Self-replication process holds promise for production of new materials

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New York University scientists have developed artificial structures that can self-replicate, a process that has the potential to yield new types of materials. The work, conducted by researchers in NYU's Departments of Chemistry and Physics and its Center for Soft Matter Research, appears in the latest issue of the journal *Nature*.

In the natural world, self-replication is ubiquitous in all living entities, but artificial self-replication has been elusive. The discovery in Nature reports the first steps toward a general process for self-replication of a wide variety of arbitrarily designed seeds. The seeds are made from DNA tile motifs that serve as letters arranged to spell out a particular word. The replication process preserves the letter sequence and the shape of the seed and hence the information required to produce further generations.

This process holds much promise for the creation of new materials. DNA is a robust functional entity that can organize itself and other molecules into complex structures. More recently DNA has been used to organize inorganic matter, such as metallic particles, as well. The re-creation by the NYU scientists of this type of assembly in a laboratory raises the prospect for the eventual development of self-replicating materials that possess a wide range of patterns and that can perform a variety of functions. The breakthrough the NYU researchers have achieved is the replication of a system that contains complex information. Thus, the replication of this material, like that of DNA in the cell, is not limited to repeating patterns.

To demonstrate this self-replication process, the NYU scientists created artificial DNA tile motifs —short, nanometer-scale arrangements of DNA. Each tile serves as a letter—A or B—that recognizes and binds to complementary letters A' or B'. In the natural world, the DNA replication process involves complementary matches between bases—adenine (A) pairs with thymine (T) and guanine (G) pairs with cytosine (C) -- to form its familiar double helix. By contrast, the NYU researchers developed an artificial tile or motif, called BTX (bent triple helix molecules containing three DNA double helices), with each BTX molecule comprised of 10 DNA strands. Unlike DNA, the BTX code is not limited to four letters—in principle, it can contain quadrillions of different letters and tiles that pair using the complementarity of four DNA single strands, or "sticky ends," on each tile, to form a six-helix bundle.

In order to achieve self-replication of the BTX tile arrays, a seed word is needed to catalyze multiple generations of identical arrays. BTX's seed consists of a sequence of seven tiles—a seven-letter word. To bring about the self-replication process, the seed is placed in a chemical solution, where it assembles complementary tiles to form a "daughter BTX array"—a complementary word. The daughter array is then separated from the seed by heating the solution to ~ 40 oC. The process is then repeated. The daughter array binds with its complementary tiles to form a "granddaughter array," thus achieving self-replication of the material and of the information in the seed—and hence reproducing the sequence within the original seed word. Significantly, this process is distinct from the replication processes that occur within the cell, because no biological components, particularly enzymes, are used in its execution—even the DNA is synthetic.

"This is the first step in the process of creating artificial self-replicating materials of an arbitrary composition," said Paul Chaikin, a professor in NYU's Department of Physics and one of the study's co-authors. "The

next challenge is to create a process in which self-replication occurs not only for a few generations, but long enough to show exponential growth."

"While our replication method requires multiple chemical and thermal processing cycles, we have demonstrated that it is possible to replicate not just molecules like cellular DNA or RNA, but discrete structures that could in principle assume many different shapes, have many different functional features, and be associated with many different types of chemical species," added Nadrian Seeman, a professor in NYU's Department of Chemistry and a co-author of the study.

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