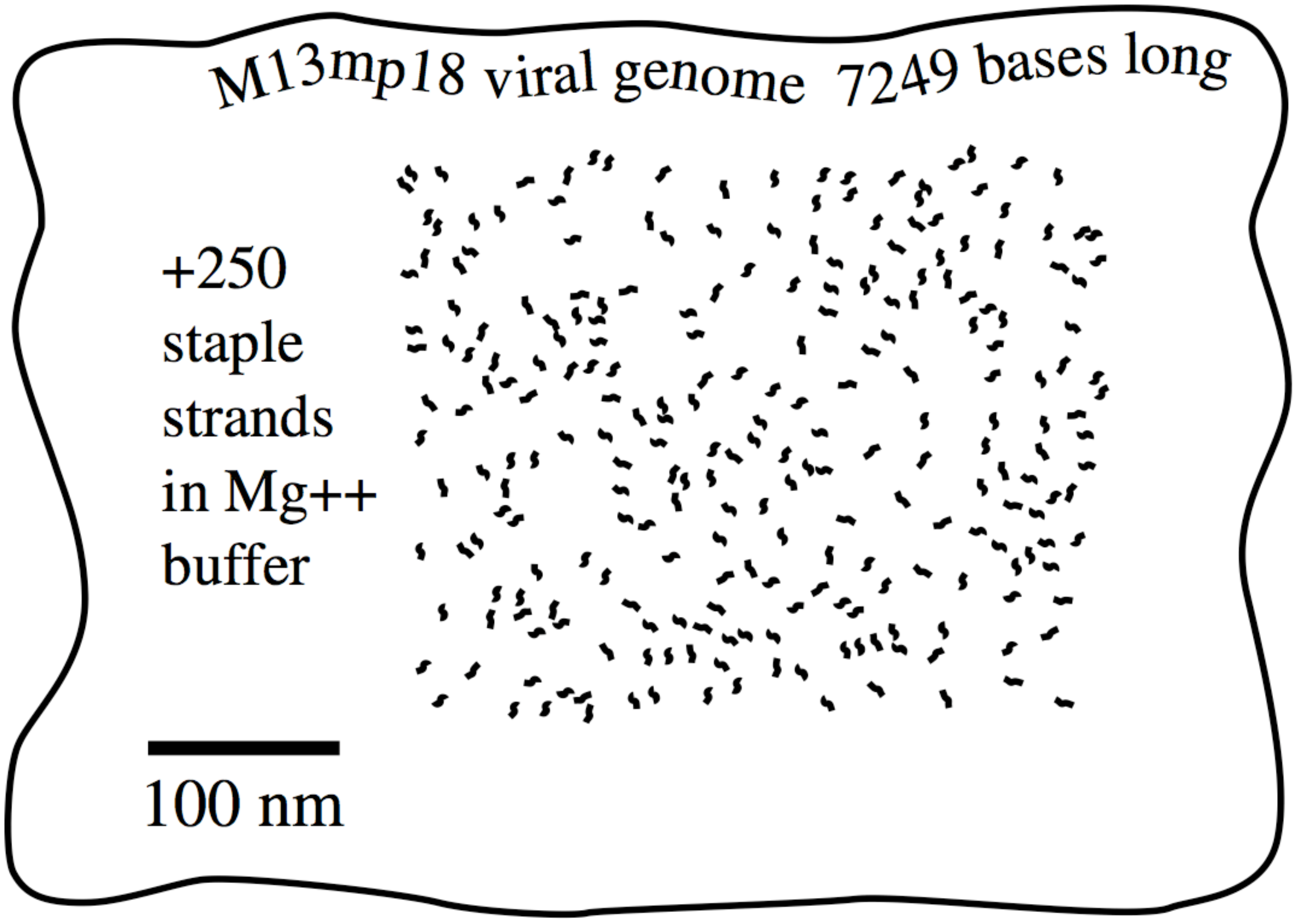
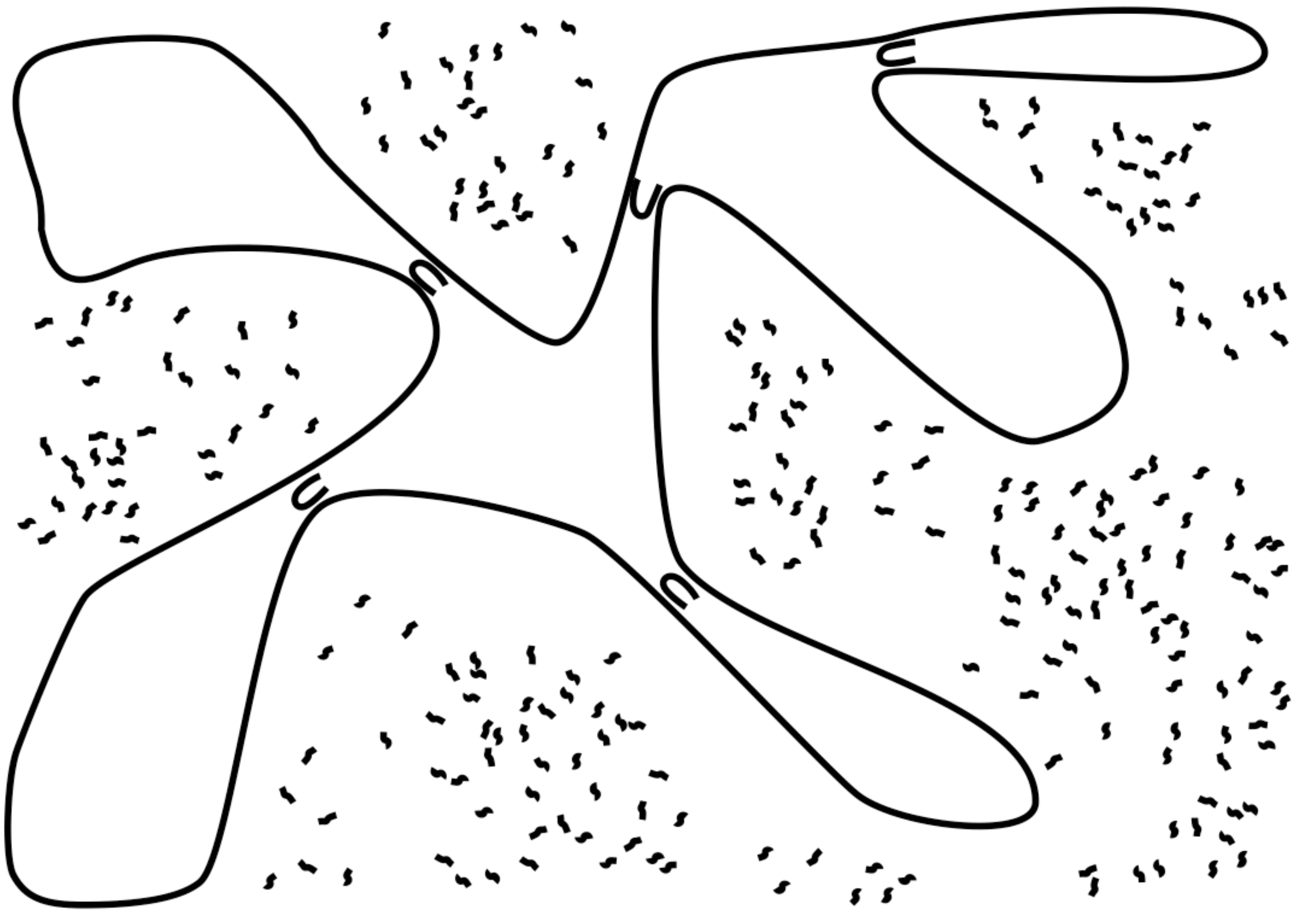
Module 2: DNA origami

CSE590: Molecular programming and neural computation

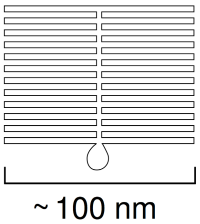
DNA origami


M13mp18 viral genome 7249 bases long
+250
staple
strands
in Mg++
buffer
100 nm

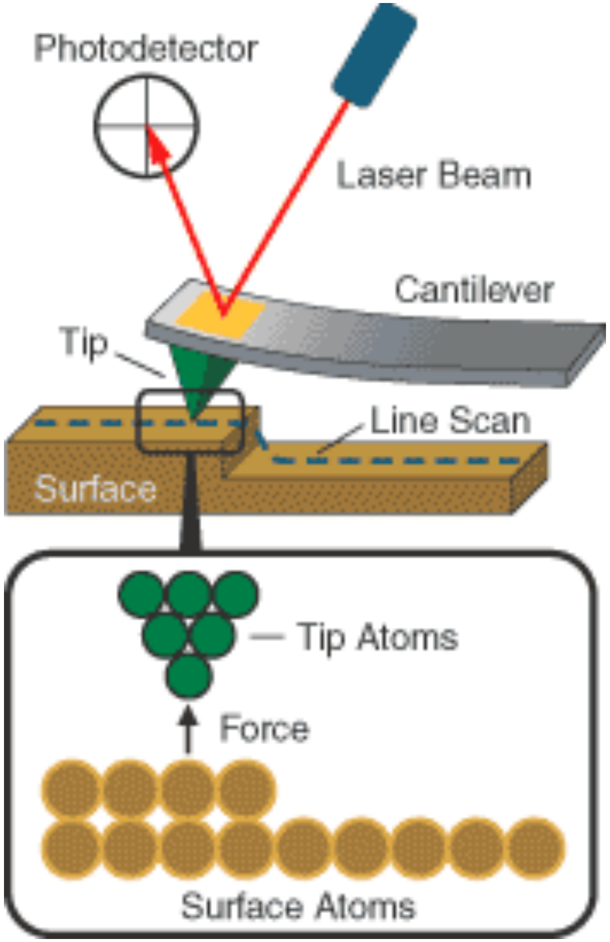
DNA origami



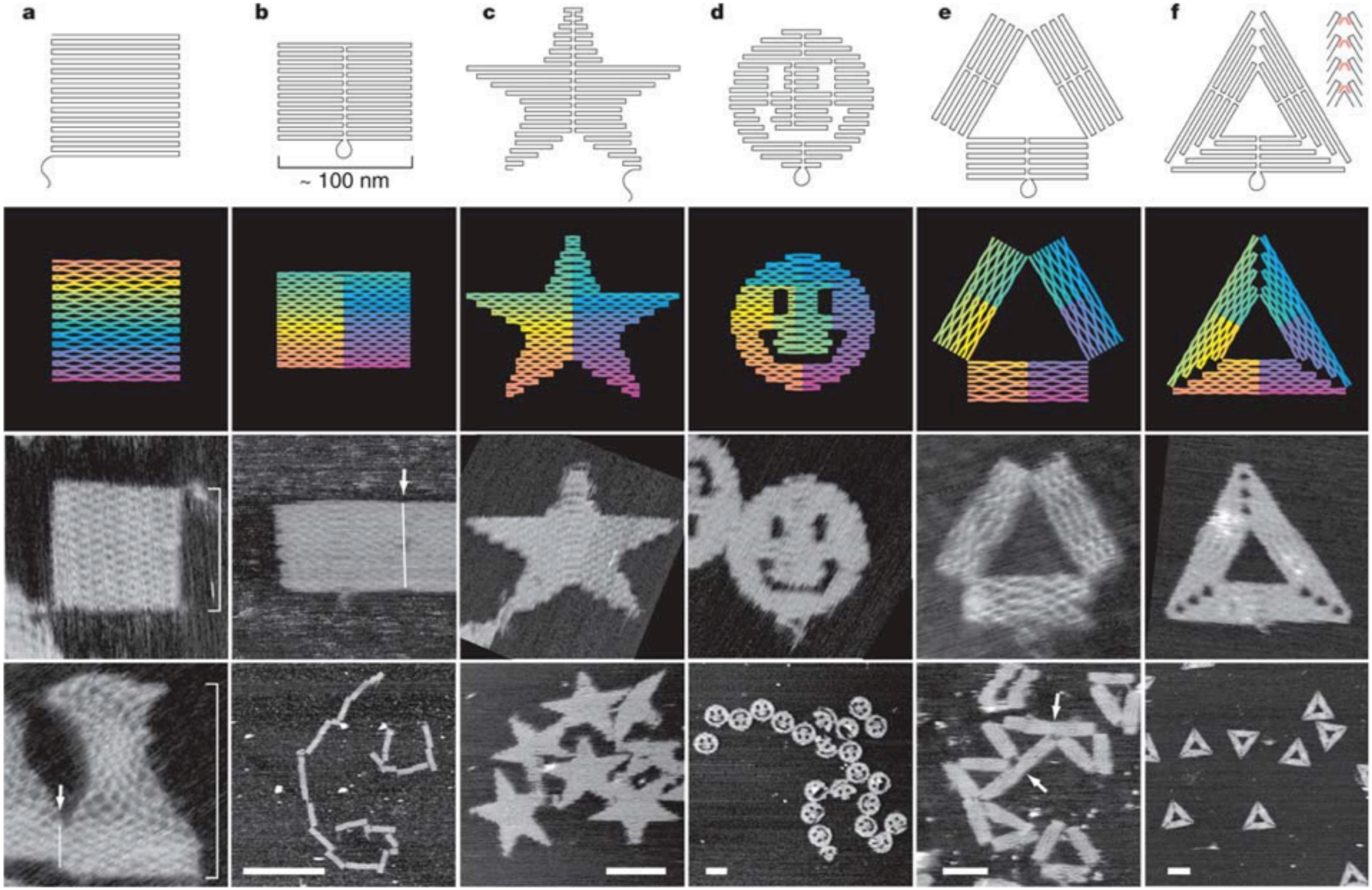
DNA origami



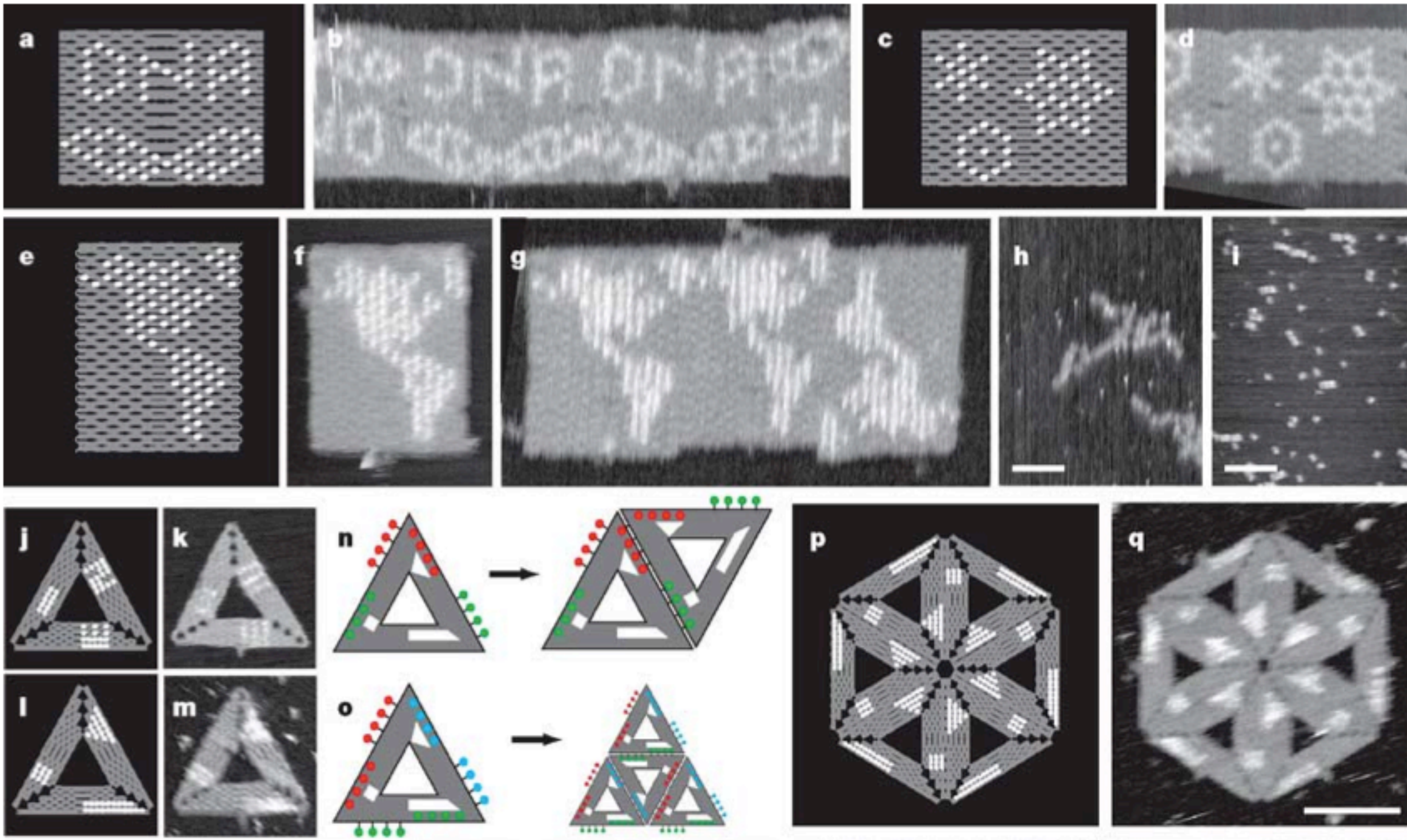
Atomic force microscopy



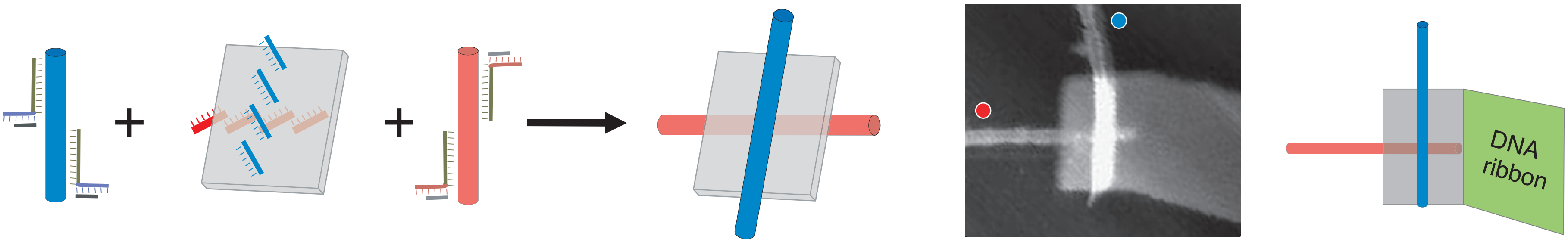
DNA origami

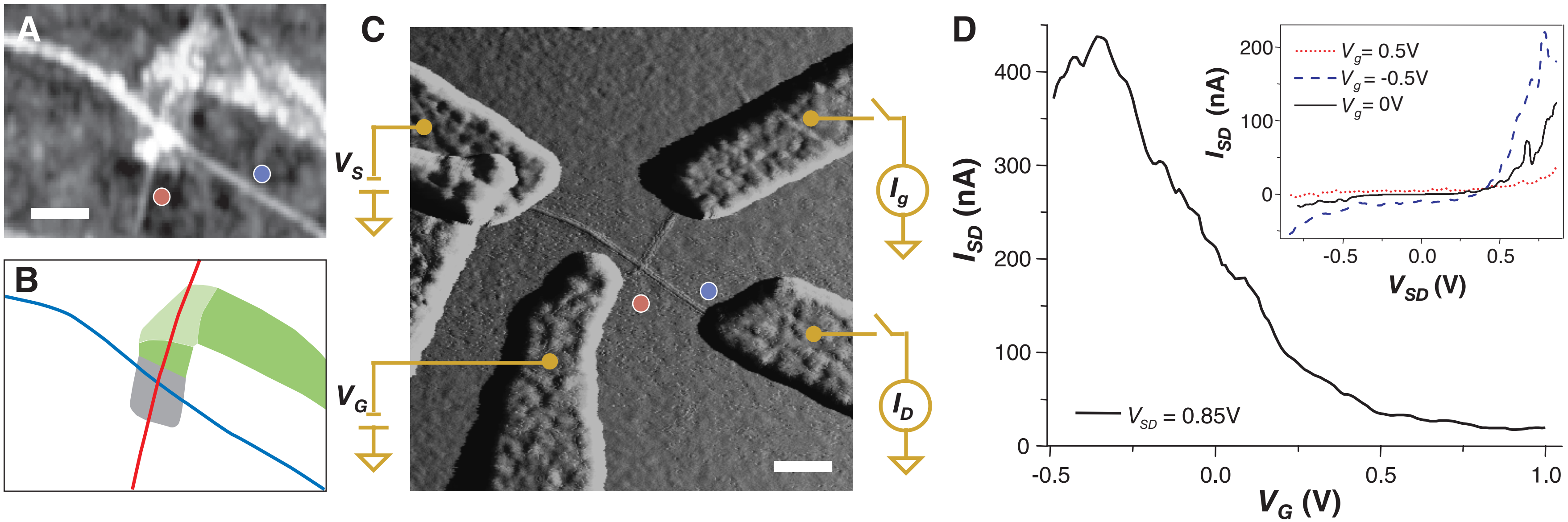


DNA origami



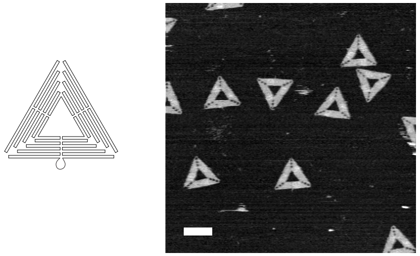
DNA-templated self-assembly of electronic devices



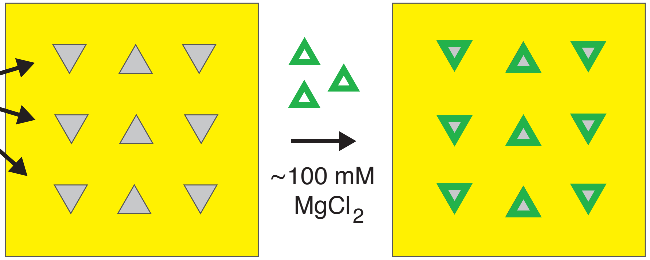


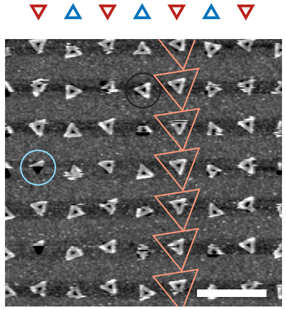
Placing DNA origami on a silicon surface

Triangles deposit randomly on a surface

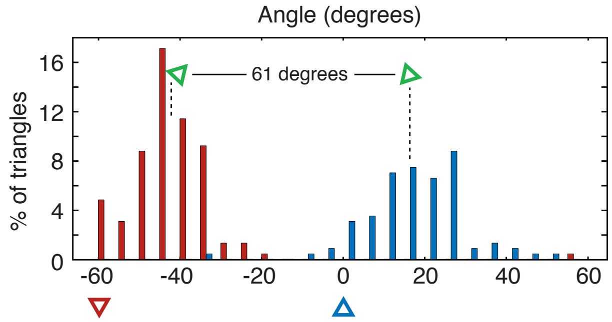


E-beam is used to pattern triangular sticky patches on silicon





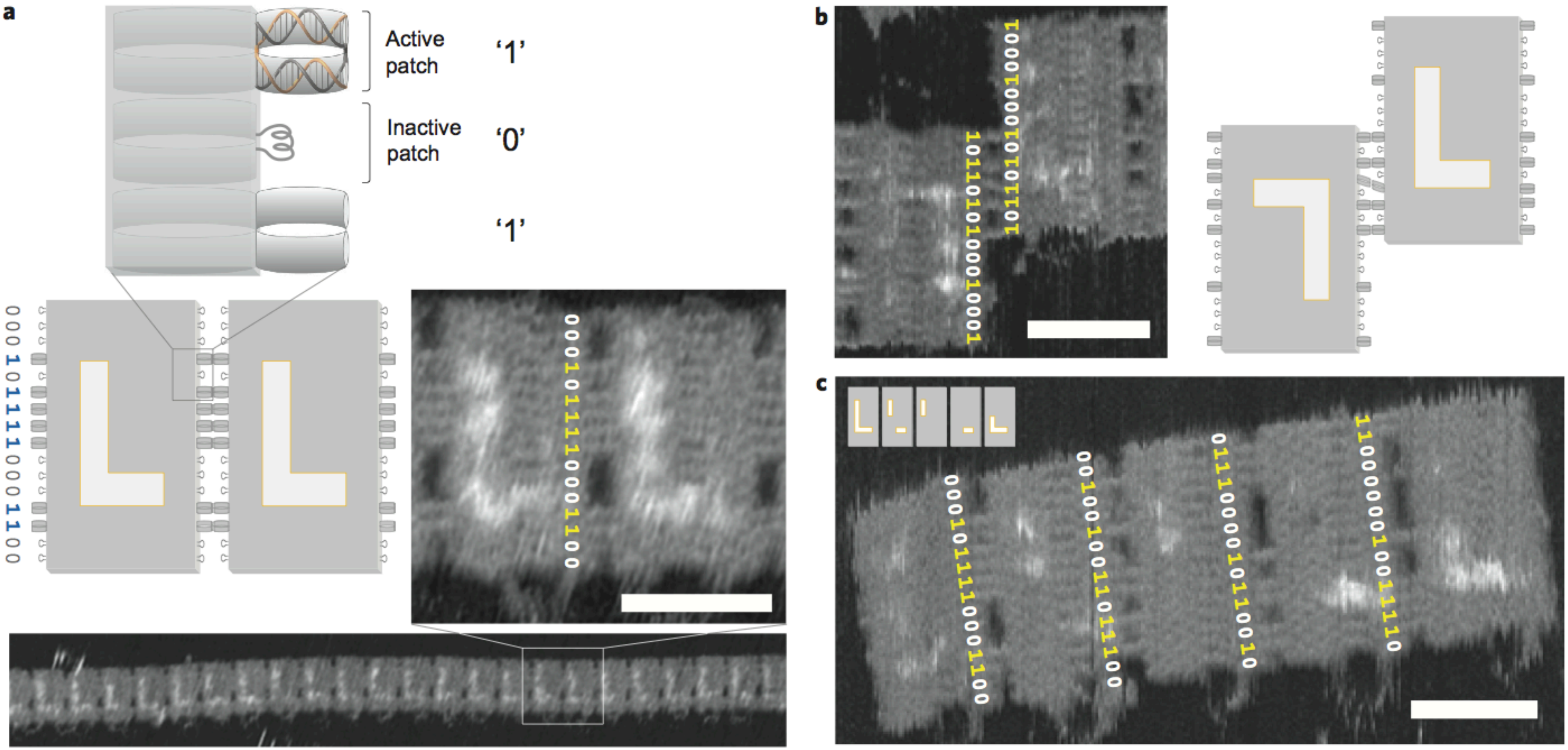
Collaboration with IBM Research Almaden



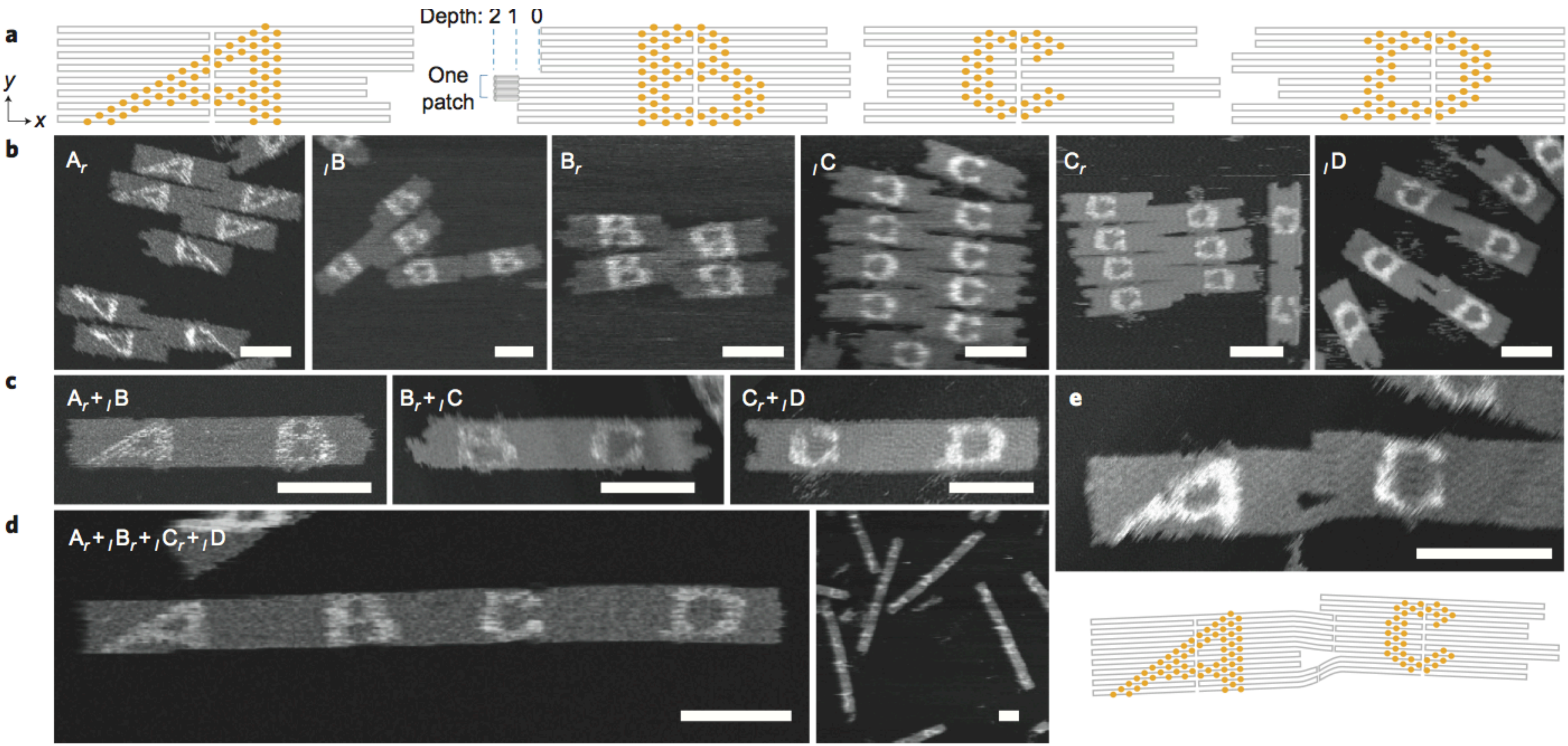
Largely single triangles (95%)
Largely well-aligned (+/- 10%)

R. Kershner, L. Bozano, C. Micheel, C. Rettner, M. Bersani, A. Hung, J. Cha, A. Fornof, J. Frommer, P.W.K. Rothemund, G. Wallraff, *Nature Nanotechnology*, 2009

Assembling origami into larger structures

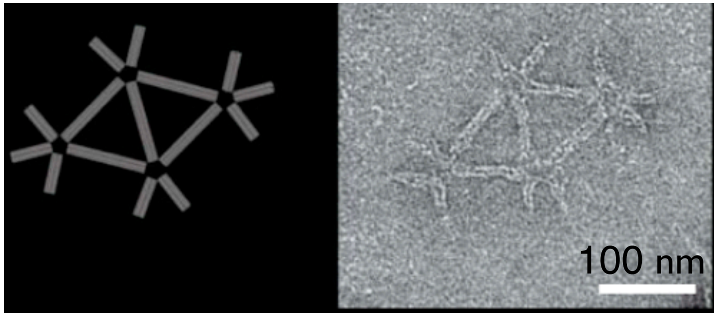


Assembling origami into larger structures

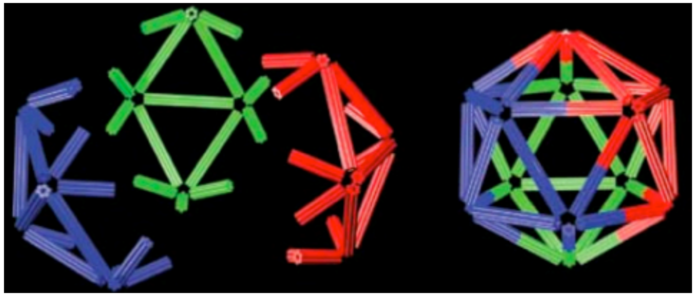


S. Woo and P.W.K. Rothemund, *Nature Chem*, 2011

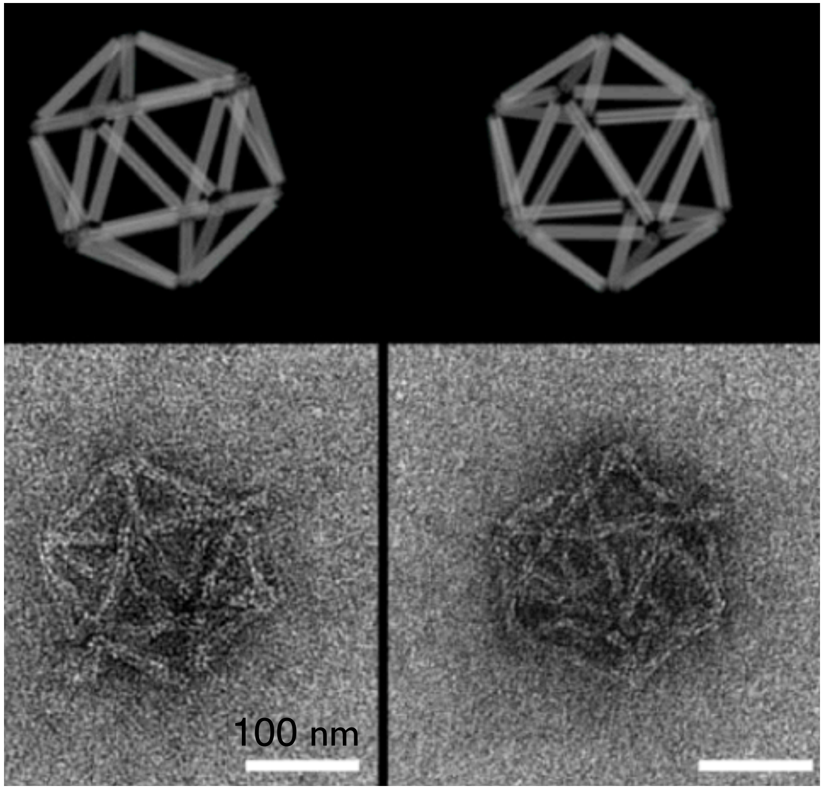
3D DNA origami



each origami forms a double-triangle



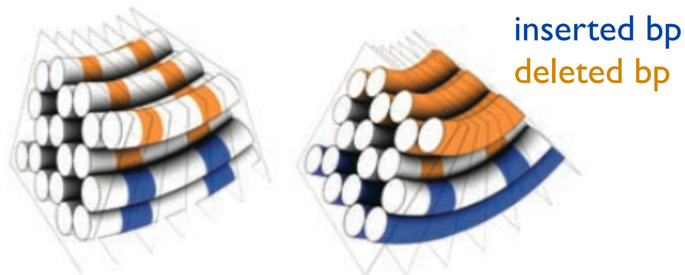
icosahedron is an origami heterotrimer
(monomers use same scaffold with different staples)

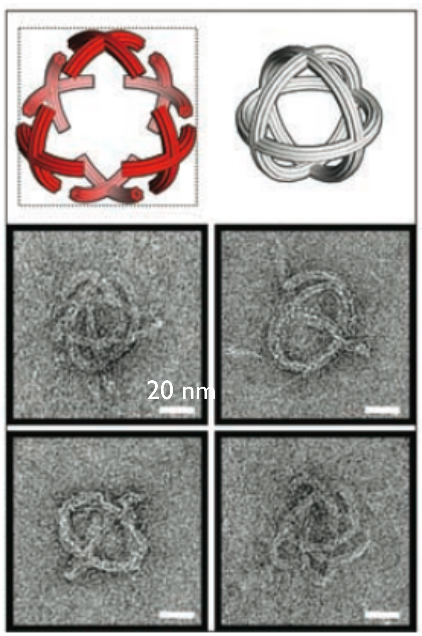


S.M. Dougas, H. Dietz, T. Liedl, B. Hogberg, F. Graf, W.M. Shih, *Nature,* 2009

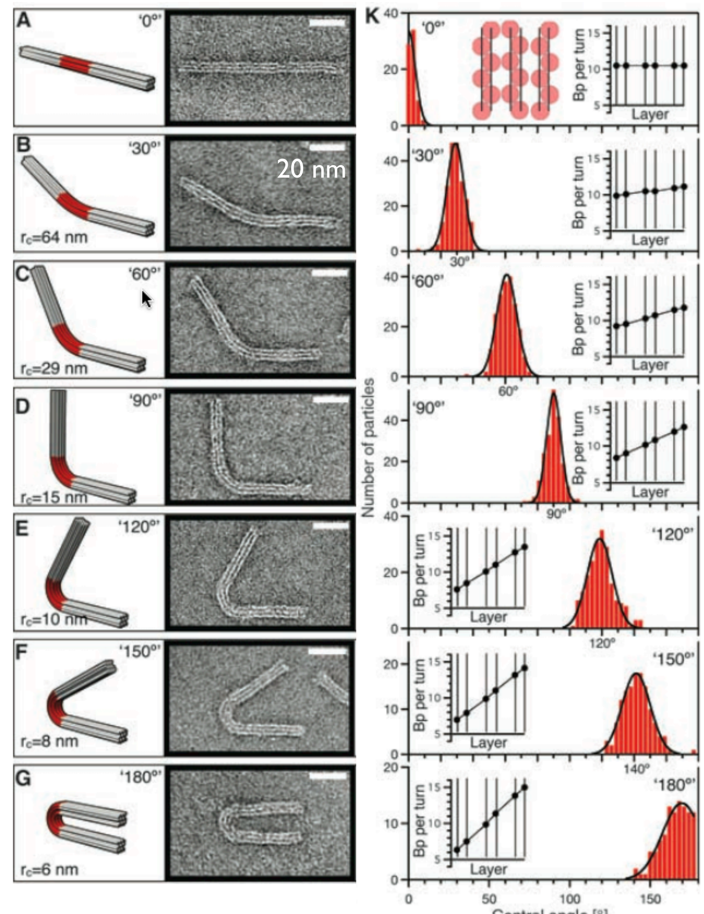
3D DNA origami

Insert and delete base-pairs between staple strands to induce curvature





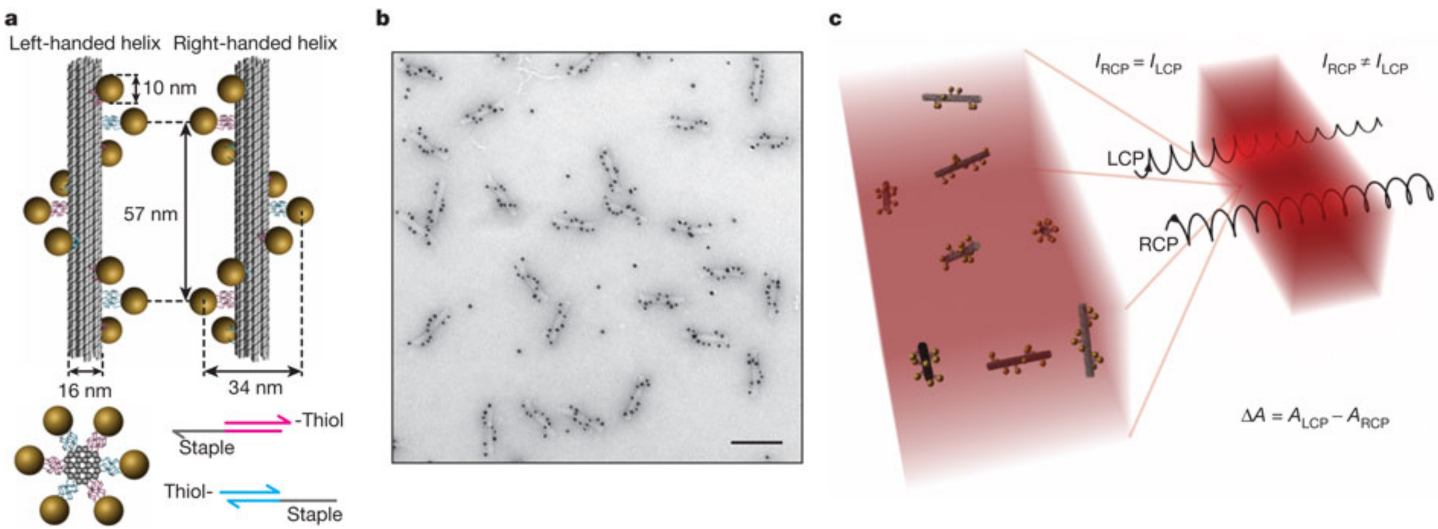
3x6 helix bundle forms curved wireframe



Controlling curvature of a 3x6 helix bundle

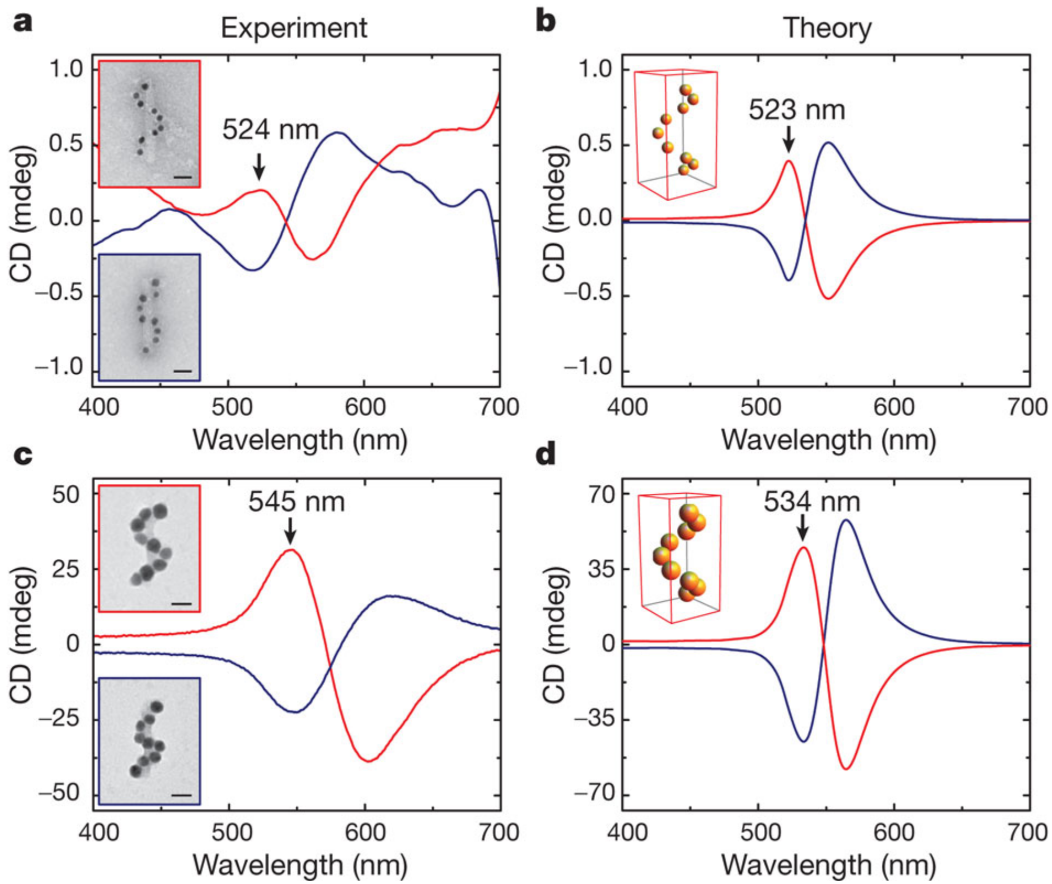
H. Dietz, S.M. Douglas, W.M. Shih, *Science*, 2009

DNA origami-based plasmonic materials



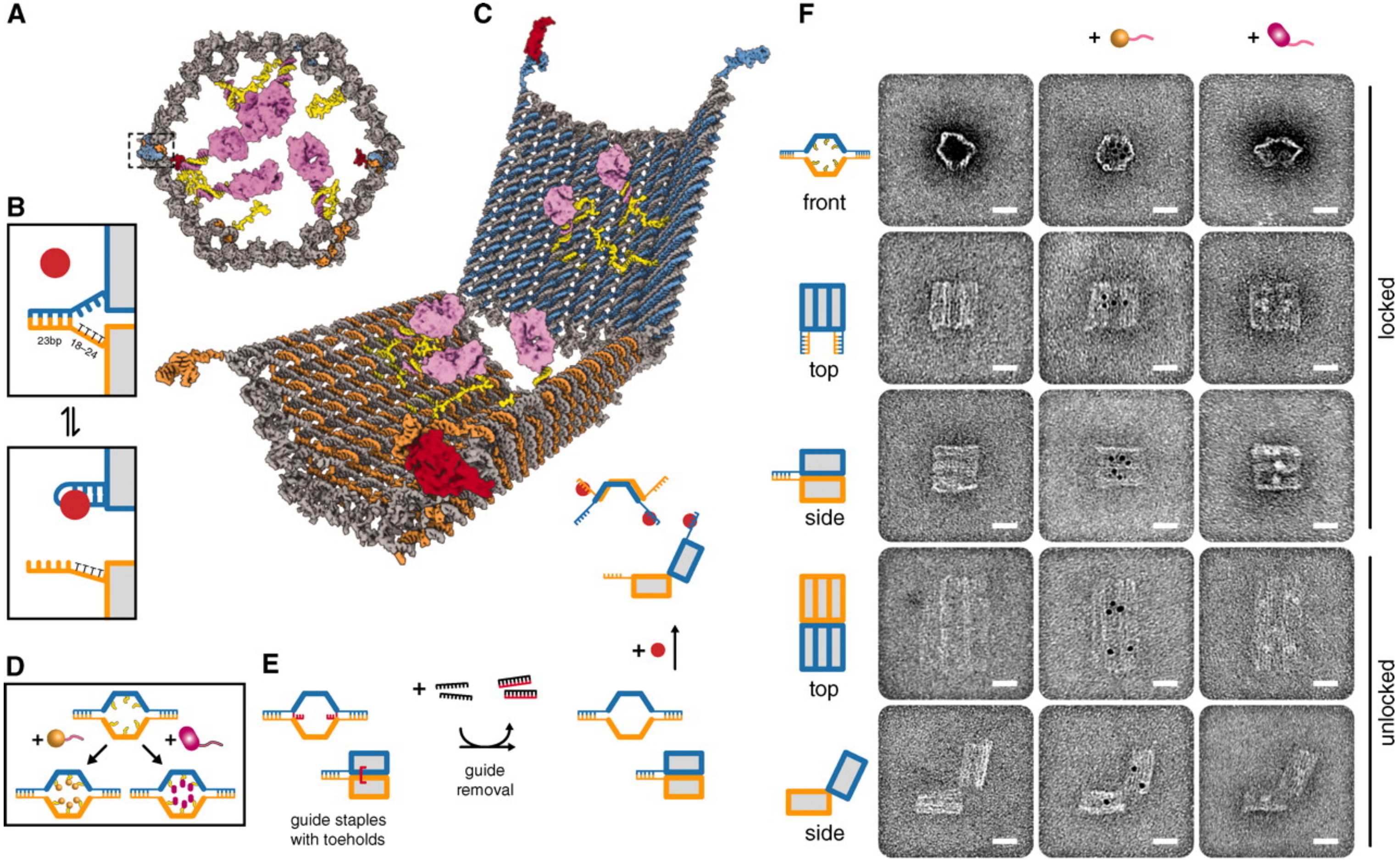
A Kuzyk *et al*. *Nature* **483**, 311-314 (2012) doi:10.1038/nature10889

DNA origami-based plasmonic materials



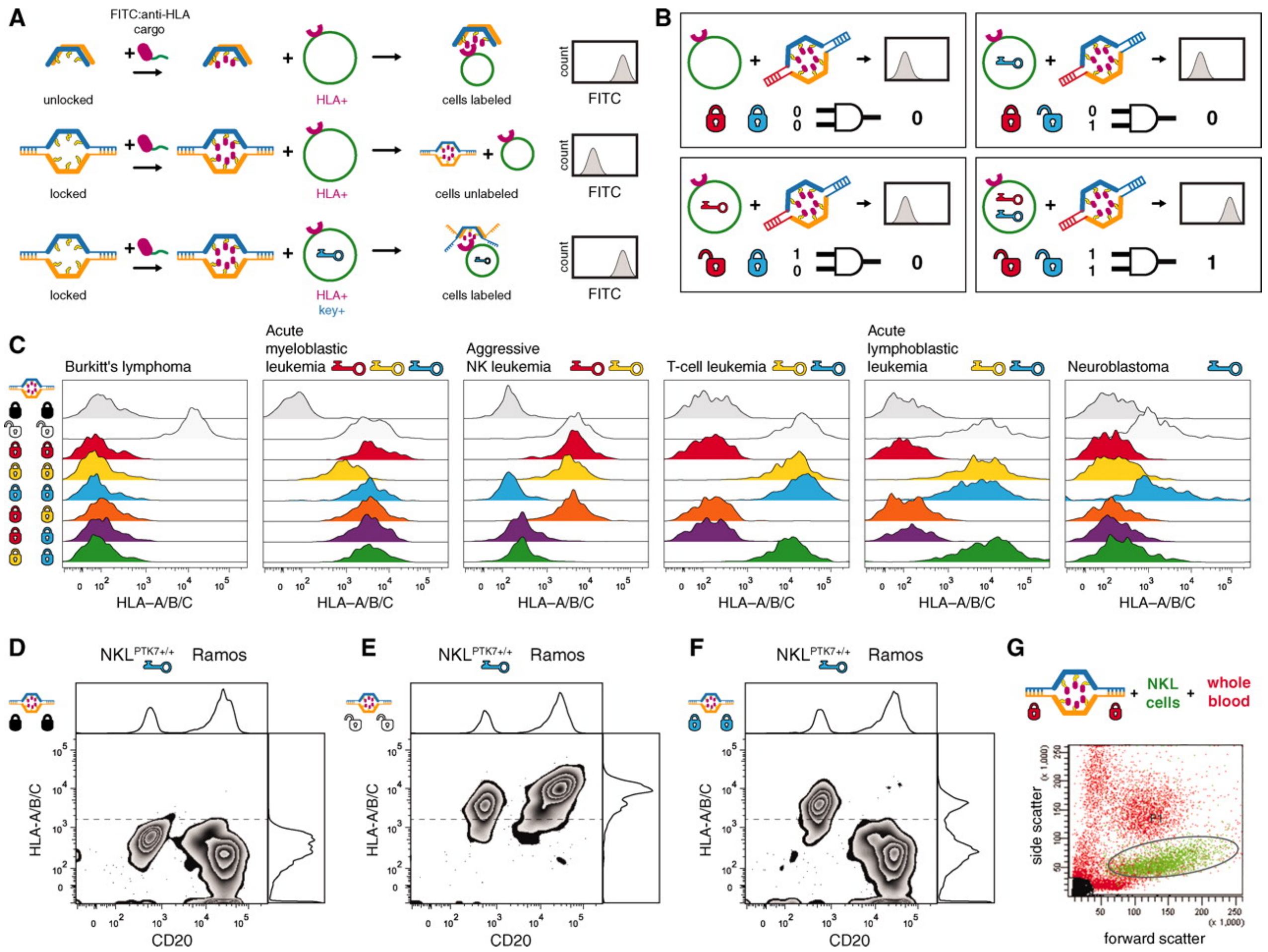
A Kuzyk *et al*. *Nature* **483**, 311-314 (2012) doi:10.1038/nature10889

Aptamer-gated DNA robot



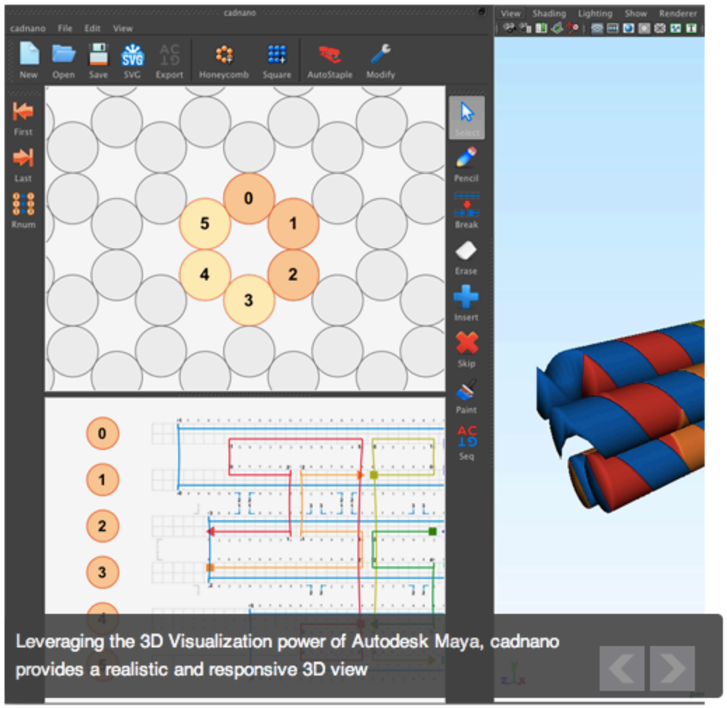
S. M. Douglas *et al*. *Science* **335**, 831-834 (2012)

Logic gate activation by different cell types



S. M. Douglas *et al*. *Science* **335**, 831-834 (2012)

cadnano: Designing DNA origami



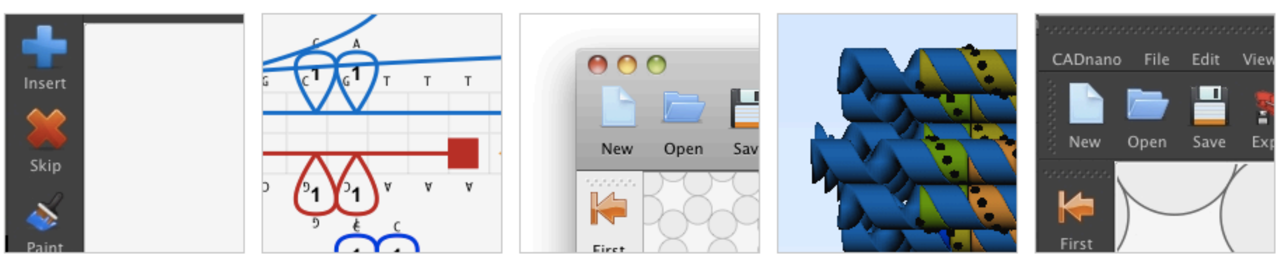
cadnano simplifies and enhances the process of designing three-dimensional DNA origami nanostructures. Through its user-friendly 2D and 3D interfaces it accelerates the creation of arbitrary designs. The embedded rules within **cadnano** paired with the finite element analysis performed by cando, provide relative certainty of the stability of the structures.

cadnano features:

- Platform independent (tested in Windows, OSX and Linux)
- Visual cues aid design process for stable structures
- 3D interface powered by Autodesk Maya*
- Open architecture for plug-in creation
- Free and open source (MIT license)

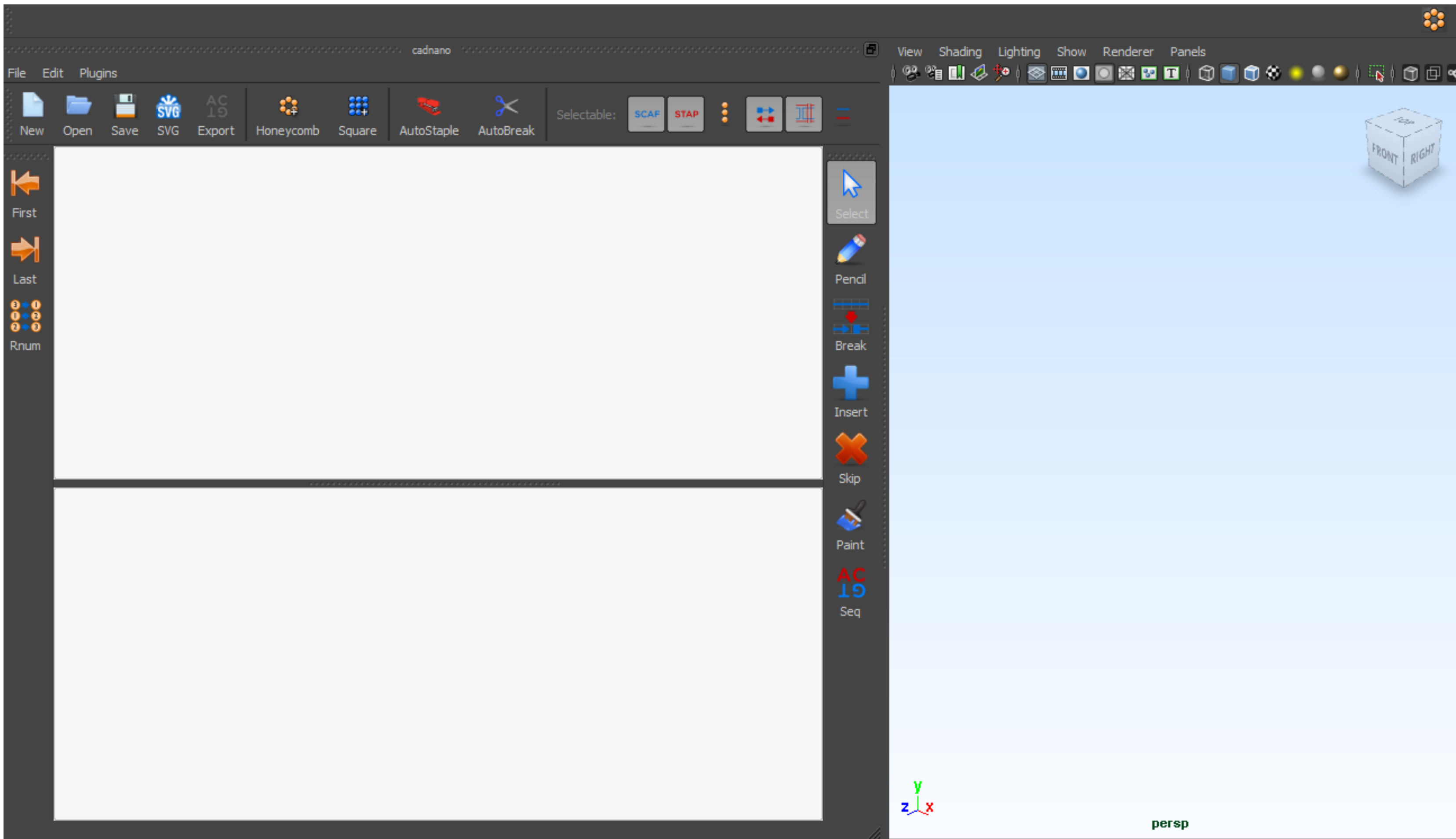
DOWNLOAD CADNANO
It's free and open source.

latest screenshots (click here for more)

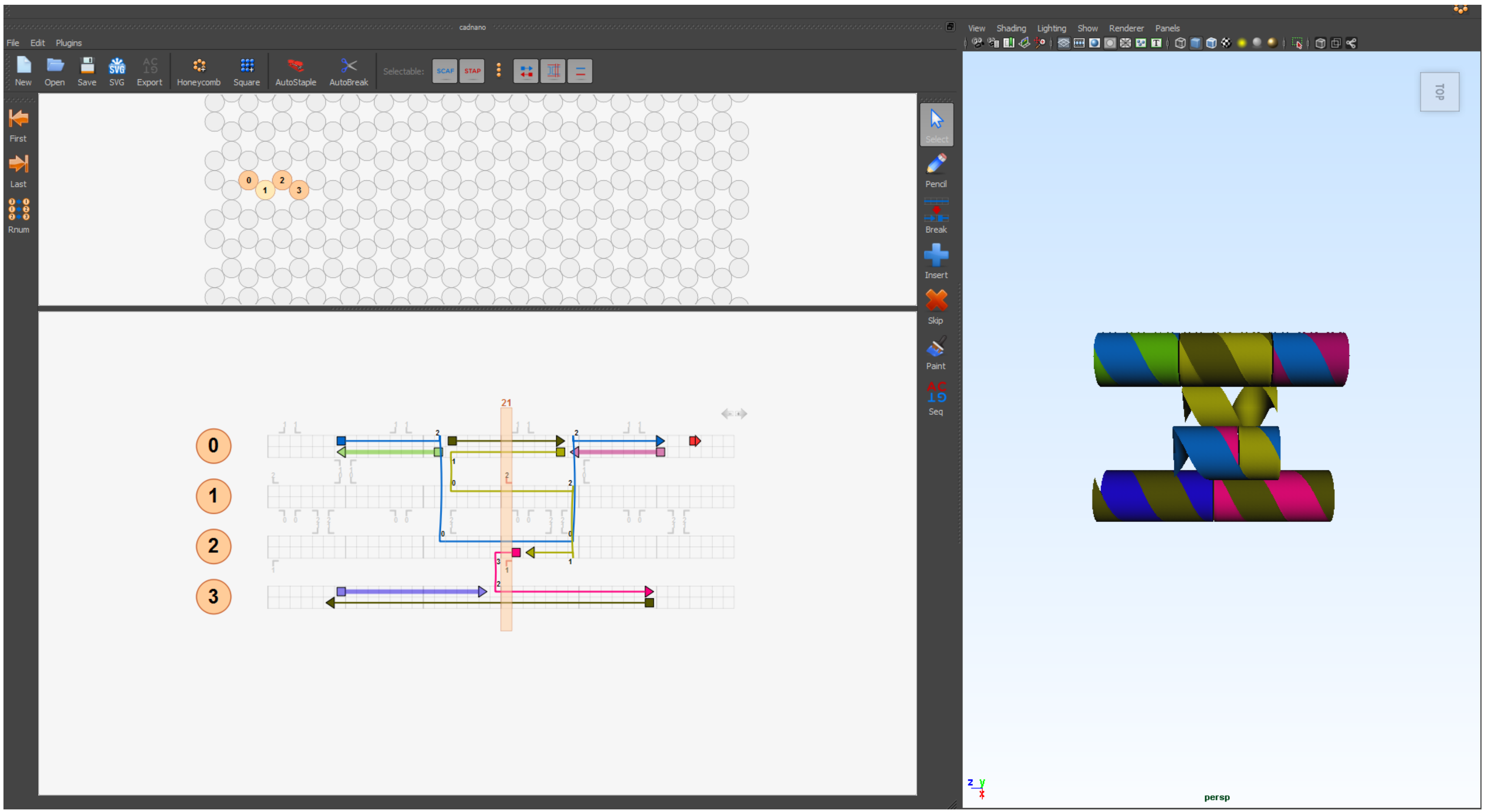


cadnano: Designing DNA origami

Autodesk Maya 2012 interface



cadnano: Designing example



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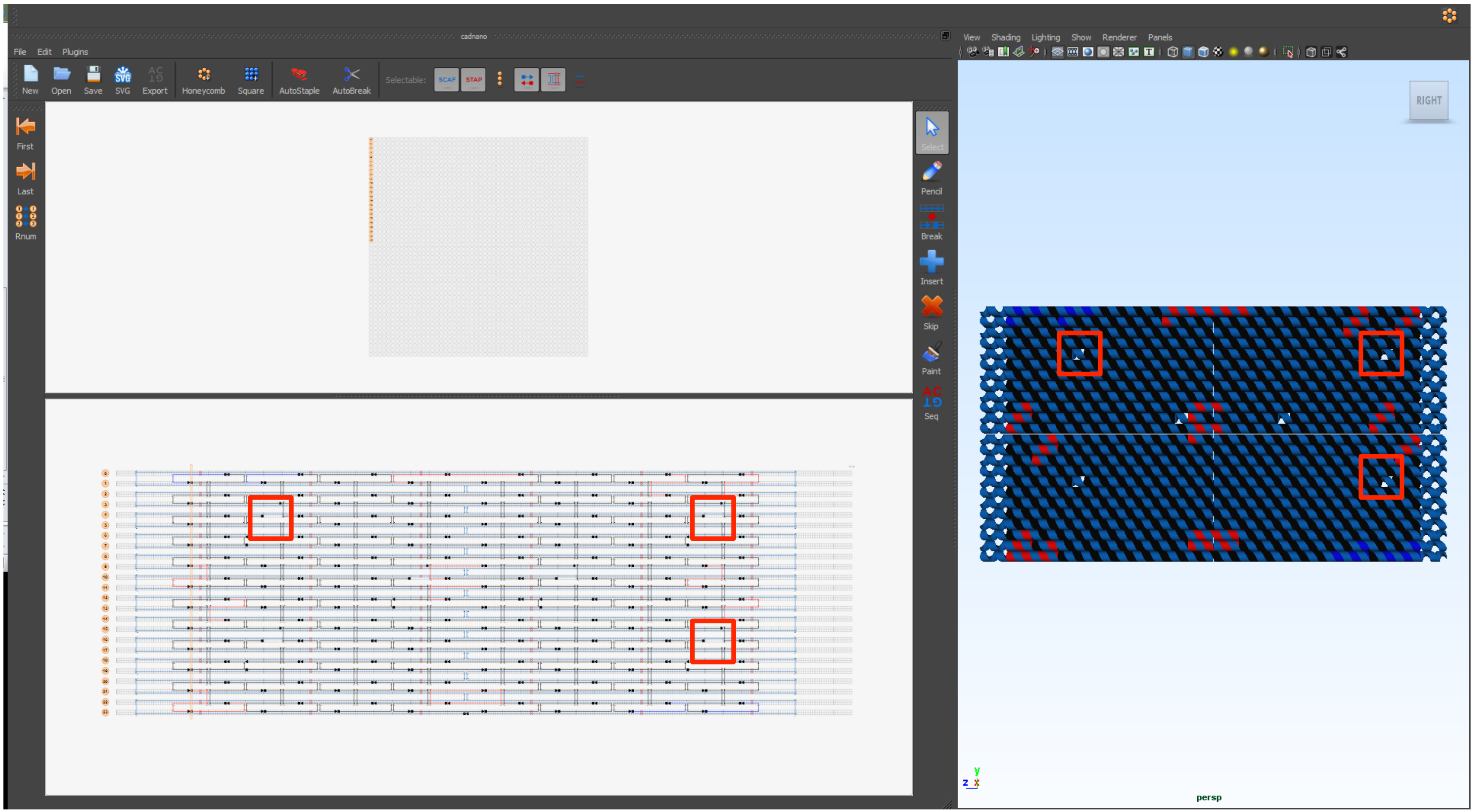
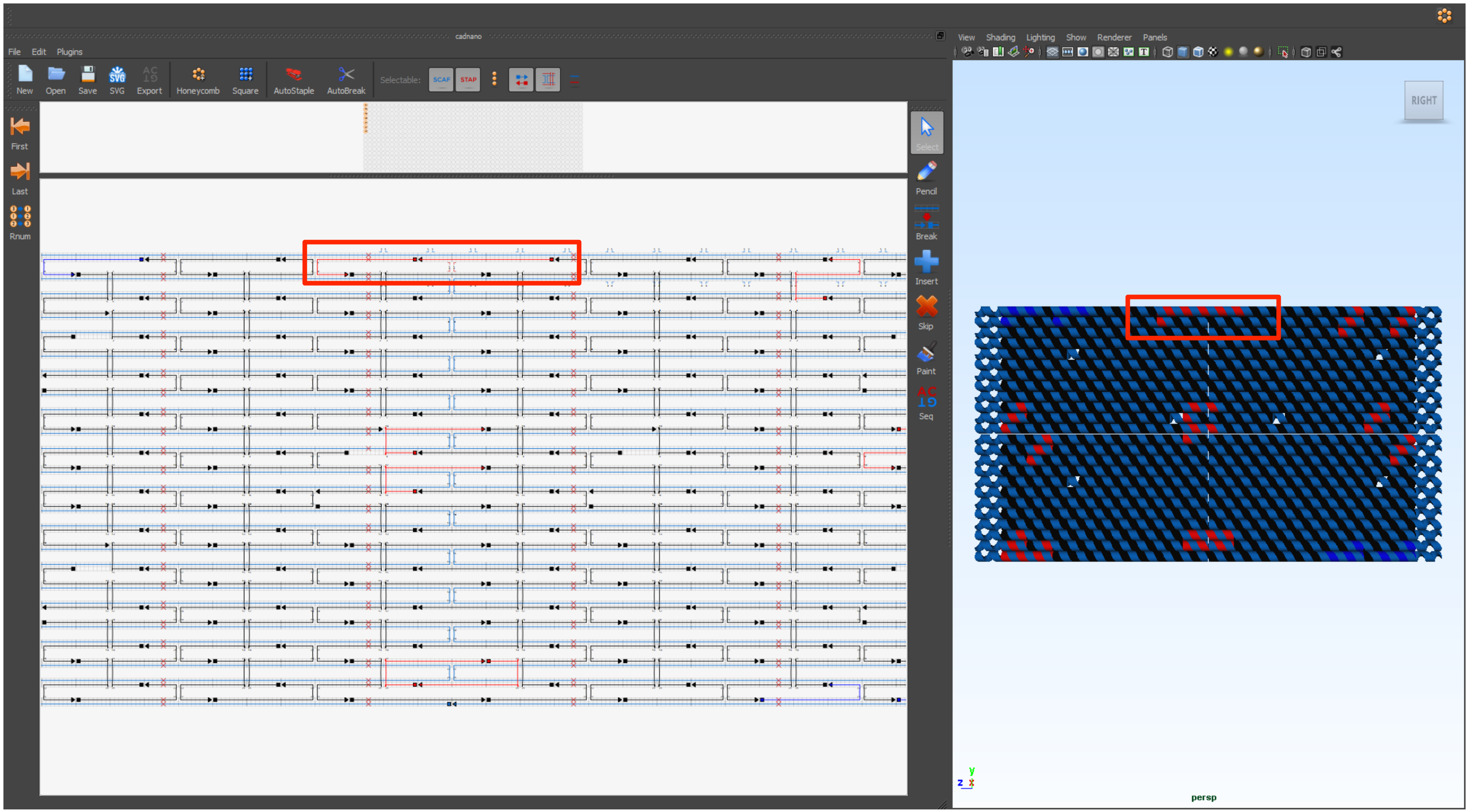


cadnano: Designing example



Outlook: Beyond origami

Advantages of DNA origami:

- Extremely complex structures can be assembled nano-scale precision. There is no other technology like it!
- The assembly process is robust to the exact concentrations of the different strands as long as the concentrations of all staples are higher than that of the scaffold
- DNA origami can be used as a “breadboard” for placement of other molecules with interesting optical, electronic and chemical properties

One issue:

- The “program” inputs (~DNA sequence) and outputs (~structure) have the same “size”. This is very different from a genetic program!