Structural DNA Nanotechnology: A Powerful Example of Self-Assembly on the Nanometer Scale

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Everything Self-Assembles

The Most Interesting Examples Entail
Biological Macromolecules

[Nucleic Acids and Proteins]

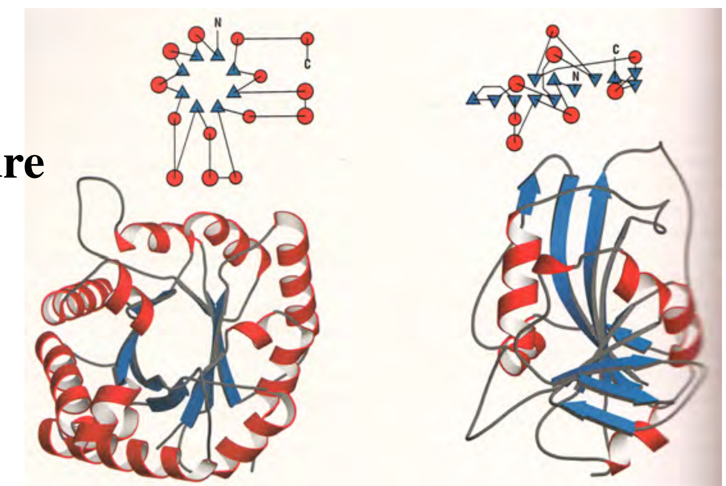
Because Their Surfaces Encode

INFORMATION

Proteins are Long Strings of Amino Acids that Fold into 3D Shapes Called Tertiary Structures

Red Coils = Alpha Helices

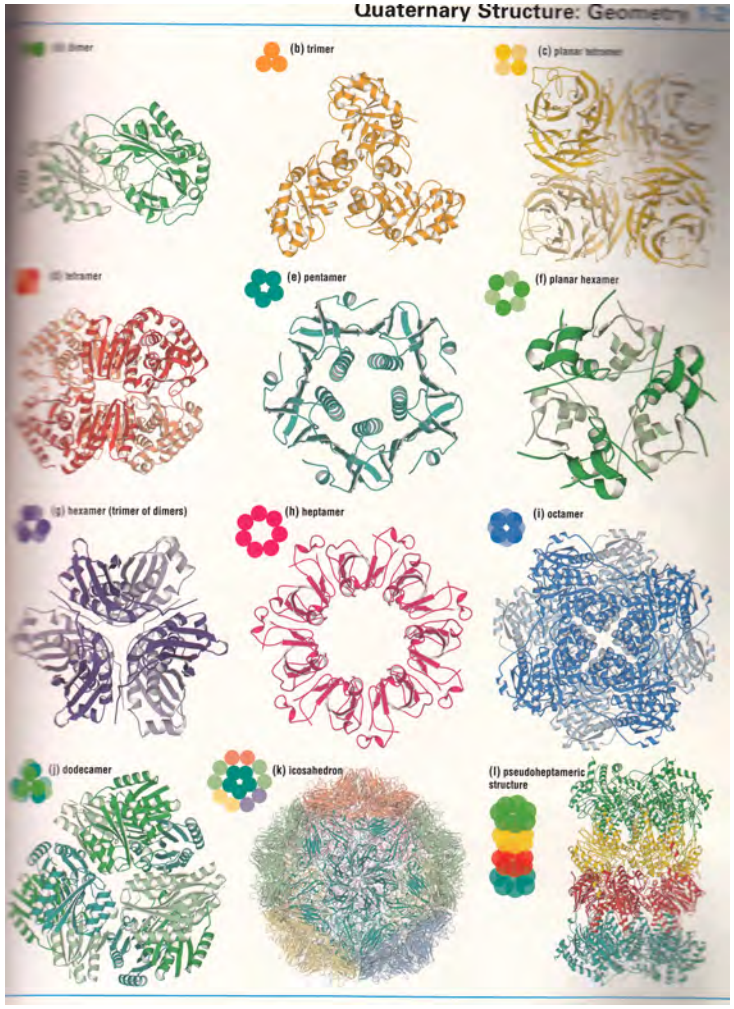
Blue Arrows = Beta Structure



We DO NOT Know How to Predict or Design Tertiary Structure Very Well

From Petsko, G., Ringe D. Protein Structure and Function

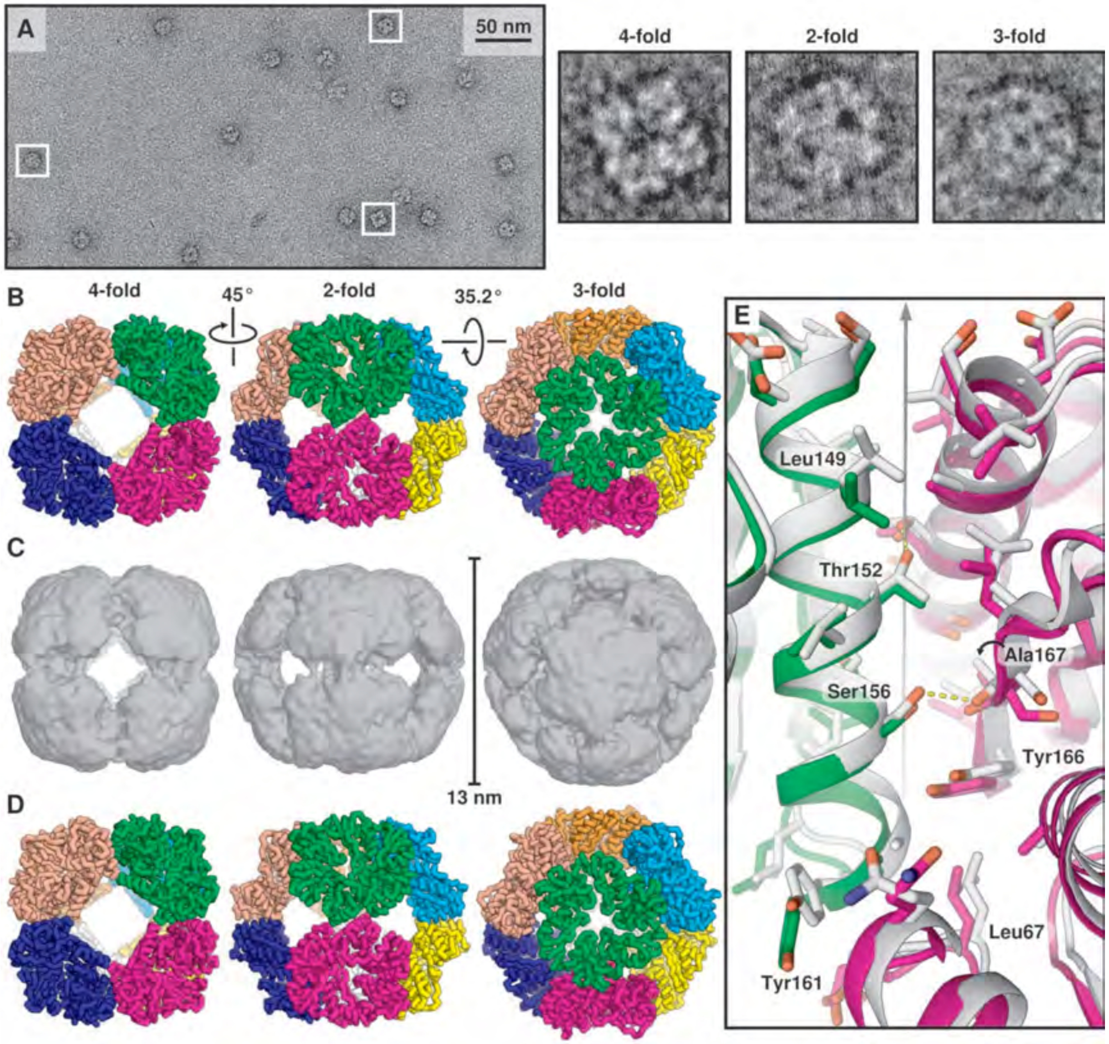
These Can Associate to Produce Quaternary Structures



We DO NOT Know How to Predict or Design Quaternary Structure Very Well Either

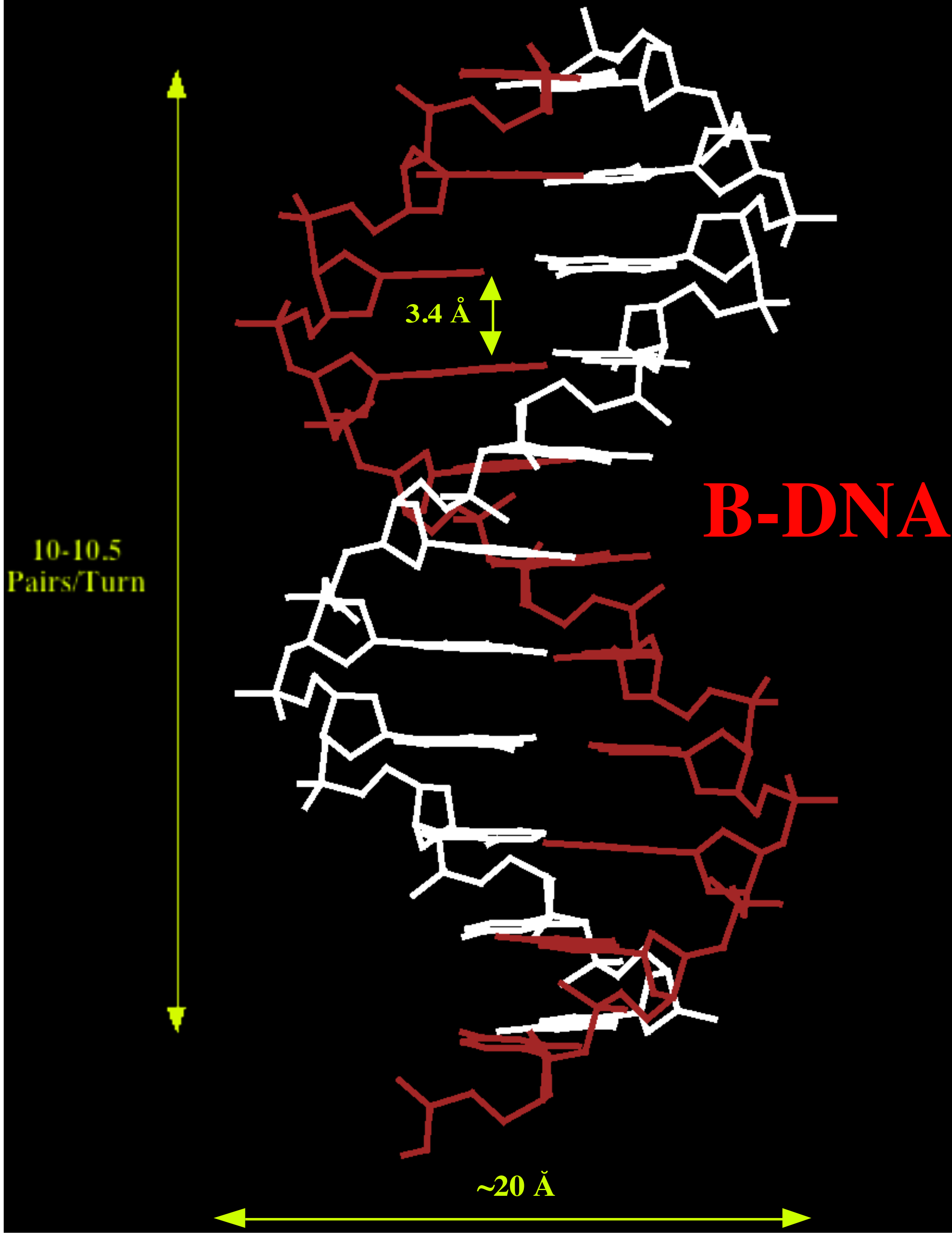
From Petsko, G., Ringe D. Protein Structure and Function

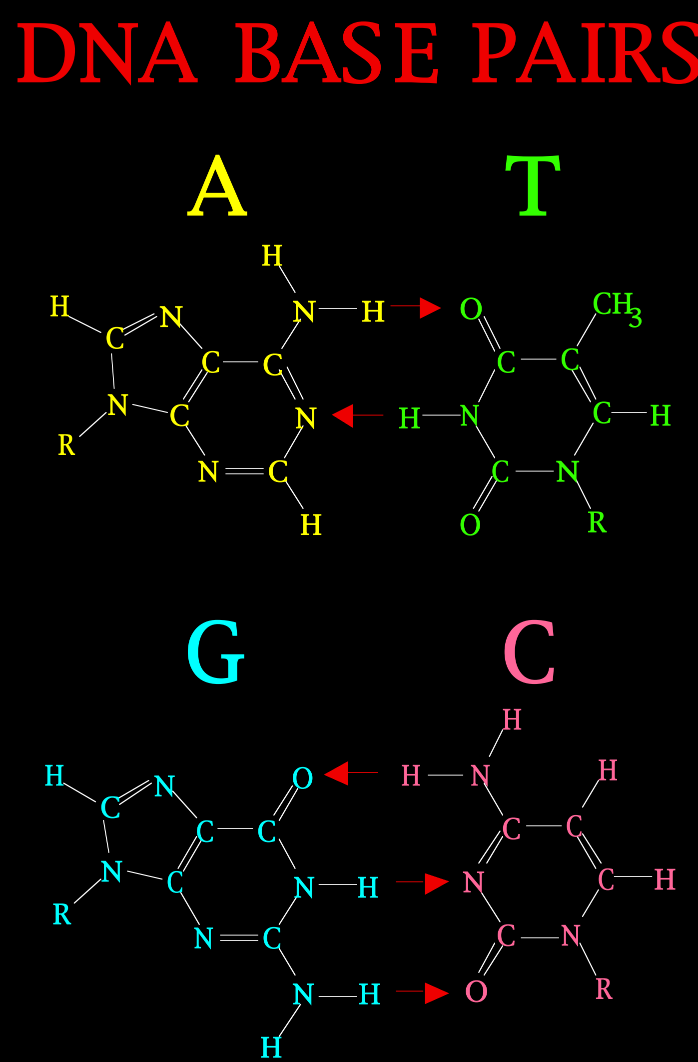
The Most Successful Example is from Yeates, Baker and Colleagues



King *et al.Science* 336, 1171 (2012) .

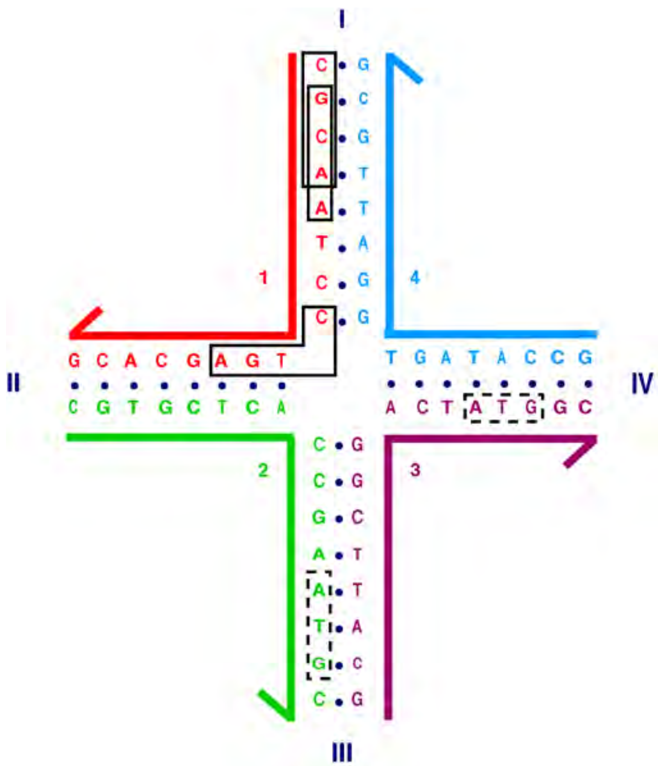
DNA Is Much Easier





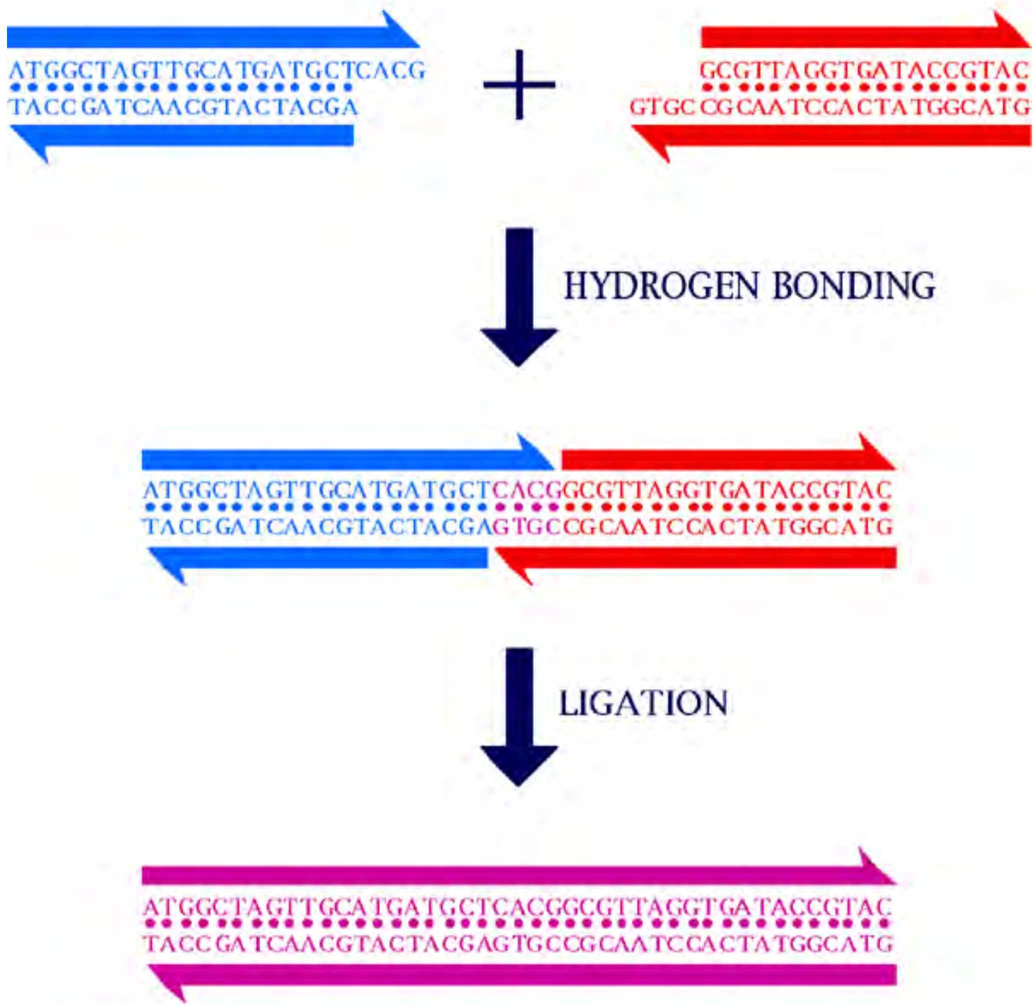
However, It Must be Branched to Produce Interesting Structures.

A Simple Algorithm Exists to Minimize Symmetry, Leading to Branching In Synthetic Molecules



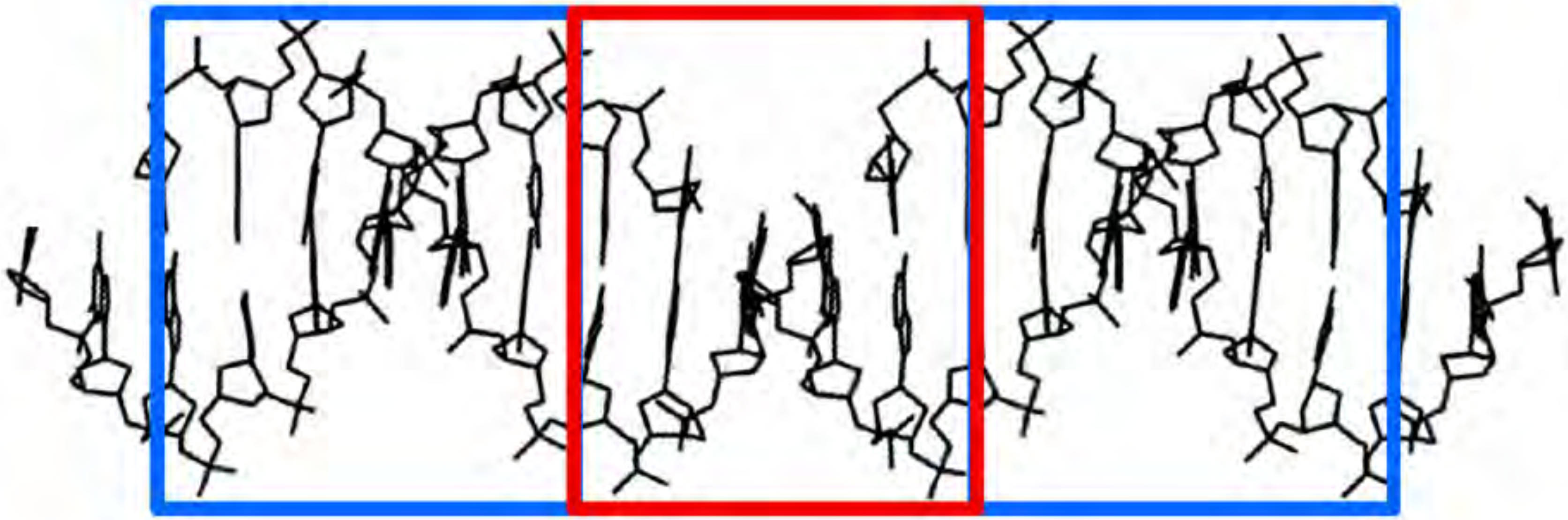
Seeman, N.C. (1982), *J. Theor.Biol*. **99**, 237-247.

Sticky-Ended Cohesion: Programmable Affinity



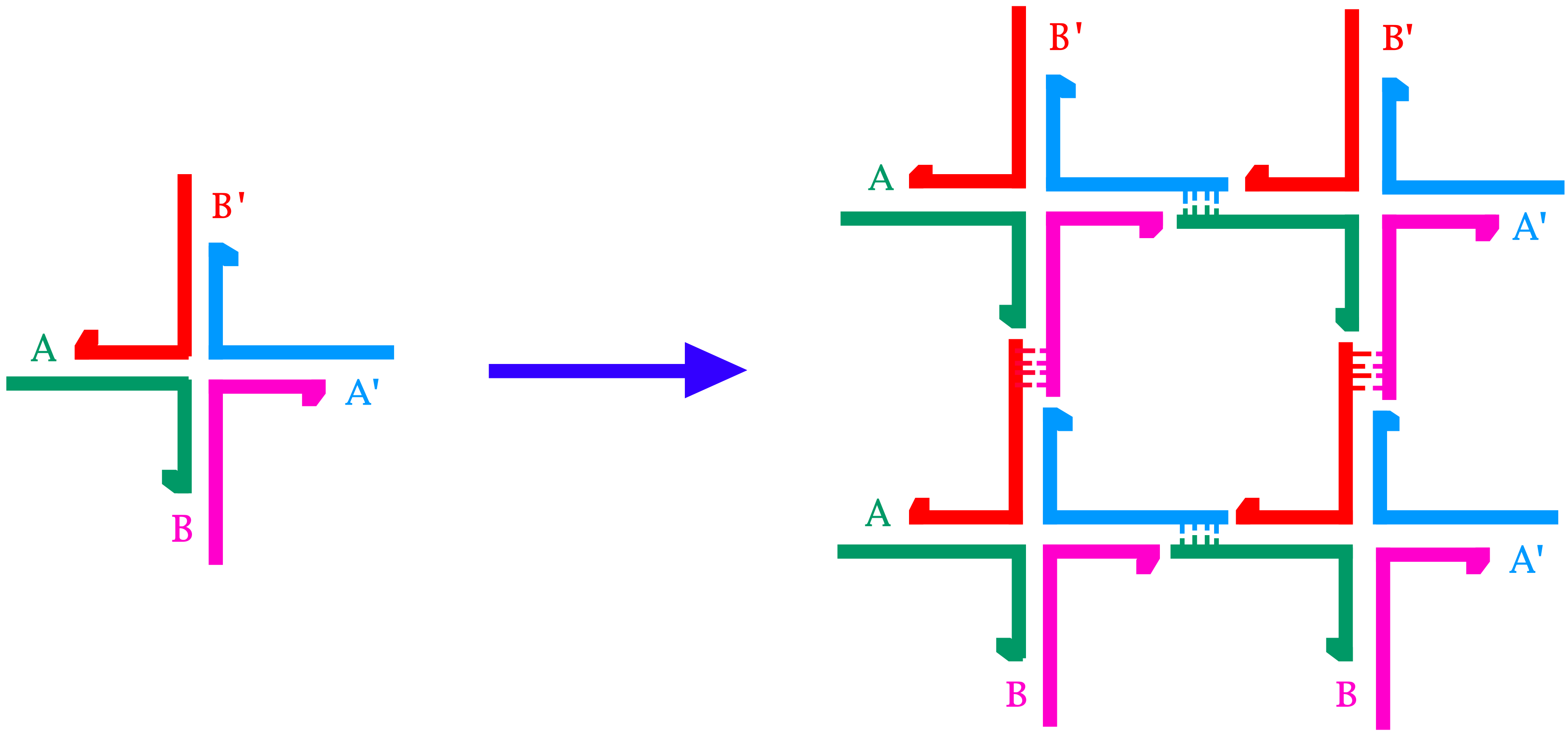
Seeman, N.C. (1982), *J. Theor.Biol*. **99**, 237-247.

Sticky-Ended Cohesion: Structure



Qiu, H., Dewan, J.C. & Seeman, N.C. (1997) *J. Mol. Biol.* **267**, 881-898.

The Central Concept of Structural DNA Nanotechnology: Combine Branched DNA with Sticky Ends to Make Objects, Lattices and Nanomechanical Devices



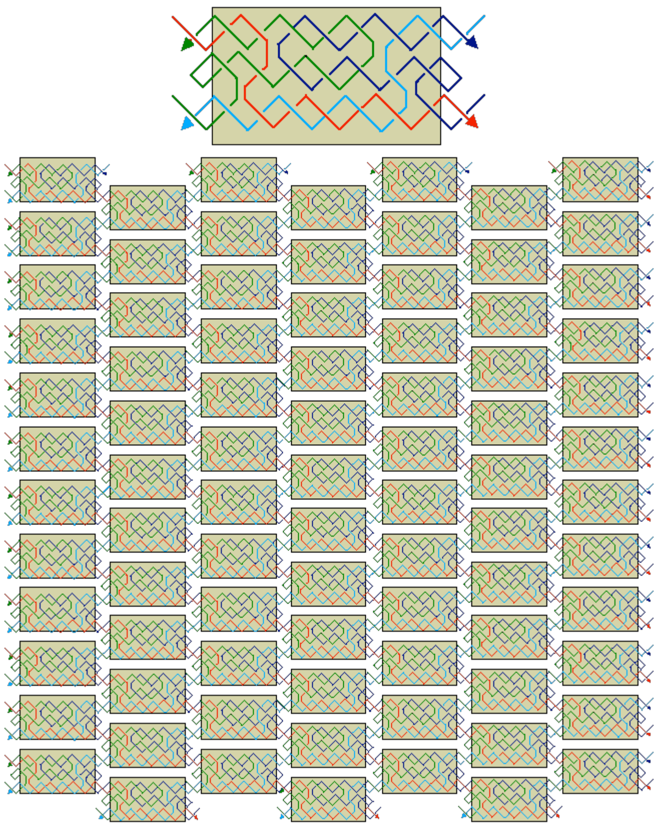
Seeman, N.C. (1982), *J. Theor.Biol*. **99**, 237-247.

DNA NANOTECHNOLOGY

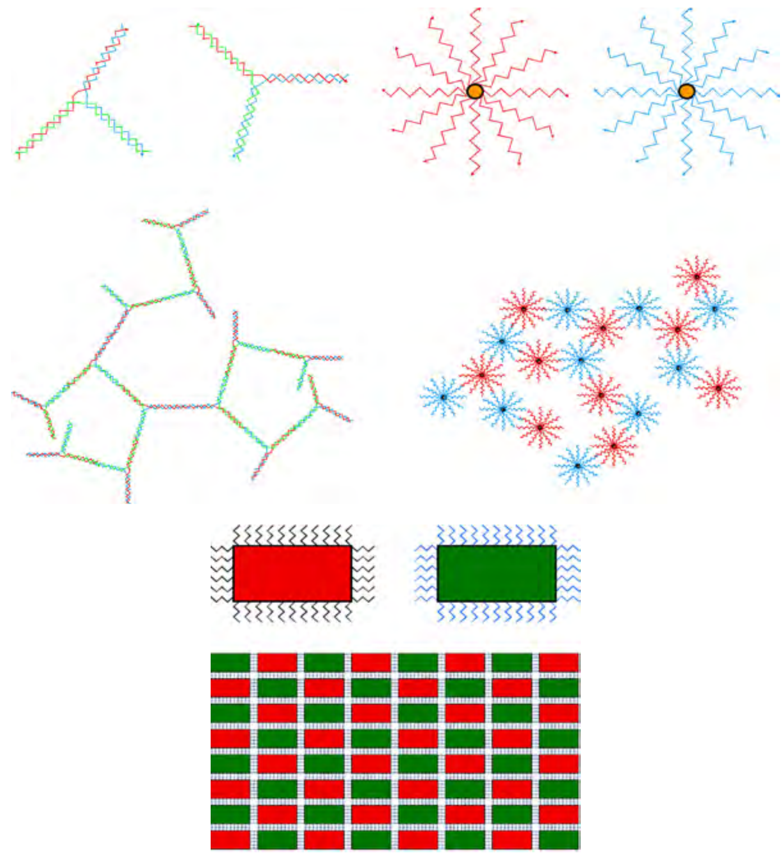
High Resolution/Structural: DNA as Bricks and Mortar

Low Resolution/Compositional: DNA as Mortar/Smart Glue Only

Propagation Directions Well-Defined

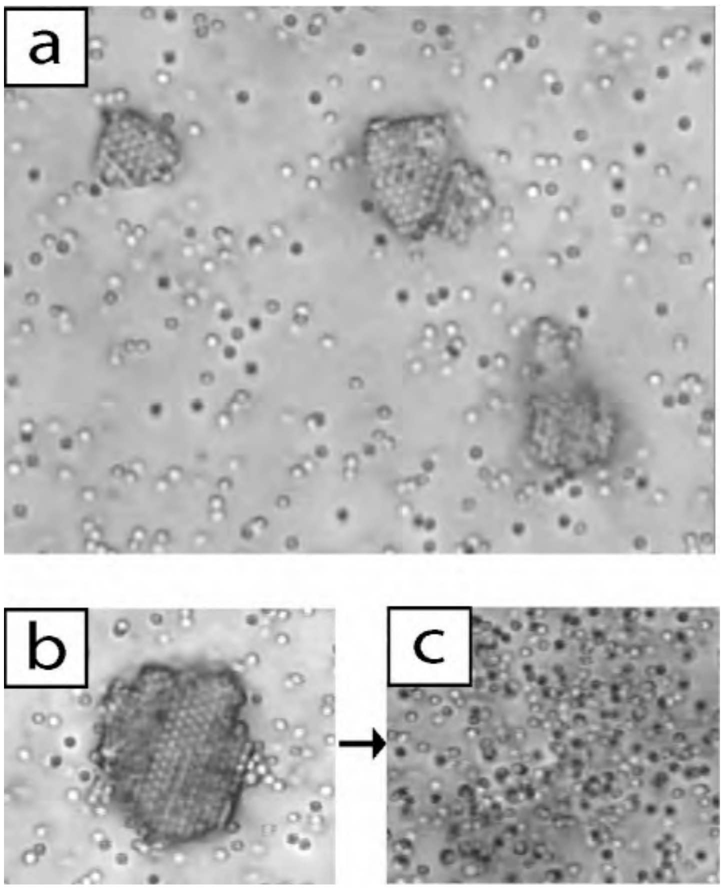


Propagation Directions Not Well-Defined

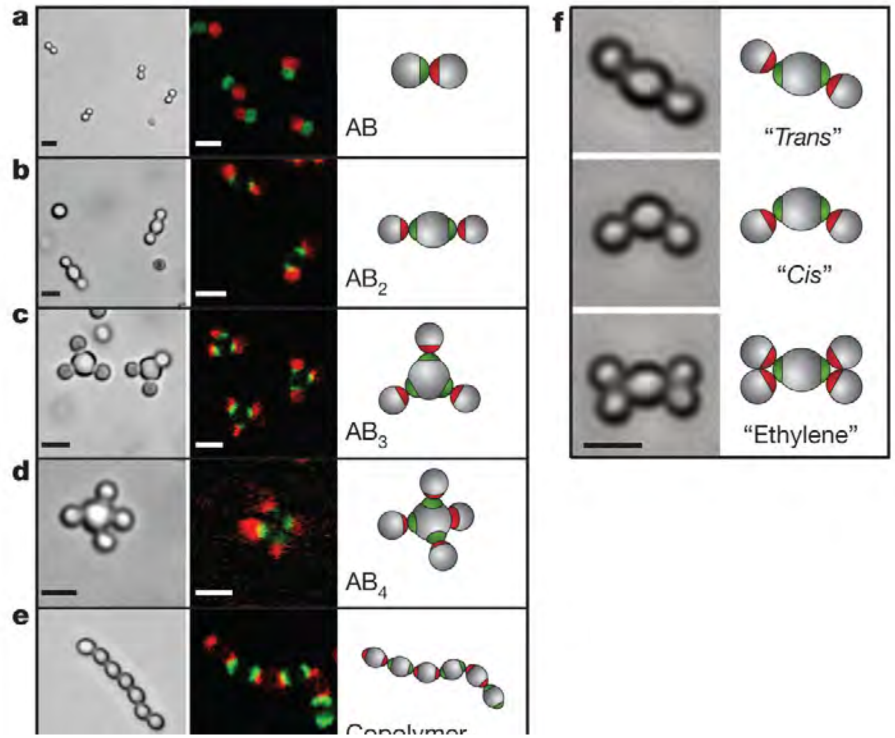


EXAMPLES OF SUCCESSFUL LOW-RESOLUTION DNA NANOTECHNOLOGY

Crocker and Colleagues



Pine and Colleagues



Langmuir 2006, 22, 1991-2001

Nature 2012, 491, 51-56

Polyhedral Catenanes

Cube: Junghuei Chen

Cube

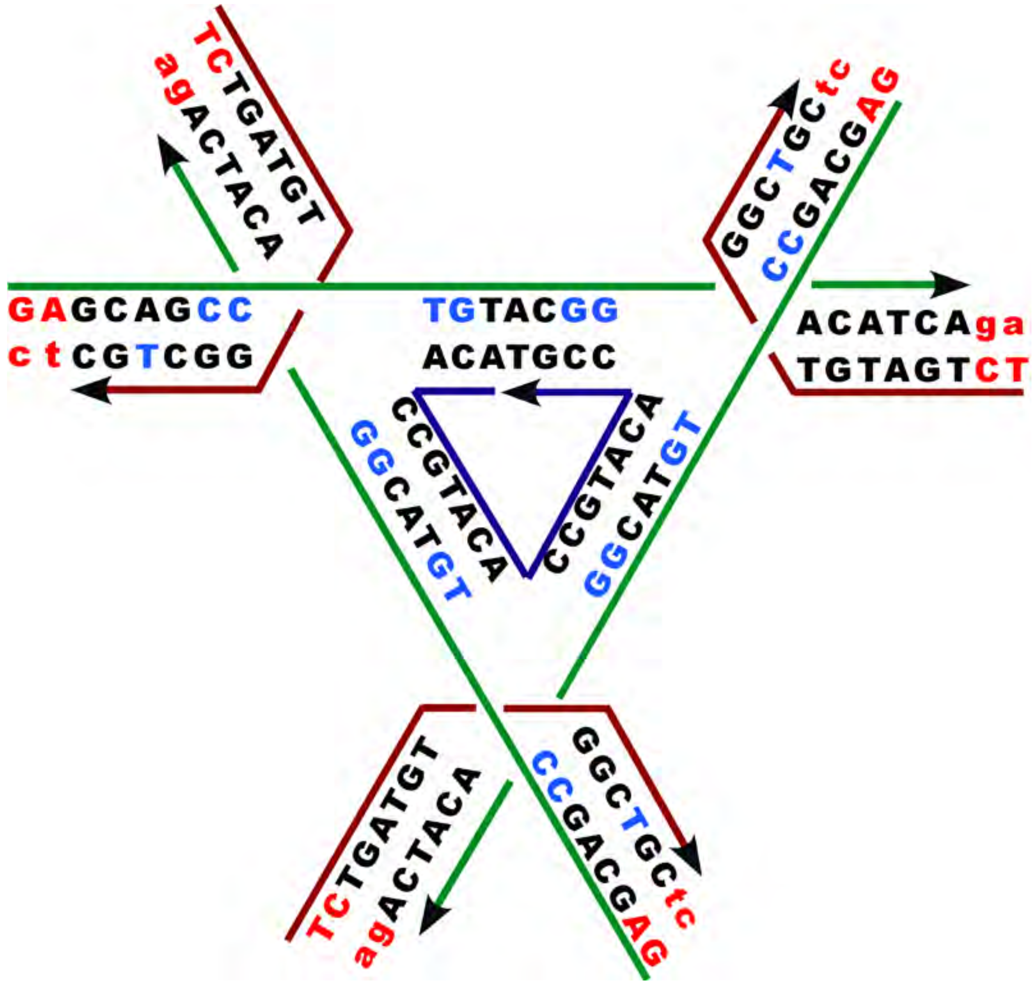
Chen, J. & Seeman. N.C. (1991), *Nature* **350**, 631-633.

Three-Dimensional Self-Assembled Arrays: DESIGNED CRYSTALS!

Jianping Zheng, Jens J. Birktoft, Yi Chen (Purdue),
Tong Wang, Ruojie Sha, Pam Constantinou,
Steve Ginell (Argonne), Chengde Mao (Purdue)

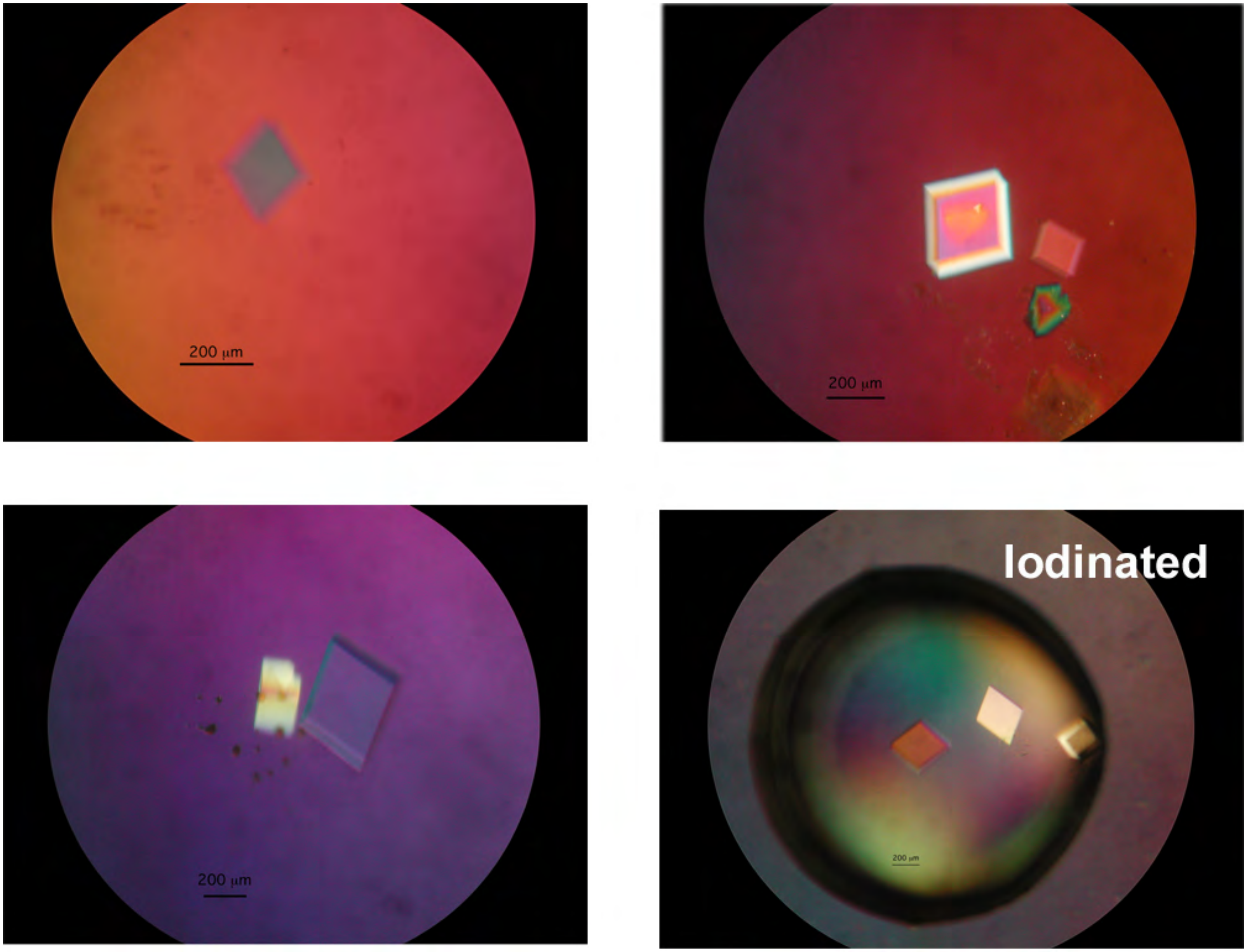
Diffraction Data Collected at
Brookhaven National Laboratory (NSLS) and
Argonne National Laboratory (APS)

A Small Threefold Pseudosymmetric DNA Tensegrity Triangle



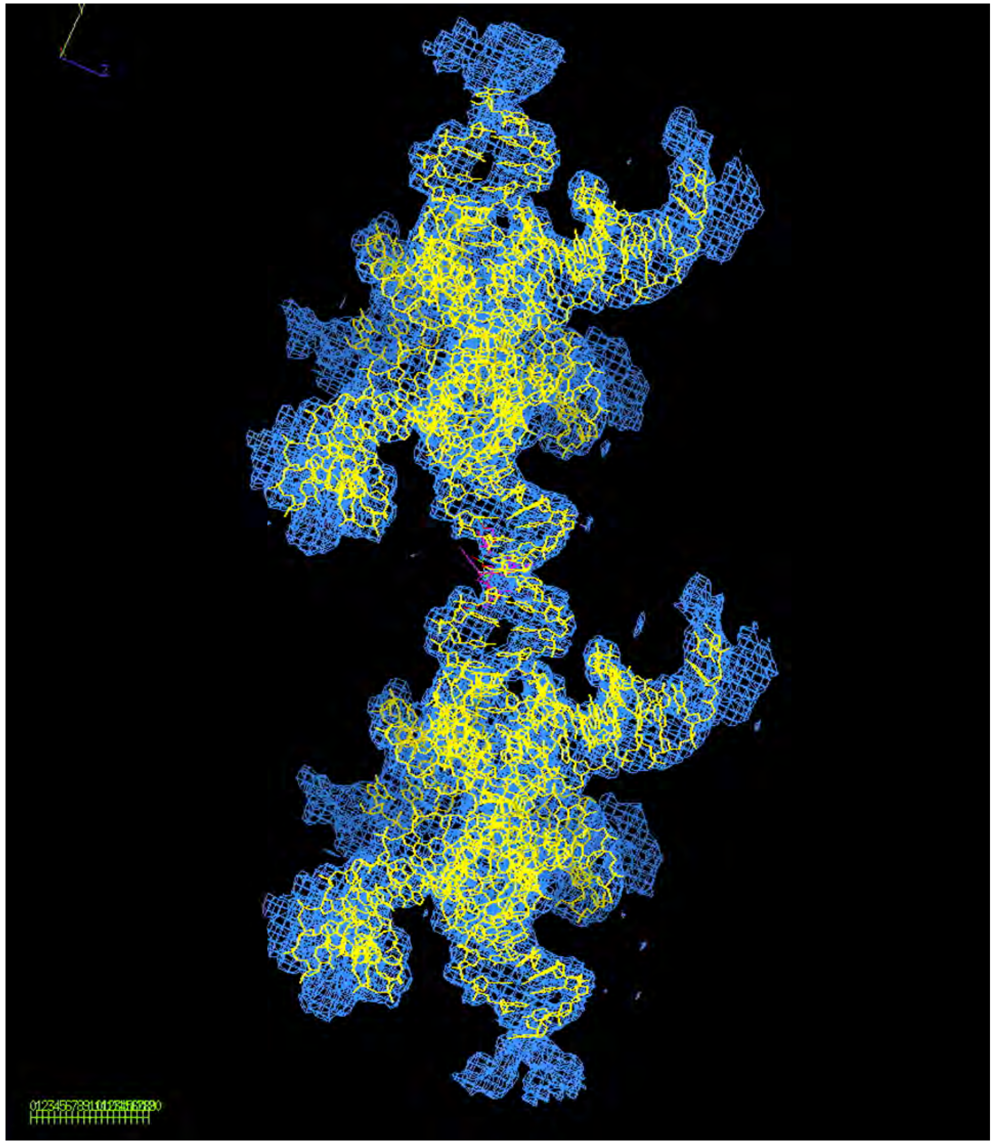
J. Zheng, J.J. Birktoft, Y. Chen, T. Wang, R. Sha,
P.E. Constantinou, S.L. Ginell, C. Mao & N.C. Seeman, *Nature* 461, 74-77 (2009).

Crystal Images



J. Zheng, J.J. Birktoft, Y. Chen, T. Wang, R. Sha, P.E. Constantinou, S.L. Ginell, C. Mao & N.C. Seeman, *Nature* 461, 74-77 (2009).

4 Å Map Perpendicular to a Helix



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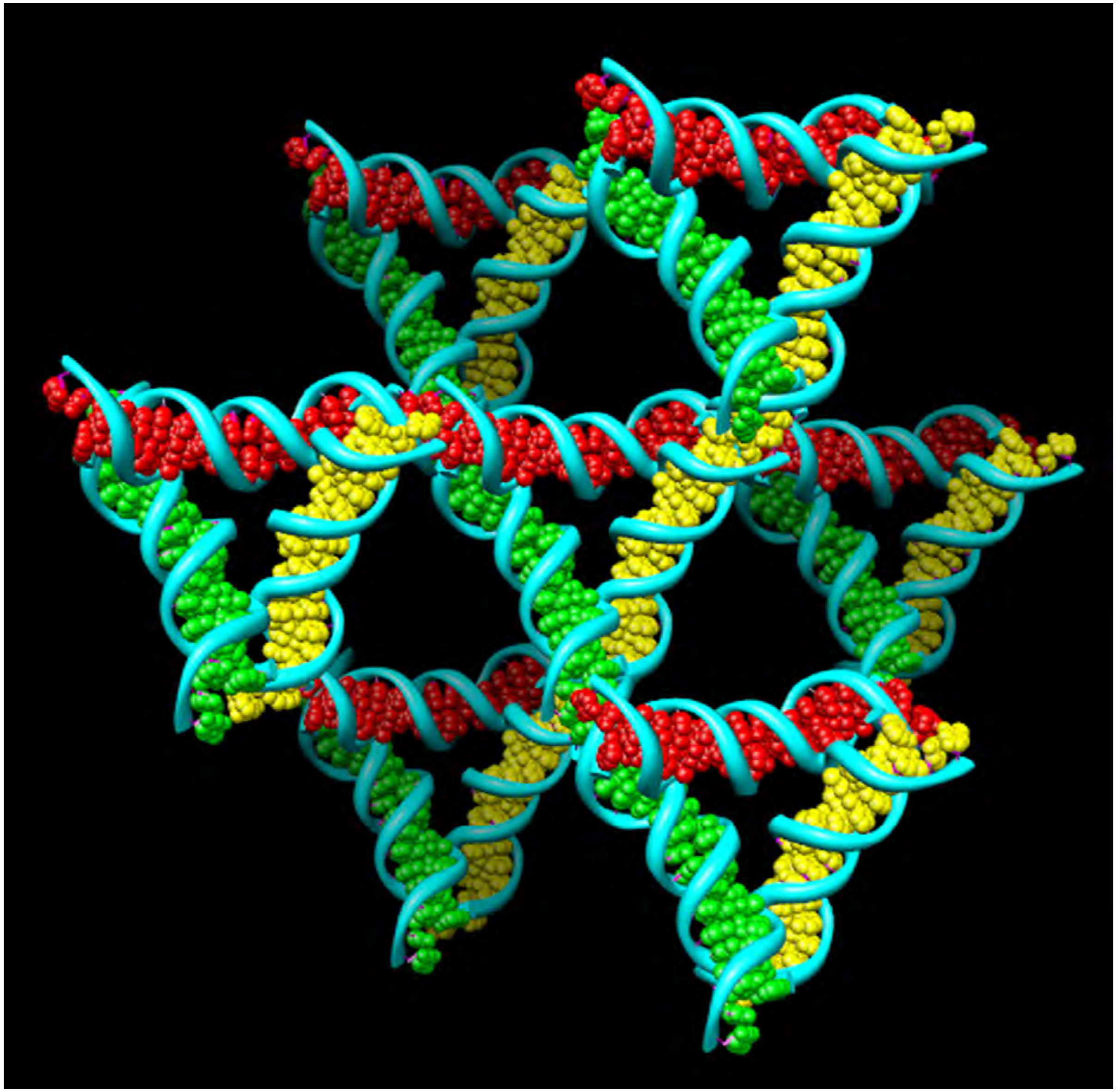
Environment of a Single Triangle



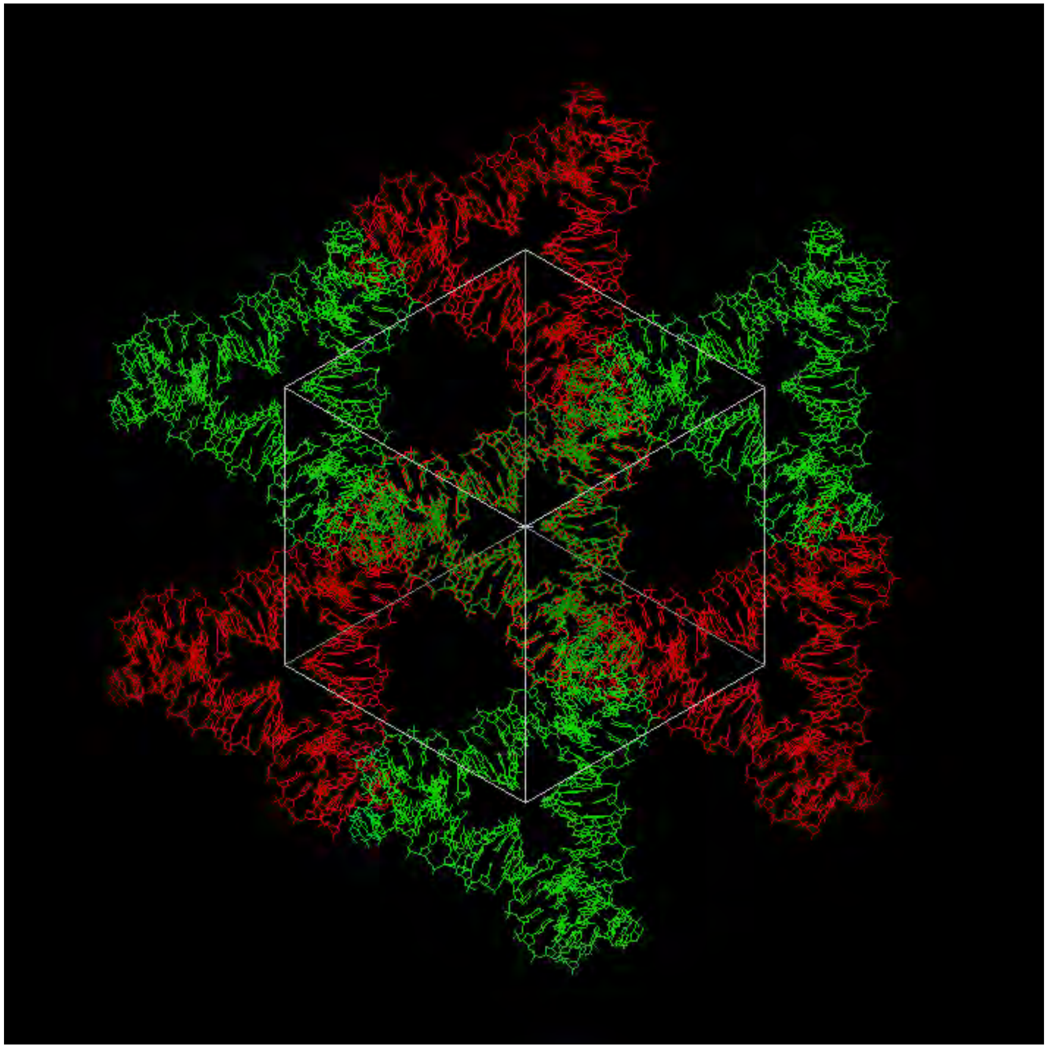
J. Zheng, J.J. Birktoft, Y. Chen, T. Wang, R. Sha,
P.E. Constantinou, S.L. Ginell, C. Mao & N.C. Seeman, *Nature* 461, 74-77 (2009).

Table 1. Crystalline Tensegrity Triangles

Edge Length	Symmetry	Inter-junction Pairs	Rhombohedral Cell Dimensions		Resolution (Å)	Cross Section (nm^2)	Cavity Size (nm^3)
21	+	7	a = 68.3,	α = 102.4°	4.0	23	103
21	-	7	a = 68.0,	α = 102.6°	5.0	23	101
31	+	17	a = 102.0,	α = 112.7°	6.1	62	366
31	-	17	a = 100.9,	α = 111.6°	6.3	61	373
32	+	18	a = 103.6,	α = 113.6°	6.5	64	367
32	-	18	a = 103.3,	α = 112.2°	6.5	64	395
42	+	17	a = 134.9,	α = 110.9°	11.0	123	1104
42	-	17	a = 133.7,	α = 111.3°	14.0	120	1048
42	+	28	a = 134.9,	α = 117.3°	10.0	117	643

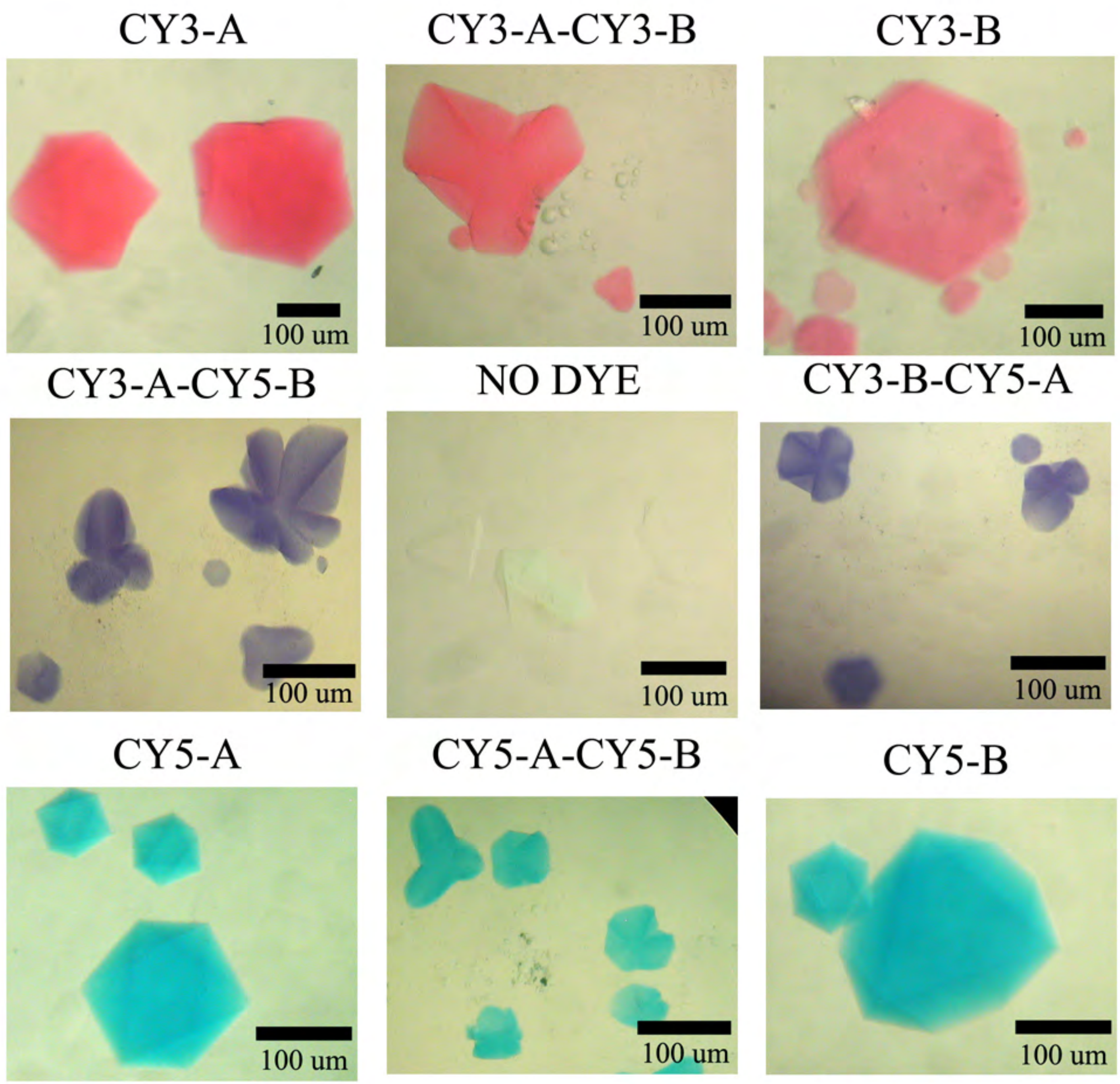
J. Zheng, J.J. Birktoft, Y. Chen, T. Wang, R. Sha,
P.E. Constantinou, S.L. Ginell, C. Mao & N.C. Seeman, *Nature* 461, 74-77 (2009).

The Rhombohedral Cavity
With Alternating A and B Molecules



T.Wang, R. Sha, J.J. Birktoft, J. Zheng, C. Mao, N.C. Seeman, *J. Am. Chem. Soc.*, **132,** 15471-15473 (2010).

Attachment of Cy3 & Cy5 to Triangles



T.Wang, R. Sha, J.J. Birktoft, J. Zheng, C. Mao, N.C. Seeman, *J. Am. Chem. Soc.*, **132**, 15471-15473 (2010).

SUPPORT

National Institute of General Medical Sciences (1982-)
Office of Naval Research (1989-2004; 2009-)
National Science Foundation (1997-)
DARPA/AFOSR (2001-2003)
Army Research Office (2005-)
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Department of Energy -- (2006-2008; 2012-)

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