భారతీయ సాంకేతిక విజ్ఞాన సంస్థ హైదరాబాద్
भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

Introduction of Bio-nanotechnolgy BT1110

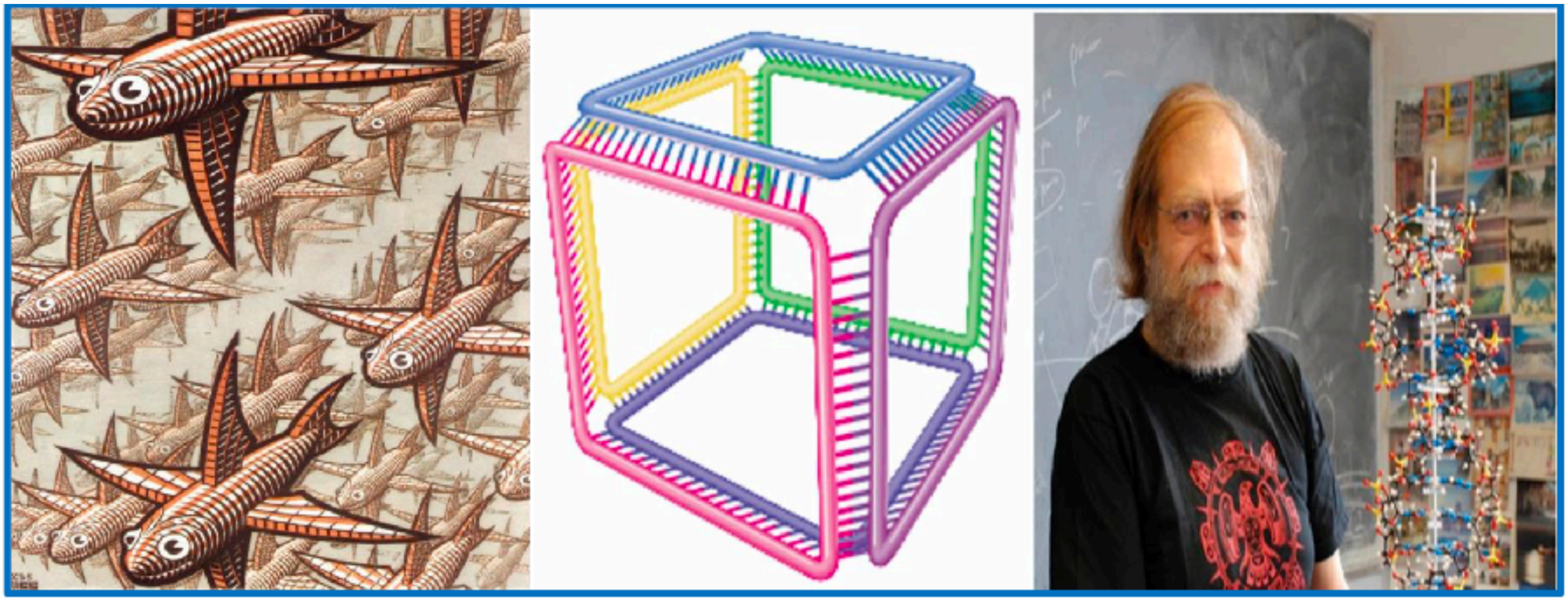
Lecture 6 : DNA origami

Himanshu Joshi 13 November 2023

Course contents

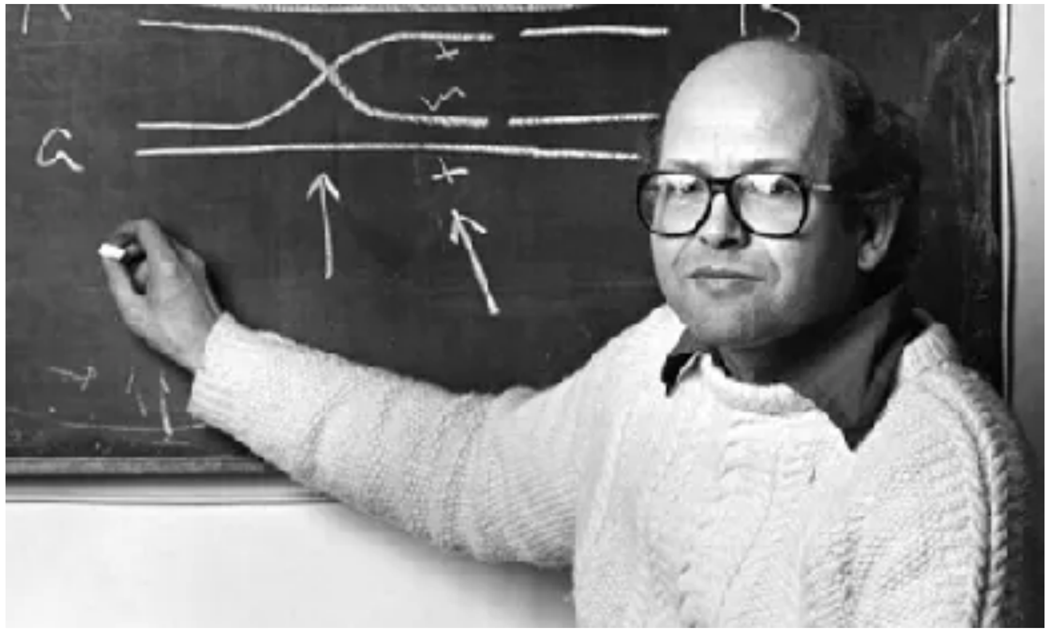
- Introduction to nanotechnology and bionanotechnology,
- Biological self-assembly
- Biologically inspired nanostructures - introduction to biomimetics
- Nucleic acid nanotechnology
- **DNA origami**
- Protein engineering
- Lipid nanotechnology
- Chirality in biological systems
- Interaction of nanomaterials with biological systems
- Virology: viruses and vaccines

Recap
DNA Nanotechnology



Various forms of DNA

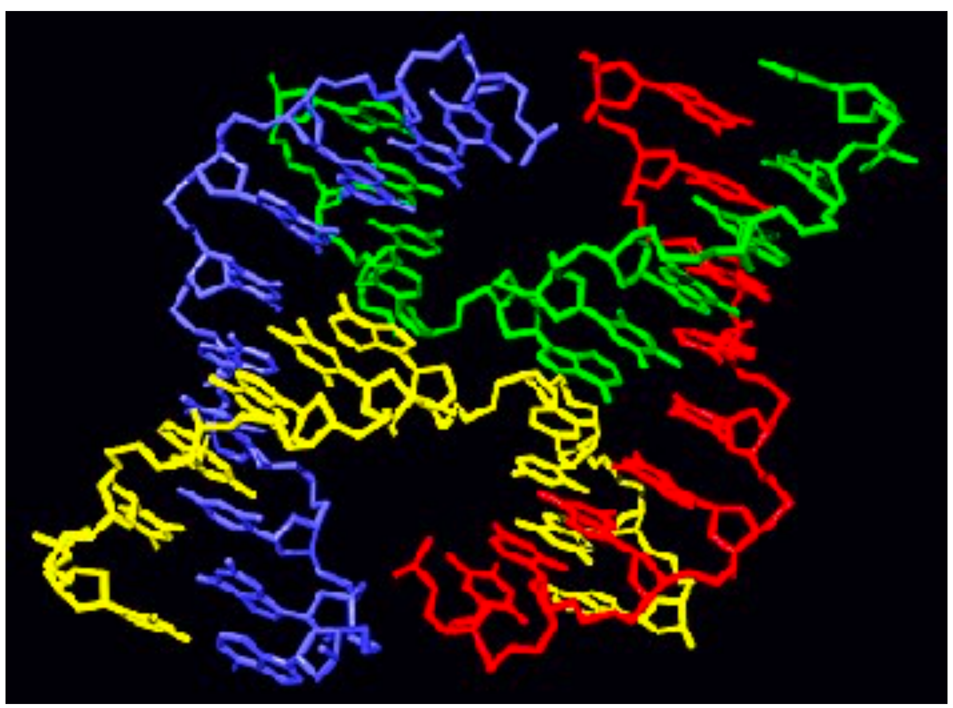
ssDNA A-DNA B-DNA (canonical) Z-DNA G-quadruplex

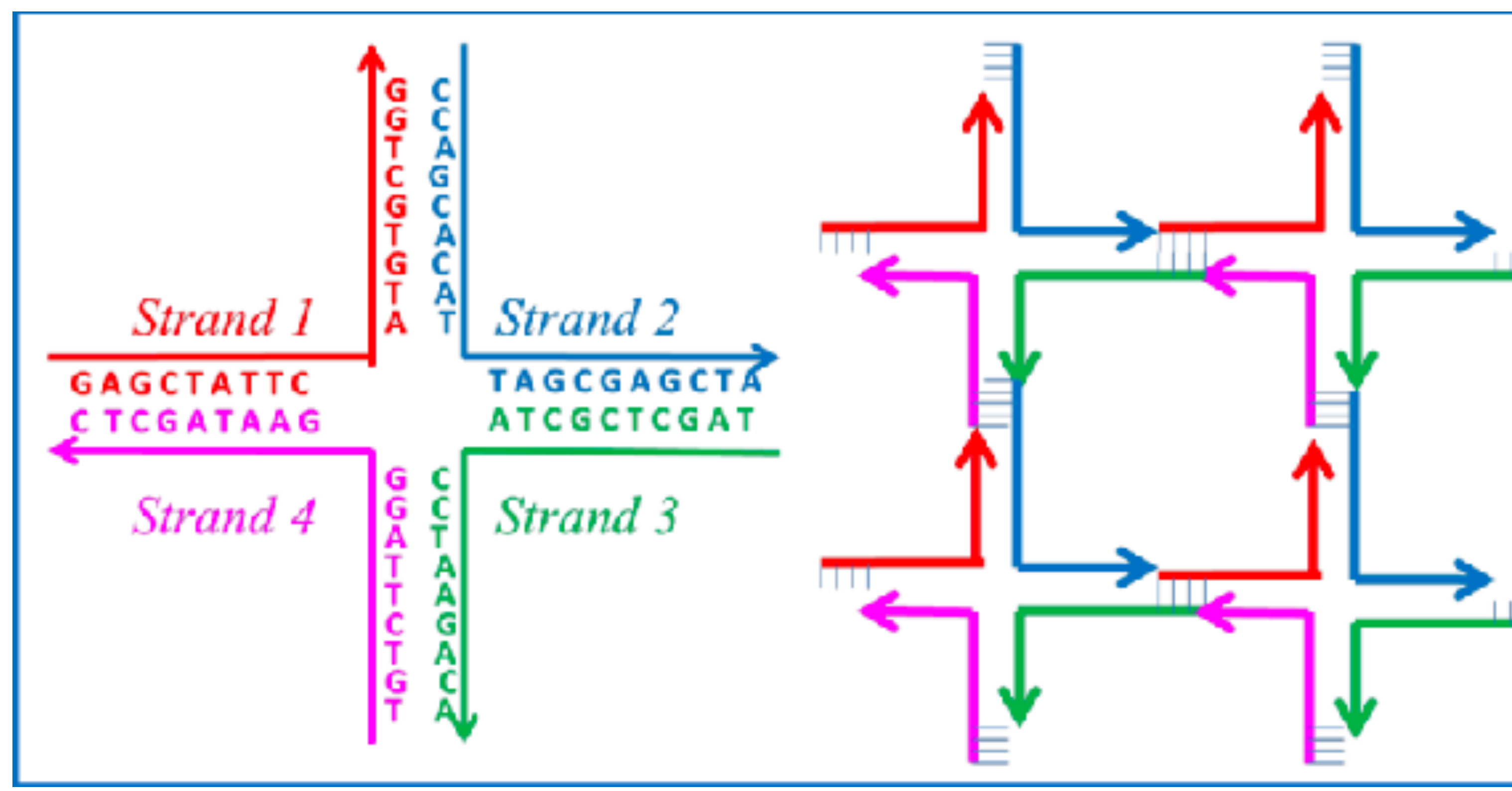


Robin Holliday in 1964

Holliday Junctions

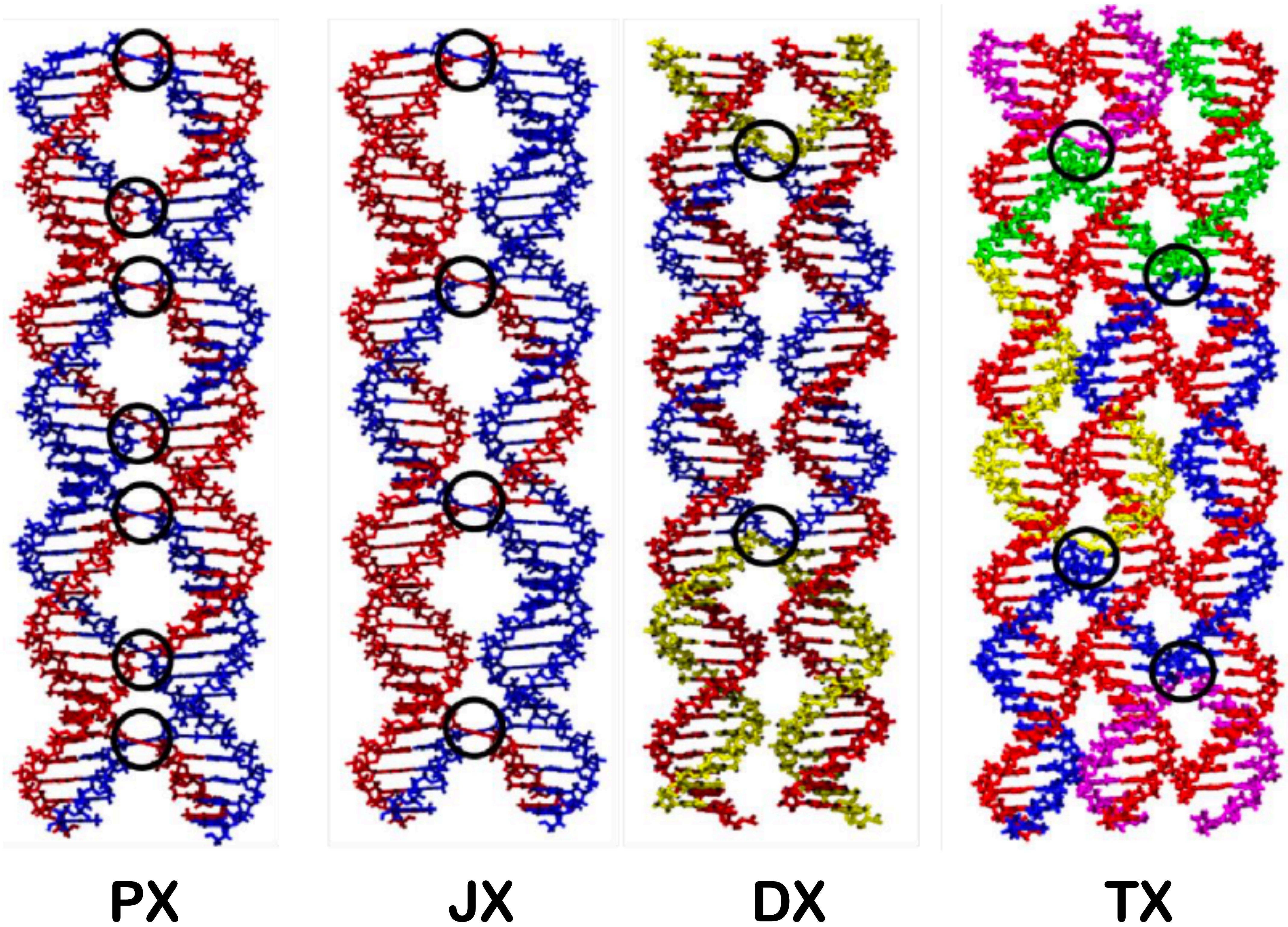
The mobile Holliday junctions are the intermediates in genetic recombination and dSDNA break repair which further breaks into the copies of DNA through branch migration



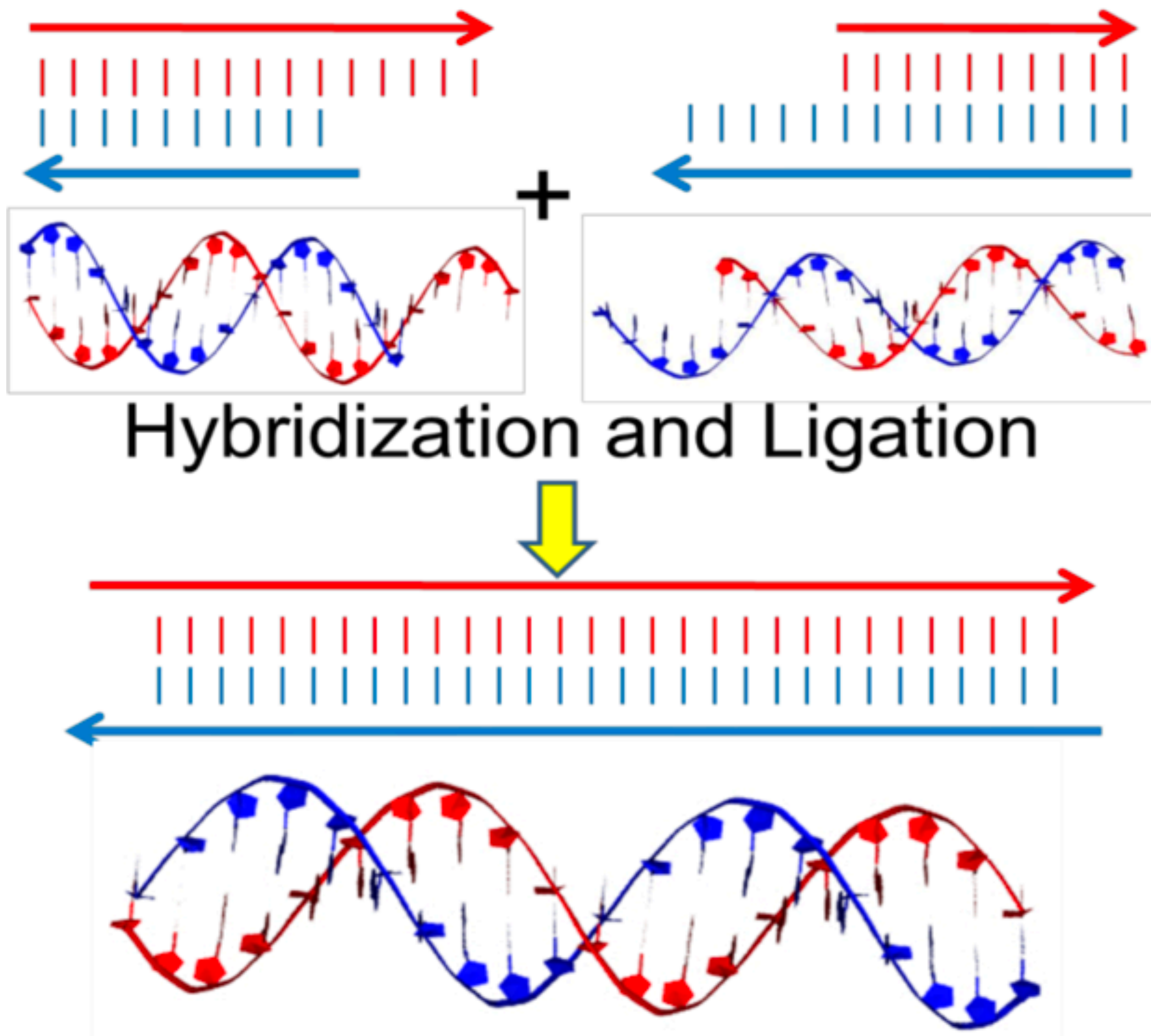


Ned Seeman identified that the immobile Holliday junctions ca
be used a building blocks to

Crossover DNA Nanostructures

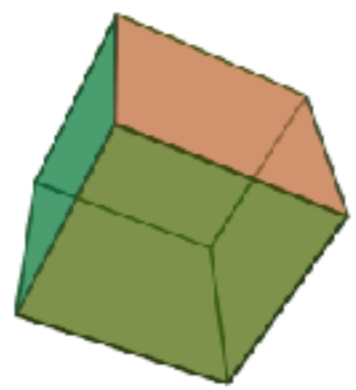
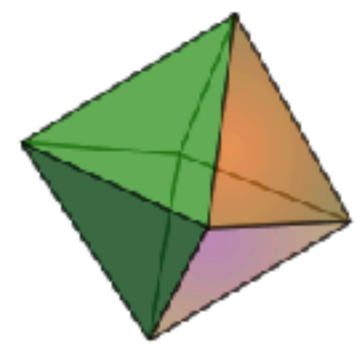
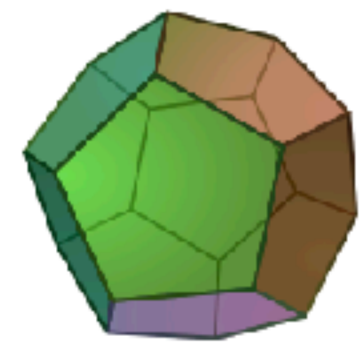
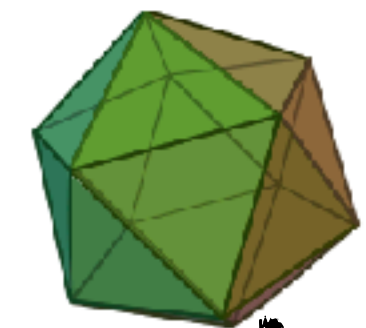


Sticky end cohesion



Platonic solids

Only five convex regular polyhedron exist in 3d euclidian space

Tetrahedron	Cube	Octahedron	Dodecahedron	Icosahedron
Four faces	Six faces	Eight faces	Twelve faces	Twenty faces
				

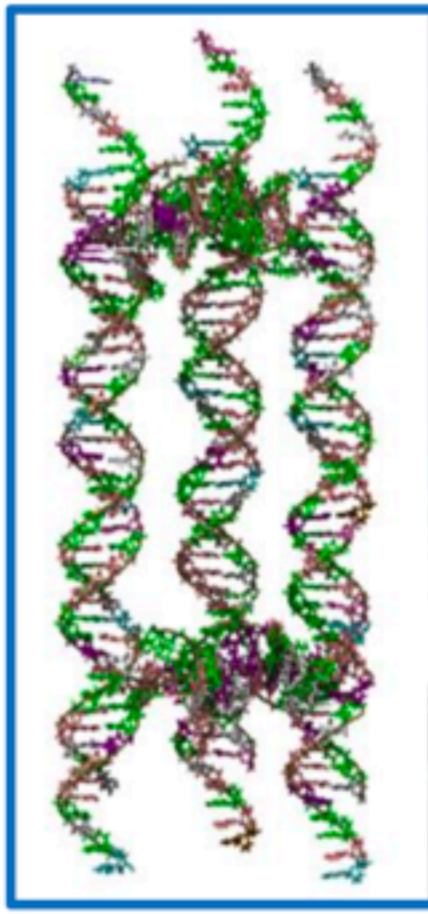
Parameters

Figure	Tetrahedron		Octahedron	Cube	Icosahedron		Dodecahedron	
Faces	4		8	6	20		12	
Vertices	4		6 (2 × 3)	8	12 (4 × 3)		20 (8 + 4 × 3)	
Position	1	2			1	2	1	2
Vertex coordinates	(1, 1, 1) (1, −1, −1) (−1, 1, −1) (−1, −1, 1)	(−1, −1, −1) (−1, 1, 1) (1, −1, 1) (1, 1, −1)	(±1, 0, 0) (0, ±1, 0) (0, 0, ±1)	(±1, ±1, ±1)	(0, ±1, ±ϕ) (±1, ±ϕ, 0) (±ϕ, 0, ±1)	(0, ±ϕ, ±1) (±ϕ, ±1, 0) (±1, 0, ±ϕ)	(±1, ±1, ±1) (0, $\pm\frac{1}{\phi}$, ±ϕ) ($\pm\frac{1}{\phi}$, ±ϕ, 0) (±ϕ, 0, $\pm\frac{1}{\phi}$)	(±1, ±1, ±1) (0, ±ϕ, $\pm\frac{1}{\phi}$) (±ϕ, $\pm\frac{1}{\phi}$, 0) ($\pm\frac{1}{\phi}$, 0, ±ϕ)

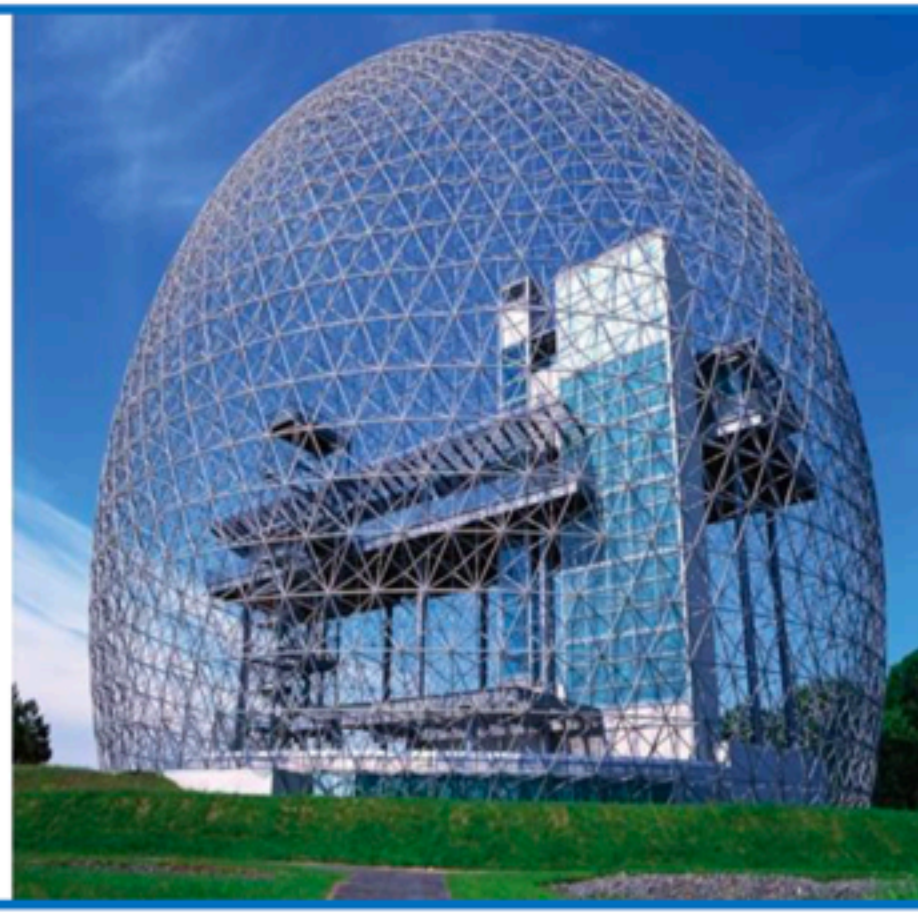
Virus assembly

ϕ = Golden ratio = ~1.61 = $\frac{1+\sqrt{(5)}}{2}$

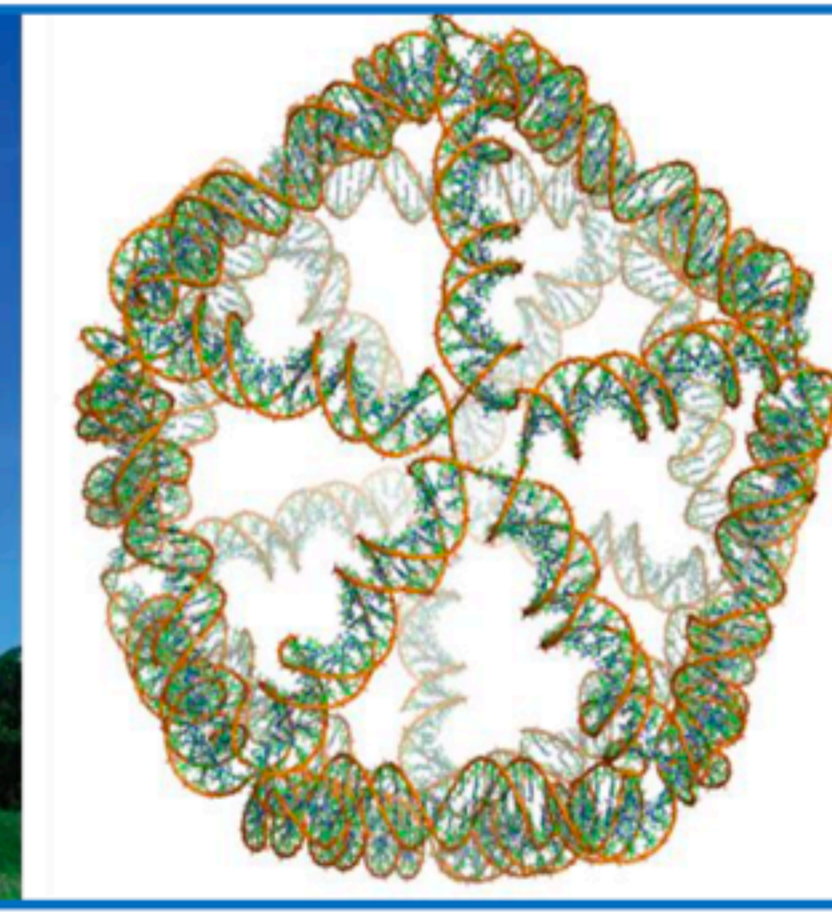
Polyhedra and Tensegrity Nanostructures



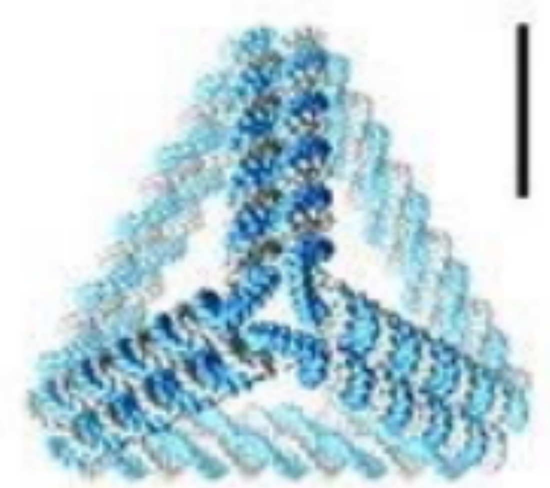
Triangular DNA nanotube



Geodesic domes



DNA icosahedra



DNA tetrahedra

Extremely stable, stress balanced, interconnected polyhedrons

Triangular frames, remain stable even during earthquake

DNA origami

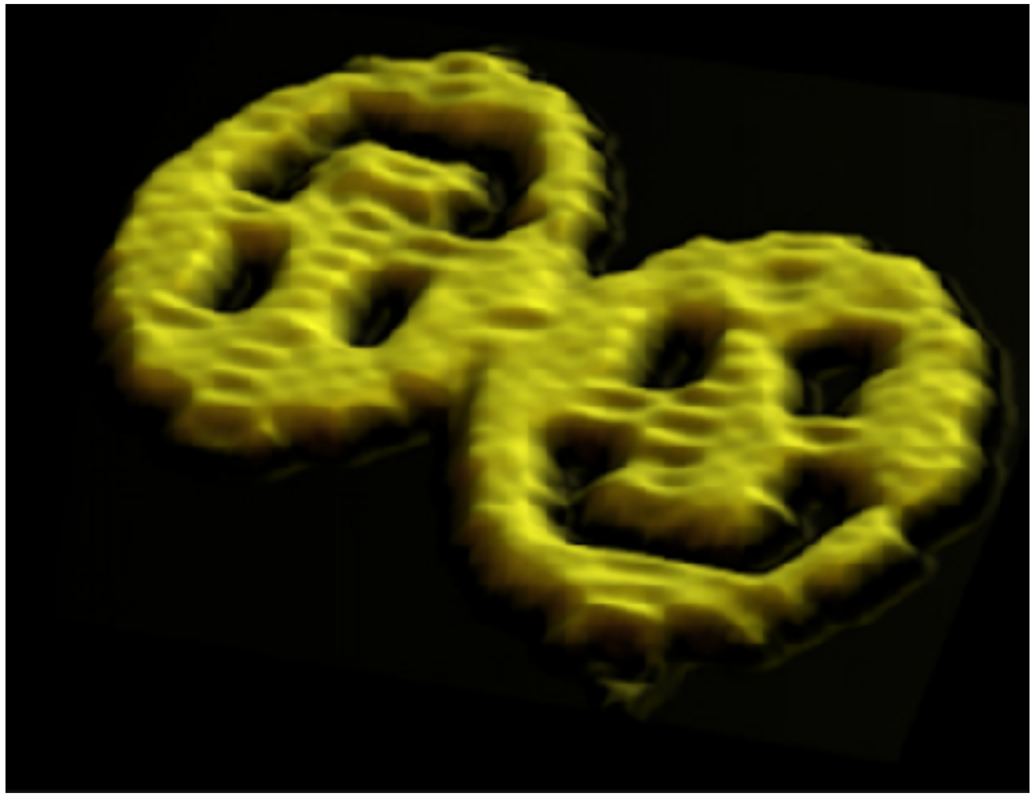
P. Rothemund
Computer scientist
Caltech

- DNA origami is a method of folding long strand of DNA to create 2D and 3D materials.

- Before that scientists used to tile based methods to create larger DNA nanostructure.

- Computer programes like caDNAno help in designing the staple strands

Staple strand
Template strand

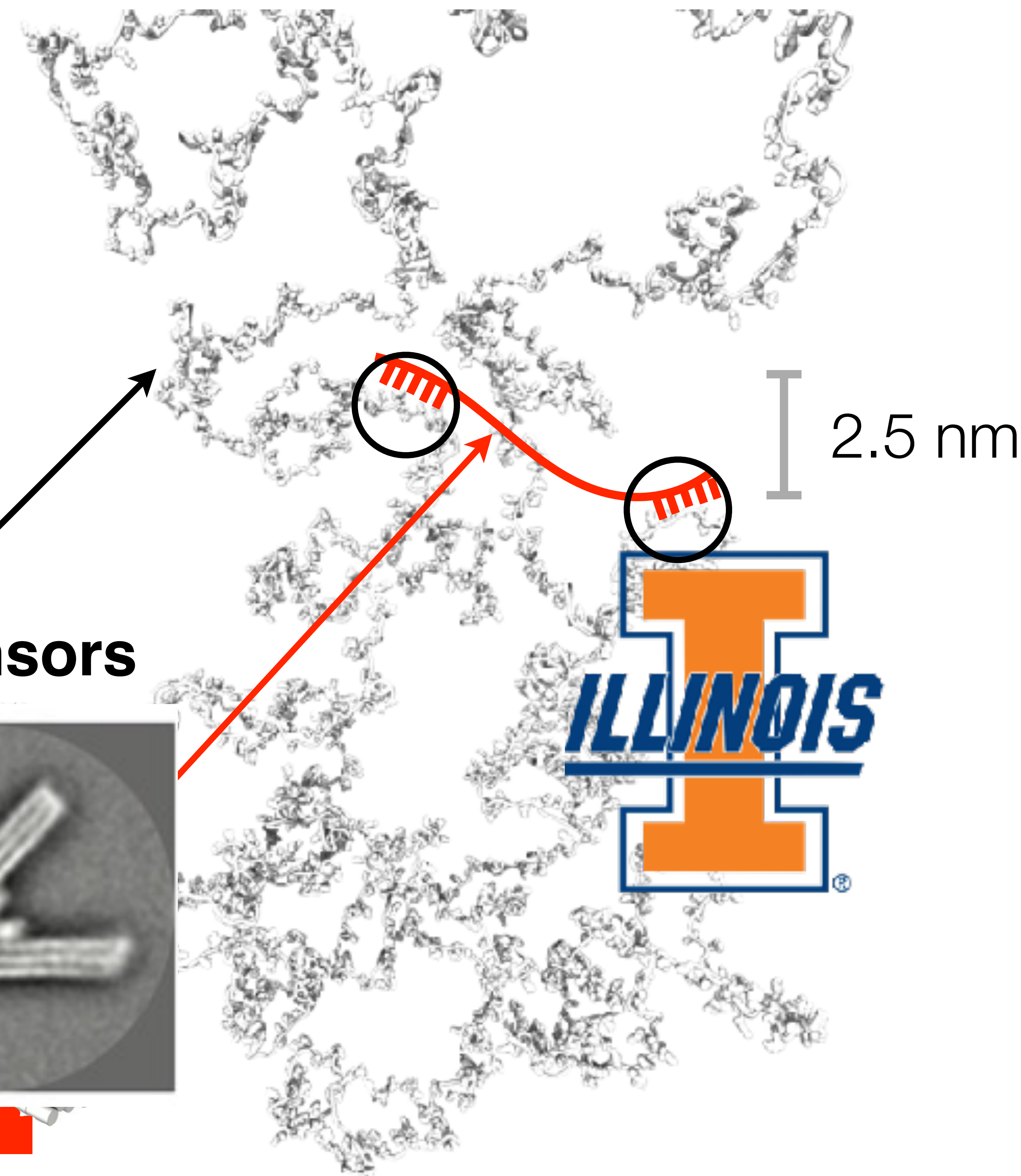


~ 14000 bases

How does DNA origami works

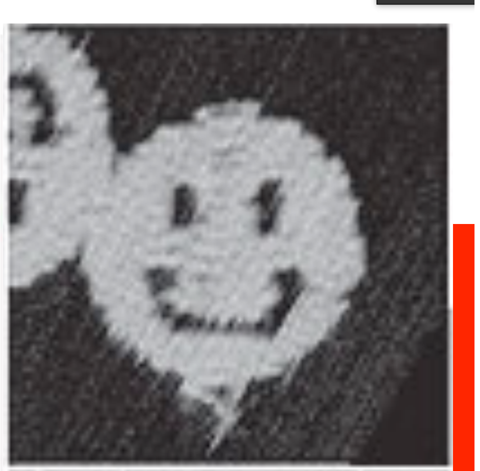
DNA origami: a method to **program** a custom-shape 3D structure of a long viral DNA (>5000 nucleotides) using short synthetic DNA oligomers.

- Nanometer-scale precision
- High yield
- No expensive fabrication facilities.

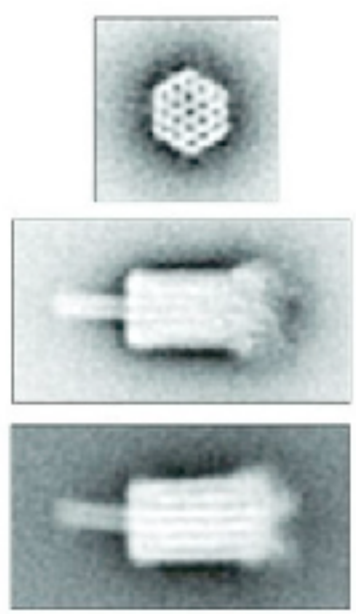


Source: *J. Yoo, Aksimentiev lab*

Custom shapes, channels, and sensors



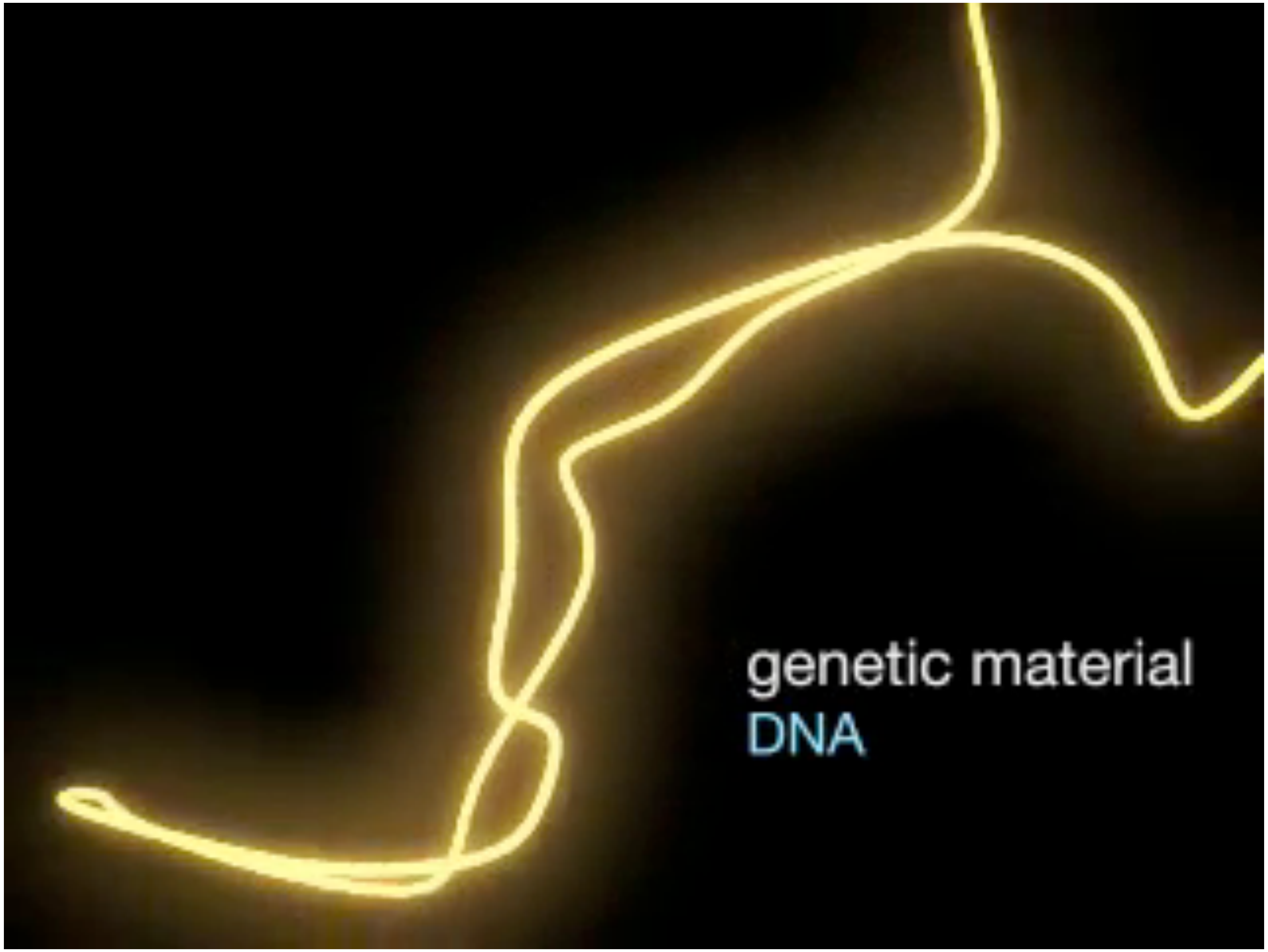
Nature 2005
Paul Rothemund



Science 2012
Simmel el al.

Science Adv. 2016
Dietz et al.

Another video illustrating the process of DNA origami



Bottom up synthesis

Self-assembly

Non-covalent electrostatic interactions

DNA nanotubes