DNA Origami – A window into nanoscale design and building

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Inspirational Education for 14 - 19 year olds

1982 – Synthetisation
The first chemical synthesis of a DNA cube was first achieved by Nadrian Seeman (5)

2006 – Nadrian
Introduction
Paul Rothemund introduces the DNA origami technique for the first time, demonstrating that complex structures can be formed by folding a DNA molecule in a specific way.

2009 – Creation
Researchers create 3D shapes from DNA origami, paving the way for more complex applications.

2010 – Demonstration
The first demonstrations of DNA origami functionality are achieved, including for the assembly of optical nano-antennas.(3)

2011 – 1st functional nanorobot
Researchers create functional nanorobot from DNA origami, capable of moving in complex cellular environments.(6)

2012 – 1st Molecular machine
DNA origami is used to create complex molecular machines, paving the way for a new generation of programmable nanorobots.

2014 – 1st Molecular robot
Researchers create a molecular robot using DNA origami, capable of performing simple tasks such as drug delivery.(2)

2016 – 1st Molecular digital data storage using DNA
Researchers develop a method for using DNA origami to store digital data, paving the way for a new generation of molecular data storage media.(1)

2018 – Hybrid protein-DNA nanostructure
DNA origami is used to create complex three-dimensional structures that mimic the shape and function of proteins, offering a new approach to engineering artificial proteins.(7)

2020 – DNA-Nanodevices
Researchers demonstrate the ability of DNA origami to control cell organization in complex three-dimensional environments, offering potential applications in cell biology and tissue regeneration. (4)

Today

SUMMARY:

DNA origami technology is a revolutionary technique that enables the precise folding of single-stranded DNA into complex three-dimensional shapes, using short complementary strands as staples. This technique has great potential in various fields nanotechnology, material science, medicine and dentistry.

Application of DNA origami:

Materials science:
Create new materials with unique properties e.g. ultra-thin wires and coatings.

Energy:
Create new types of solar cells and other energy-harvesting devices.

Nanotechnology:
Create precise and complex nanostructures with unique properties and functions,e.g. biosensors, molecular machines, and drug delivery vehicles.

Biosensing:
Biosensors that can detect specific molecules, such as disease markers, with high sensitivity and specificity.

Molecular computing:
molecular computing devices could be faster and more energy-efficient than traditional silicon-based computers.

Medicine:
Targeted drug delivery, tissue engineering, biosensing, and molecular imaging. Leading to more effective and personalized treatments for diseases.

Biotechnology:
Creates nanoscale templates for assembling other molecules, such as proteins and nanoparticles, with precise spatial arrangements, enabling the creation of new biomaterials and biocatalysts.

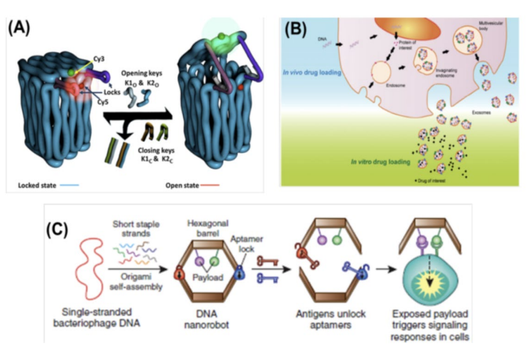
Data storage: a storage medium for digital data, due to its high storage density and long-term stability.

Biomedical research:
delivers drugs to specific cells or tissues, as well as to create synthetic antibodies and other biomolecules.

Tissue engineering: creates scaffolds for tissue engineering, providing a 3D structure for cells to grow and develop into functional tissue.

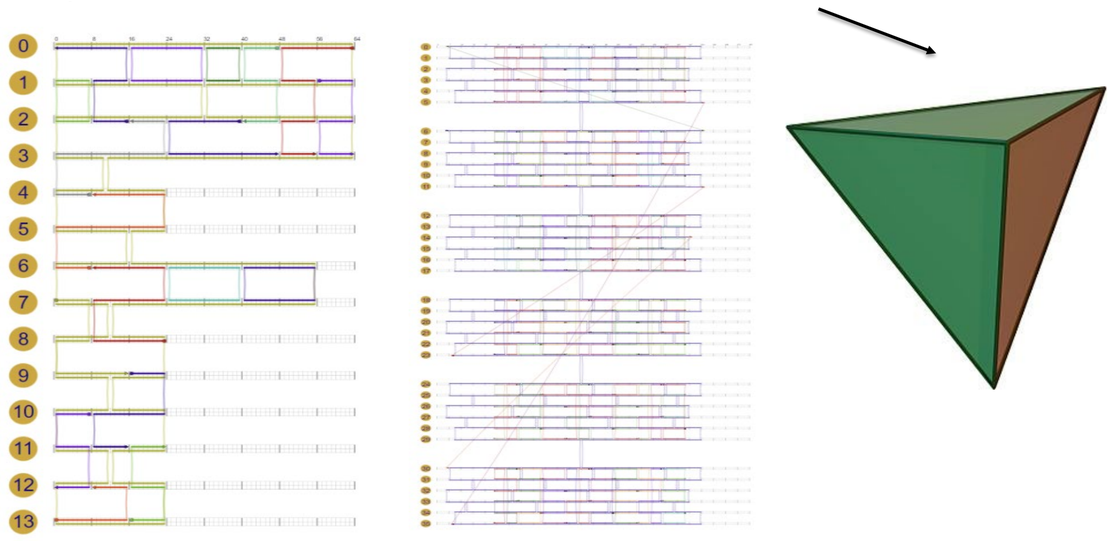
What are the advantage of using DNA origami in nanotechnology and biotechnology, etc ?

- Precise structural control
- Biocompatible
- High yield
- Stability
- Functionalization
- Self-assembly



Method to create a nanostructure using DNA :

ScaDNAno and caDNAno can be used to design structures, using a sequence of the single-stranded DNA scaffold and the complementary staples. That can fold the scaffold into the desired shape.



The second step to synthesise the scaffold and staple strands is using standard DNA synthesis techniques (chemical and enzymatic synthesis methods).

Once the scaffold and staple strands have been synthesized, they are mixed together in a buffer solution and heated to near-boiling temperatures to denature the DNA strands. The solution is then slowly cooled to allow the staple strands to anneal to the scaffold and fold it into the desired shape.

After the DNA origami structure has been formed, it must be purified to remove any unbound scaffold or staple strands, using gel electrophoresis or other chromatography techniques.

Finally, the DNA origami structure is characterized using various techniques such as atomic force microscopy, transmission electron microscopy, or fluorescence microscopy to confirm its size, shape, and stability.

Alternative methods for creating DNA origami structures include rolling-circle amplification (RCA) and single-stranded tile (SST) assembly, but scaffolded DNA origami remains the most widely used technique due to its simplicity, versatility, and scalability.

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