

DNA structures

Reviews were due today by 5 pm

The beauty of DNA

- Minuscule size-diameter of about 2 nm
- Short structural repeat (helical pitch)-about 3.4-3.6 nm
- Stiffness (persistence length) 50 nm

DNA nanotechnology

- Objects, arrays and devices can be made from DNA
- Structural DNA technology
- Cube, Truncated octahedron, Borromean rings (3 intricately linked circles), knots
- 2D arrays with programmable features
- Improved macromolecular crystallinity
- Organizing nanoelectronics
- DNA based computation

Principles for Nanomachines

- Exploitation of DNA structural transitions
- Watson-Crick binding
- Non Watson-Crick binding
- Hybridization
- Protein binding
- Autonomous devices

Early DNA nanomechanical device

- Based on DNA supercoiling

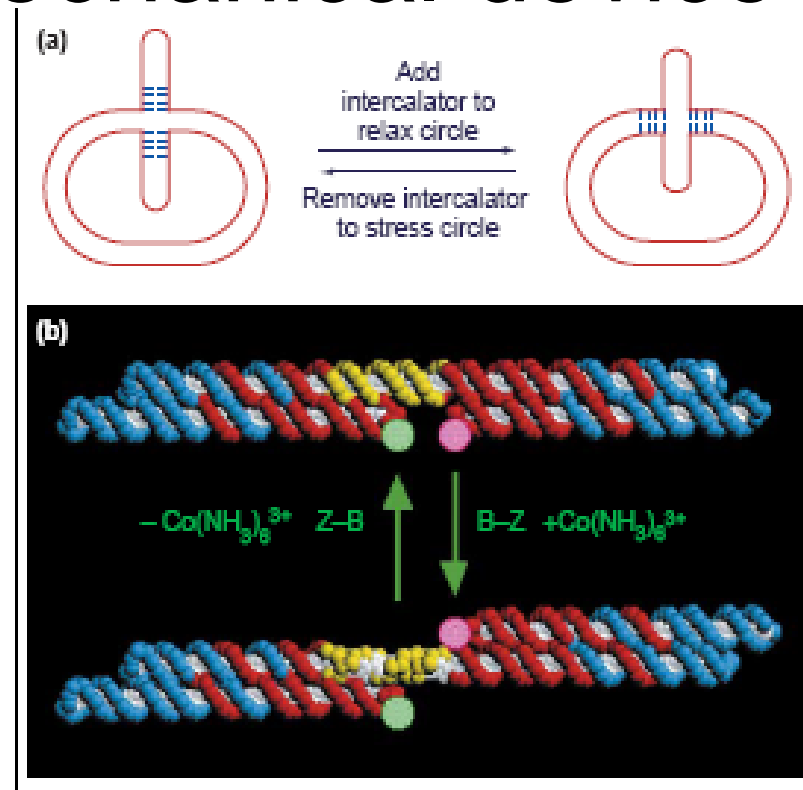


Figure 1. Early DNA nanomechanical devices. (a) A device based on DNA supercoiling. The system consists of a small DNA circle that contains a permanent cruciform. The four nucleotide pairs at the base of the cruciform are capable of branch migration because they are the same in both arms of the extended cruciform (left). When the circle is relaxed by the addition of an intercalator, the mobile nucleotide pairs move to the circle. (b) A device based on the B \rightarrow Z transition of DNA. Two DX molecules (red and blue) are connected by a double-helical-DNA shaft that contains 20 nucleotide pairs (yellow) that are capable of undergoing the B \rightarrow Z transition. In the B-state, both domains are on the same side of the shaft (top), but when $\text{Co}(\text{NH}_3)_6^{3+}$ is added to the solution, the system switches to the Z-state, and the domains are on opposite sides of the shaft. The red and green circles represent a pair of dyes that are used in the FRET experiment that reports their separation: when the solution is in B-promoting conditions, the dyes are close together, but in Z-promoting conditions, they are further apart. Part (b) reproduced, with permission, from Ref. [19] (www.nature.com).

Our focus

- Ned Seeman at NYU
- DNA scaffolds
- DNA as a construction tool
- Past 6 years explosion of activity in the field of DNA nanomachines
 - Molecular beacons
 - Nanomechanical motion

Nature. 2003 Jan
23;421(6921):427-31.

- DNA in a material World
- This powerful molecular recognition system can be used in nanotechnology to direct the assembly of highly structured materials with specific nanoscale features
- as well as in DNA computation to process complex information.

DNA nanotechnological Construction

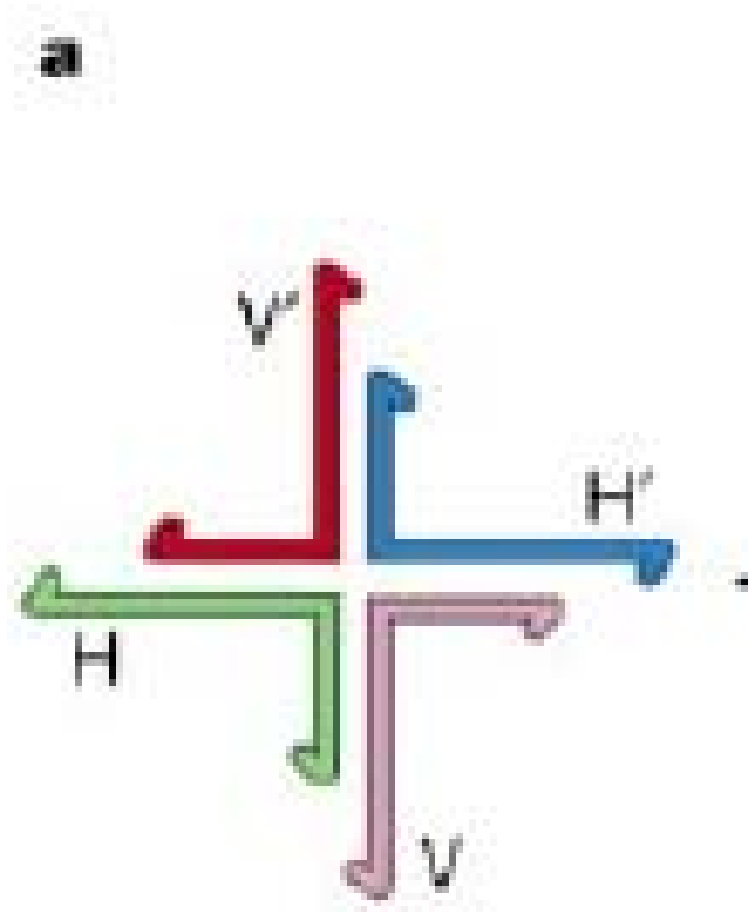
- Top down
 - Microscopic manipulations of a small number of atoms or molecules to create elegant structures
- Bottom up
 - Using the molecular ability to self-assemble in parallel steps to create novel structures

Sticky ends

- Short single stranded overhang protruding from the end of a double-stranded helical DNA molecule.
- Flaps of Velcro
 - Two sticky ends with complimentary arrangement of the nucleotide bases adenine, cytosine, guanine, and thymine
 - Stick together to form a larger complex

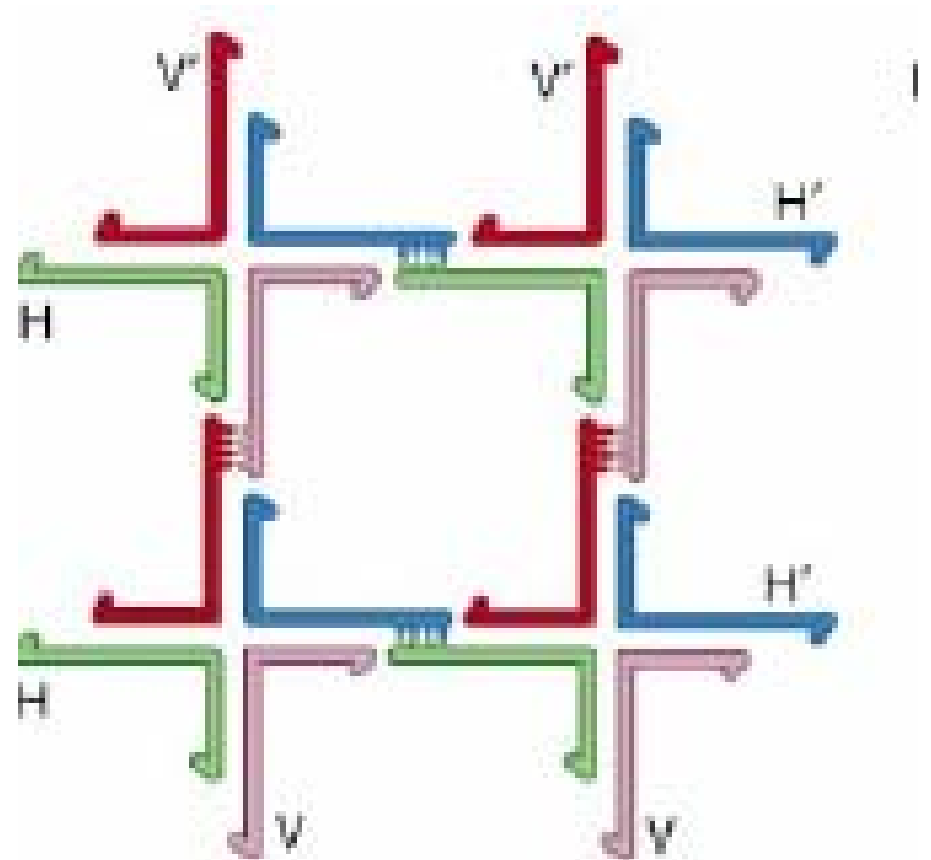
Holliday junction

- Self assembly of branched DNA molecules into a 2-D crystal
- 4 DNA strands form the branched DNA junction
- Complimentary sticky end overhangs H/H' and V/V'



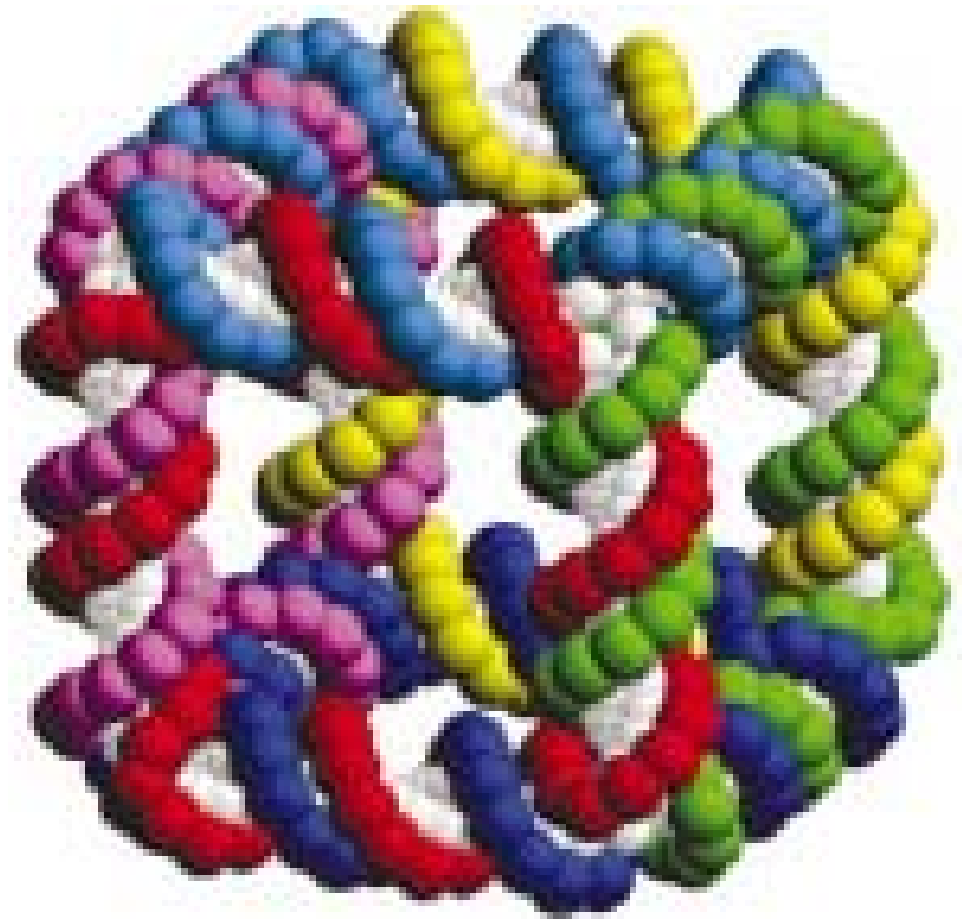
Sticky Ended cohesion

- Best example of programmable molecular recognition
- 2-D Crystal of DNA
- Can increase as long as there are complimentary sticky ends
- All you need is synthetic branched DNA molecules with programmed sticky ends, get them to self assemble into the desired structure



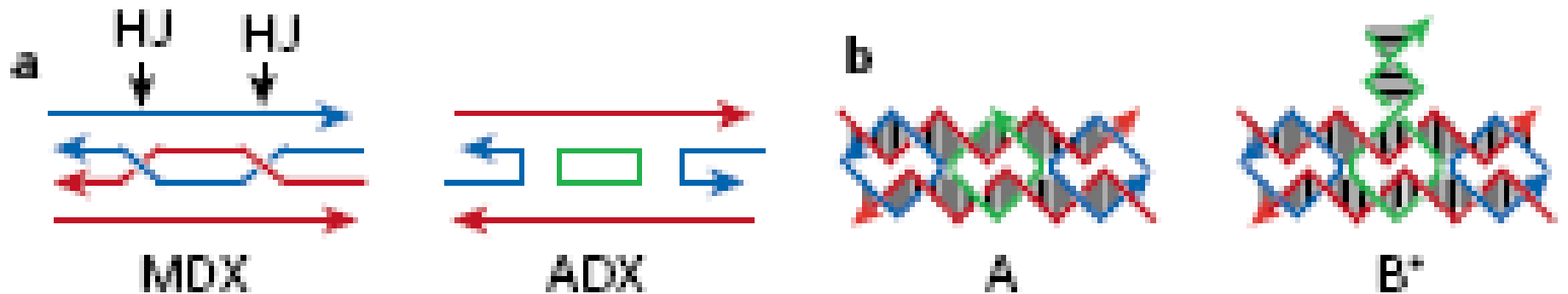
Cube like structure

- Ligated DNA molecules form interconnected rings to create cube-like structure. The structure consists of 6 cyclic interlocked single strands each linked twice to its four neighbors
- 1st artificial DNA structure
- Edges are double helices

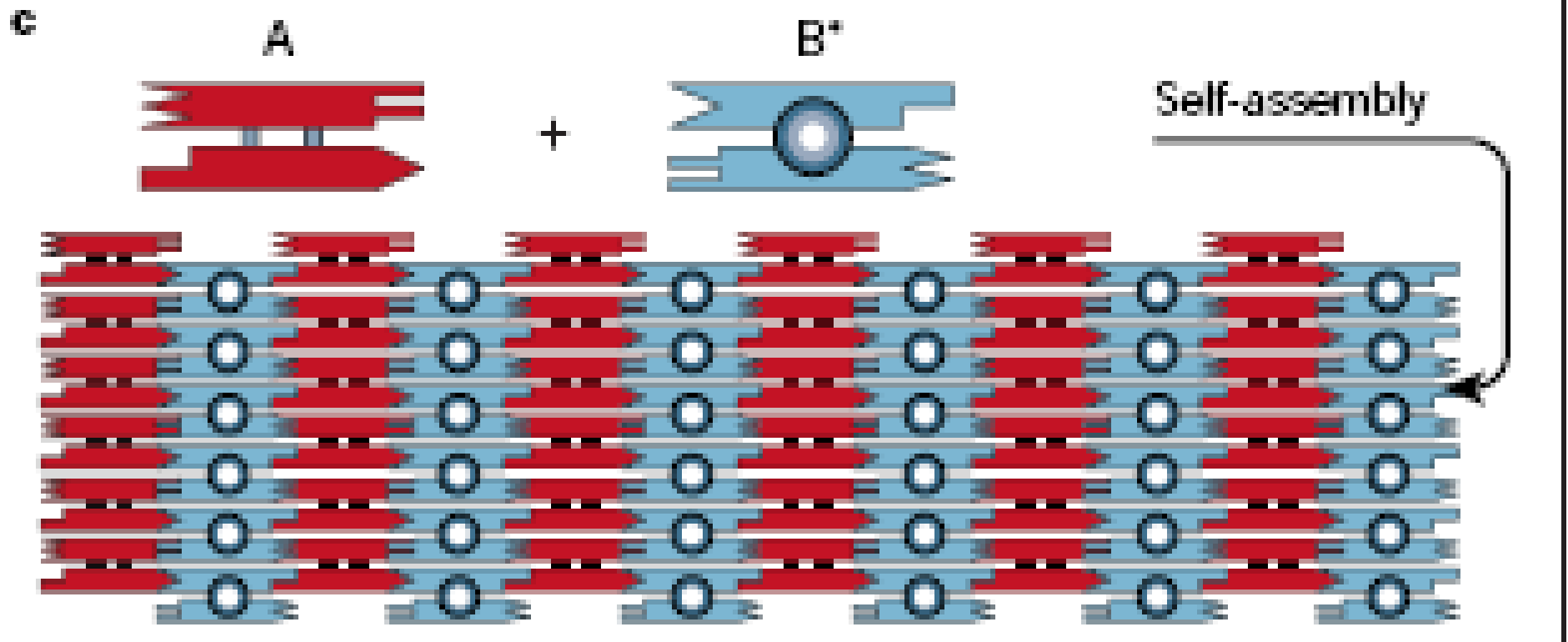


Floppiness of branched junctions

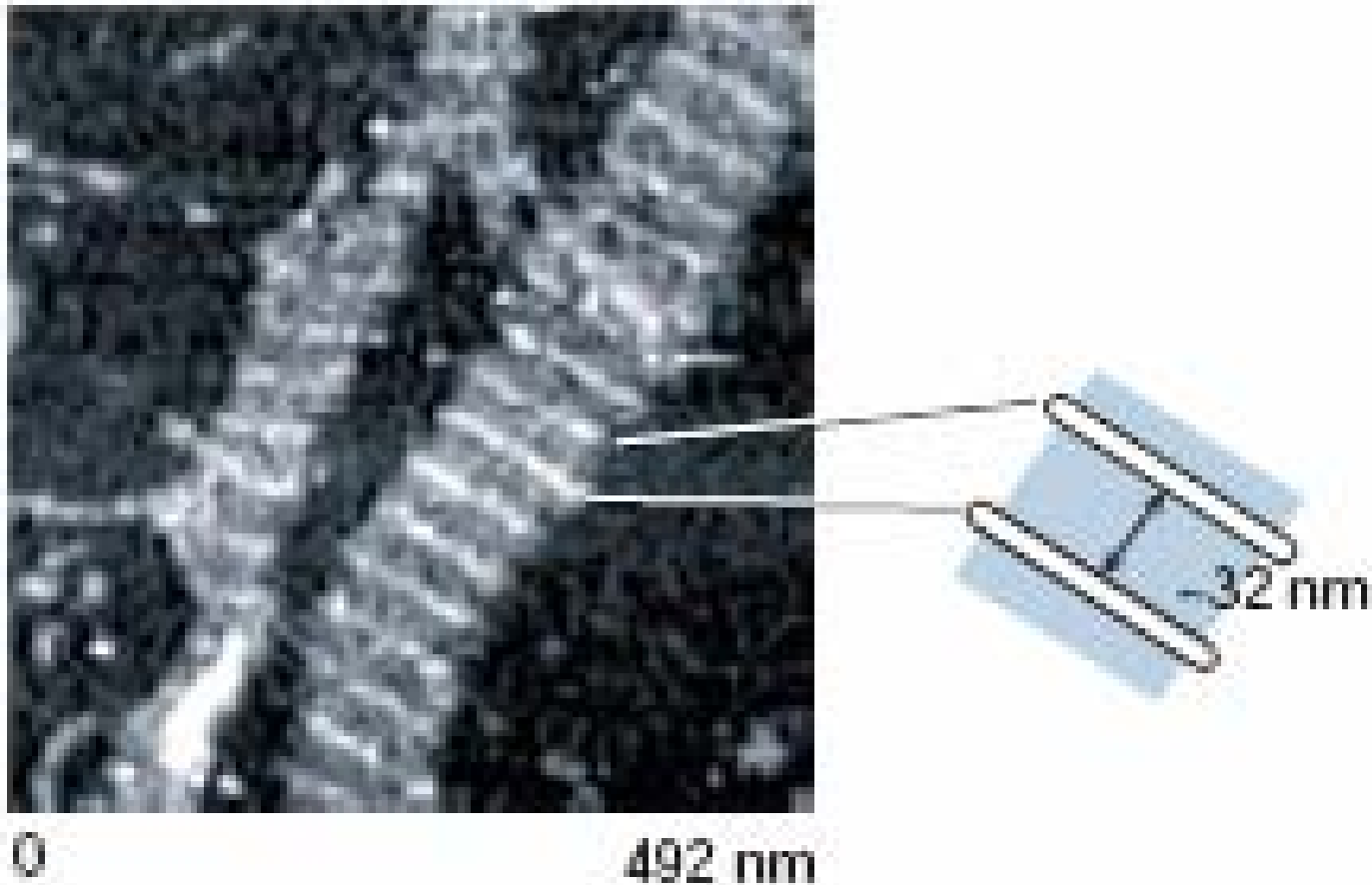
- Prevents more robust structures and 2-D arrays even with a well defined sticky end blue print
- To solve this problem DNA double crossover molecules were created (DX)
- HJ is the holiday junction outlined before
- 4 strands come together in MDX (meiotic DX) homologous
- ADX (analogue unit) tiling unit



Take the previous A and B*

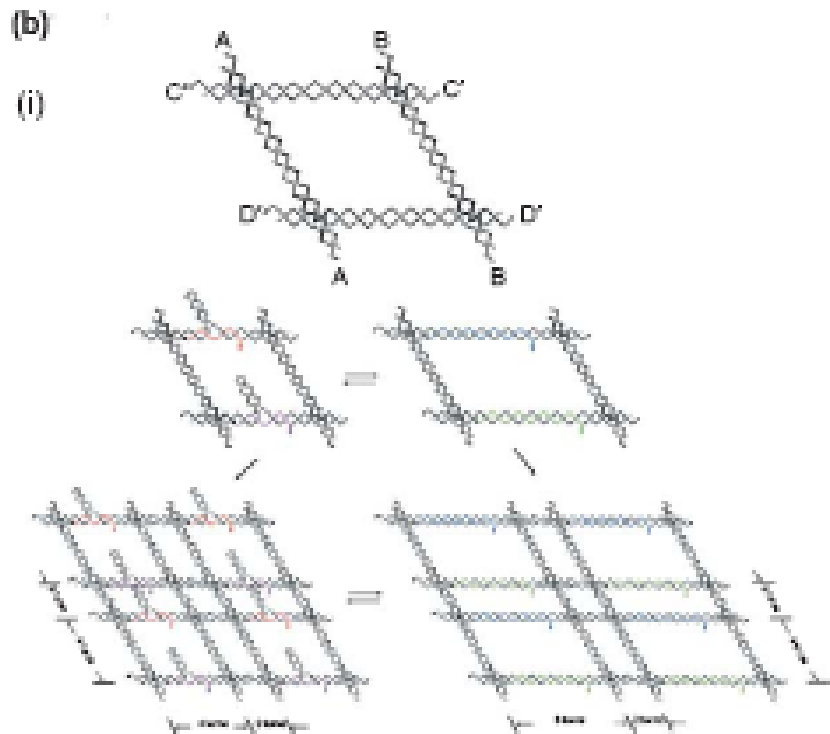


Using AFM to investigate

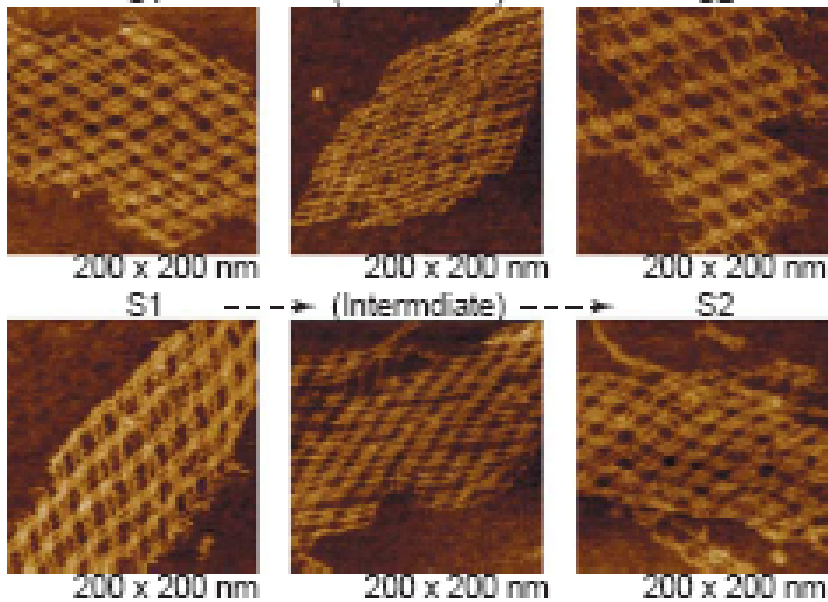


Shape changing

- DNA polyhedra and arrays are static objects
- Can control their nanoscale structure
- Can also control their ability to take shape
- Pre shape through their sequence
- Post shape in response to external stimulus



DNA modifying device
Can change cavity dimensions



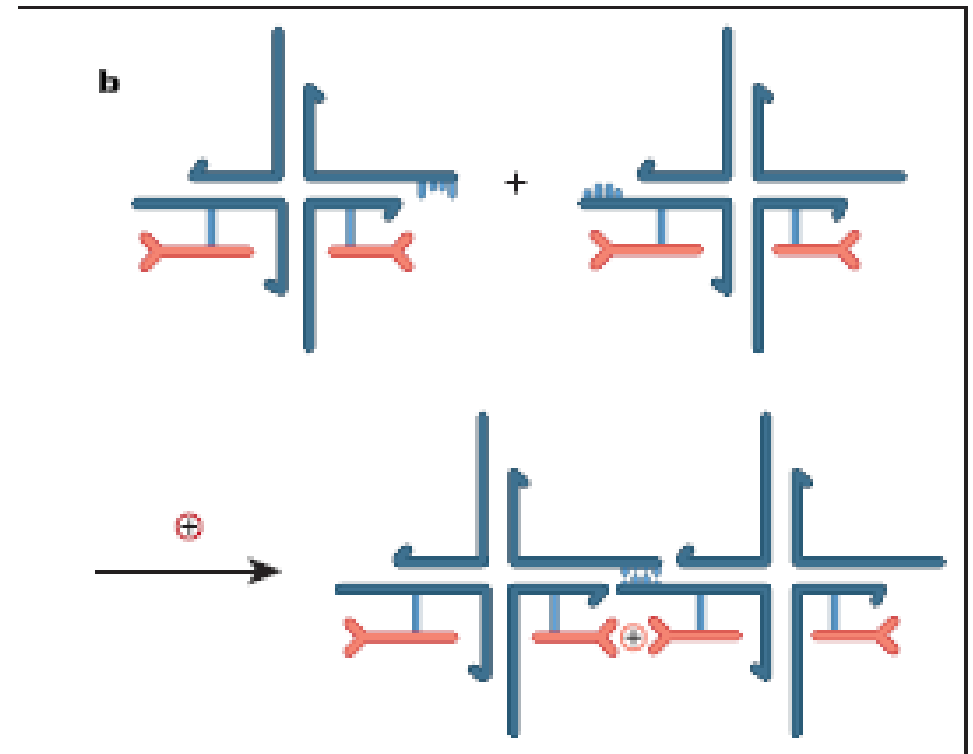
L. Schauer

DNA nanomechanical Devices

- DNA-based shape-shifting structures
- gears and walkers
- a DNA-stress gauge
- a translation device.
- The devices are activated by mechanisms as diverse as small molecules, proteins and, most intriguingly, other molecules of DNA.

Organizational capabilities

- DNA directed assembly of nanoscale electrical circuits
- Branched DNA junctions
- Nanoelectronic components
- Stabilized by the addition of a positive charged ion
- Debate over DNA as a conductor vs insulator
- Organize metallic nanoparticles



Organizational capabilities

- Platforms to study the structure of biomolecules through x-ray
- Bring enzymes close enough together to fuse multiple enzymatic activities

