Title of the Ph.D. dissertation:

Modeling spatial RNA structures in evolutionary studies at the molecular level and designing RNA nanoparticles

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Abstract

The main objective of my Ph.D. dissertation was to investigate the evolutionary processes of RNA molecules and design functional RNA nanoparticles using advanced computational methods for predicting RNA spatial structure. These studies were performed using the full capabilities of the RNAComposer application. RNAComposer is based on machine learning and fragment assembly modeling, which proceeds very fast and in a highly automated manner.

At the molecular level, evolution primarily concerns biological macromolecules such as RNA, DNA, and proteins. Detailed study of evolutionary mechanisms allows for understanding the structural and functional changes of macromolecules over time. Molecular evolution mechanisms have not been definitively determined thus far.

As part of my Ph.D. thesis, I constructed models of the spatial structure for the most evolutionarily variable fragment of ribosomal RNA, known as the Expansion Segment 7 (ES7). I predicted ES7 models from various organisms, differing in sequence, size, and level of structural complexity. However, a common feature among them was the conserved core structure, referred to as the signature fold. In this study, we confirmed an accretionary model of RNA molecule evolution at the molecular level and proposed a model for the growth of rRNA molecule structures.

Nanotechnology is a rapidly advancing field with tremendous application potential. Currently, several RNA molecules are used as therapeutic agents, and several more are undergoing testing. The development of methods that enable the efficient design of custom-tailored RNA structures would allow for the characterization of other nanoscale particles with dedicated properties.

In my Ph.D. thesis, I presented the possibilities of designing RNA nanoparticles using the example of an RNA nano-square structure. The nano-square structure was designed to form spatial molecular networks through the introduced RNA hairpin structure. This additional hairpin allows RNA - RNA interaction between molecules through the loop – loop pairing.