Origin of life - from structural and energetic perspectives

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50 years after the historical Miller-Urey experiment\(^1\) the formamide-based scenario\(^2\) is perhaps the most powerful concurrent hypothesis for the origin of life on Earth besides the traditional HCN-based concept. Nowadays the formamide-based origin model represents the most continuous known way leading from simple prebiotic precursors up to the first catalytically active RNA molecules. In my talk I will overview the major events of this long pathway from a theoretical perspective, mainly concentrating on the structural and energetic aspects of the processes allowing for the emergence of more and more complex molecular systems from simple prebiotic precursors.

I will illustrate how the energy-driven chemistry characterizing the earliest stages of abiogenesis could translate to a structure-driven chemistry with increasing molecular complexity. Whereas prebiotic synthesis of the building blocks of the first genetic molecules involves a less selective high-energy chemistry, at higher levels of molecular evolution other aspects, like structural compatibility, become decisive.

In particular, we will address the following steps of the formamide-based synthetic route. At first, we will scrutinize the thermal\(^2\) and radical\(^3\) pathways leading from formamide to the four nucleobases that form the basis of genetic coding in modern organisms. Further, we will analyze the structural and energetic conditions of the spontaneous oligomerization of cyclic nucleotides\(^4\) that could lead to the simplest oligonucleotide sequences. Finally, we will discuss how these simple oligonucleotide sequences could acquire their catalytic activity,\(^5\) i.e. a property that stays behind the evolution of species on our planet.

Figure 1: Formamide’s long trek towards life through the „free-energy hill“. The first part of the path is the synthesis of prebiotic building blocks which is clearly energy-driven. The second part of the path, i.e. self-assembling of the precursor nucleotides to form functional RNA-molecules, involves small energy changes, and, therefore, is controlled mainly by structure-related effects.