MOLECULAR ENGINEERING

DNA origami in 3D

Complex, curved three-dimensional DNA nanostructures can be created using new DNA origami folding techniques.

In the traditional Japanese art of origami, pieces of ordinary paper are folded into extraordinary shapes. In the DNA origami technique, strands of DNA are folded into a variety of nanostructures. In recent work, Hao Yan, Yan Liu and Dongran Han of The Biodesign Institute of Arizona State University report new DNA origami design principles that allow them to engineer complex, curved three-dimensional nanostructures with a high degree of control.

In the typical DNA origami technique, multiple short single strands of DNA known as 'staples' are used to direct the folding of a large single DNA strand, called a 'scaffold'. But this block-based design does not allow for much control over curvature. Yan, Liu, Han and colleagues thus came up with a different approach. First, they create a blueprint for a particular shape, for example, several concentric rings. They introduce periodic cross-overs from short staple strands, such that the strand forming part of one ring makes a cross-over to an adjacent ring, where it forms part of that ring as well, and so on; in this way, the rings are connected and constrained to the same two-dimensional plane. The pattern and number of cross-overs depend on the blueprint for the structure. Finally, they wind a long scaffold DNA strand onto the blueprint such that it comprises one of the two strands in every helix.

Extending their design process to three dimensions (3D), the researchers constructed nanostructures such as hemispheres, spheres, ellipsoids and even a 'nanoflask.' Taking the nanosphere as an example, they spool the DNA around latitudinal rings; the rings are smallest at the 'north and south poles', and largest at the 'equator.' Although the latitudinal curvature is in-plane, much like the two-dimensional example described above, the longitudinal curvature is necessarily out of plane, which again is achieved by the careful choice of cross-over patterns between adjacent rings.

The researchers note that software tools to automate the design of such nanostructures in 3D would be tremendously useful. Additionally, the availability of longer single-strand DNA scaffolds would facilitate the construction of larger, more complex nanostructures.

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RESEARCH PAPERS

Han, D. *et al.* DNA origami with complex curvatures in three-dimensional space. *Science* **332**, 342–346 (2011).