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UCSB Scientists Build Nanoscale ‘Jigsaw' Puzzles Made of RNA

Scientists at the University of California, Santa Barbara, working at the leading edge of bionanotechnology, are using assembly and folding principles of natural RNA, or ribonucleic acid, to build beautiful and potentially useful artificial structures at the nano-scale. Possible applications include the development of nanocircuits, medical implants, and improved medical testing.

This research, published in the December 17 issue of the journal Science, is led by Luc Jaeger, assistant professor in the Department of Chemistry and Biochemistry at UCSB and a member of UCSB's Biomolecular Science and Engineering Program, and by Arkadiusz Chworos, a post-doctoral fellow studying in Jaeger's lab.

"In our lab, we see ourselves as nano-architects" said Jaeger. "We are using the lessons that nature teaches us about RNA assembly and folding principles to create nano-scale buildings made of 'smart' molecular 'Lego-like' bricks." This concept, called RNA tectonics, led to the synthesis of RNA grids with finite size and various patterns. Using atomic force microscopy, the UCSB team has been able to visualize some of their assemblies made of square-shaped RNA units that form beautiful patterns and nano-grids.

One of the aims of Jaeger's group is to address one of the great challenges in supra-molecular chemistry: to attain total control of the arrangement of matter at a molecular level. The artificial RNA molecular system is based on 'smart' RNA pieces, which could self-assemble in a predictable manner into any possible two-dimensional architecture with full control over size, shape and pattern geometry, according to the scientists.

Thus, the final position of each piece can eventually be located within a network lattice of finite size. In the human-scale world, a good parallel would be a jigsaw puzzle game of different pieces for which all the pieces can precisely self-assemble without direct human intervention.

"This task may seem daunting for us, but it is not for nature," explained Jaeger. Nature takes advantage of these properties for the assembly of thousands of molecules in living organisms. Out of the three major biopolymers, RNA is thought to be the most ancient one on which life is based. RNA is different from DNA in both the stability of Watson-Crick base pairing and in that it is designed to function as a single-stranded molecule. In this way, RNA has some of the nature and functionality of self-assembled proteins.

DNA has been extensively used to generate artificial geometrical objects. Although more chemically labile than DNA, RNA is now gaining attention for its potential in building molecular components with high precision. The ability of RNA to fold into a richer treasure trove of rigid structural motifs, that can be potential modules for supramolecular engineering, is particularly attractive to scientists.

Chworos, the first author of the paper, explained that aperiodic nano-grids may eventually be used as a starting point to generate nanochips, nanocircuits and nanocrystals with potential applications in nanotechnology and materials science. For example, RNA-based materials could offer the unique possibility to act as scaffoldings for precisely aligning quantum dots or organic polymers.

Helen Hansma, co-author and adjunct associate professor of physics at UCSB, said that this advance in the basic science could eventually lead to the use of RNA supra-molecular assembly in medical applications and could be used to to help heal or regenerate bone or other body parts. She also suggested the possibility of miniaturizing some medical tests, allowing the tests to take up less space and use fewer chemicals.

"Like DNA, RNA is now entering into the realm of nano-materials but many technical challenges await us in the development of these applications," said Jaeger. "Our next immediate task is to develop 'smart' RNA pieces that will assemble into responsive, self-assembling, three-dimensional materials."

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