Structural DNA Nanotechnology

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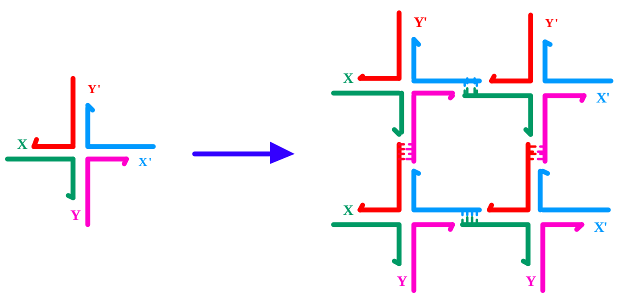
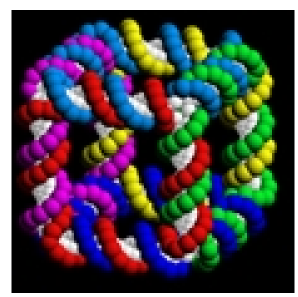
DNA nanotechnology uses reciprocal exchange between DNA double helices or hairpins to produce branched DNA motifs, like Holliday junctions, or related structures, such as double crossover (DX), triple crossover (TX), paranemic crossover (PX) and DNA parallelogram motifs. We combine DNA motifs to produce specific structures by using sticky-ended cohesion (below, left). The strength of sticky-ended cohesion is that it produces predictable adhesion combined with known structure. From simple branched junctions, we have constructed DNA stick-polyhedra, such as a cube (below, right) and a truncated octahedron, several deliberately designed knots, and Borromean rings. We have used two DX molecules to construct a DNA nanomechanical device by linking them with a segment that can be switched between left-handed Z-DNA and right-handed B-DNA. PX DNA has been used to produce a robust sequence-dependent device that changes states by varied hybridization topology.





A central goal of DNA nanotechnology is the self-assembly of periodic matter. We have constructed micron-sized 2-dimensional DNA arrays from DX, TX and parallelogram motifs. We can produce specific designed patterns visible in the AFM from DX and TX molecules. We can change the patterns by changing the components, and by modification after assembly. In addition, we have generated 2D arrays from DNA parallelograms. These arrays contain cavities whose sizes can be tuned by design. In studies complementary to specific periodic self-assembly, we have performed algorithmic constructions, corresponding to XOR operations.

The key challenge in the area is the extension of the 2D results obtained so far to 3D systems. We expect to be able to produce high resolution crystals of DNA host lattices with heterologous guests, leading to well-ordered bio-macromolecular systems amenable to diffraction analysis. Other challenges are to incorporate DNA nanomechanical devices in periodic and aperiodic lattices and to use the lattices to organize nanoelectronic components. Self-replicating structural systems present a further exciting avenue to be pursued.

Biology contains numerous lessons for the physical sciences. The existence of living systems with nanoscale structural components represents an existence proof that autonomous systems can build up and function on this scale, systems capable of energy transduction and replication. The overall challenge that biology presents to the physical sciences is to move from biokleptic to biomimetic to abiological systems that perform in this same manner.