids, carbohydrates, polypeptides--accumulated in lakes and oceans, while on land the simultaneous synthesis of polypeptides and polynucleotides was promoted by cyanide polymers (I,II), perhaps assisted by clays. On our dynamic planet this polypeptide-polynucleotide symbiosis mediated by polyamidines set the pattern for the evolution of protein-nucleic acid systems, controlled by enzymes, so characteristic of life today.

Matthews, C. N. and Moser, R. E.: 1967, *Nature* 215, 1230.

Matthews, C. N., Ludicky, R., Schaefer, J., Stejskal, E. O. and McKay, R. A.: 1984, *Origins of Life* 14, 243.