Abstract

We use the DNA origami technique recently developed by Paul Rothemund [1]. The idea is to design a strand of DNA such that it wraps into some meaningful shape. First, the DNA should fold into a two-dimensional rectangular sheet: the universal DNA-platform [2].

Secondly, this sheet should wrap itself up into the shape of a short pipe. Third, these little pipes should hook themselves up to each other such that they form one single long pipe. Once the process of DNA folding into 3D structures is understood, shapes can be chosen arbitrarily. We hope it will be possible to maintain molecular sensors, logic gates, and actuators on the surface of 3D DNA-objects, and to reach a swarm behavior of the DNA-origami agents [3].

Introduction

Our DNA-folding project isn’t a typical Synthetic Biology project, because we play with ‘dead DNA’ rather than ‘alive DNA’ coding proteins. We try to merge the DNA-origami static structures and the dynamic DNA-BioBricks constructs to create living machines. Because we’re using DNA-synthesis very actively, it could be called Synthetic Biology or DNA-nanotechnology. The eventual outcome of the project is an Artificial Life and Origami Man. Importantly, we try to add aesthetic principles and rules (symmetry, periodic patterns, recursion, and plasticity) into our future creatures. Crazy! Not at all! The basic idea is to design DNA so that it folds into DNA-sheet, which we call the addressable platform with atomic scale resolution [2]. It should be possible to mount some molecules on this DNA-sheet, as if it were graph paper. These molecules could act as sensors, logic gates, and actuators for this nano-platform. We’d attach a specific pattern of catalytic molecules to design synthetic pathways in space, or even to reach an addressable platform with 6 nm scale resolution [3].

We’d organize appropriate molecules, nanoparticles, or quantum dots (qubits) to build a new computer chip. We have a lot of imagination...

Design Rules

We dramatically simplified Rothemund’s scaffold origami method. Now students need only a browser with access to standard bioinformatics tools and a text processor, if they didn’t make their design too complex[5].

Abstraction

4. Take a sheet of graph paper; 1.5 squares on paper = 1 building block of 16 nucleotides = 1.5 nm DNA = 5.4 nm horizontal and 4 nm vertical.

5. Find a horizontal “snaking” path through the Manhattan skyline geometry of resulting bar graphs, with some vertical turns, and try to exploit symmetry.

6. Starting at one end of the DNA strand, insert a crossover to the strand section above every alternate building block. Add helper strands to bind the scaffold together. As first designed, most staples bind two helices and are 16-mers.

7. Merge helper strands to enhance the scaffold. As second designs, most staples bind three helices and are 32-mers.

8. Fill up the scaffold with letters A, T, G, C, define corresponding staple sequences by complementary mapping on the addressable platform with 6 nm scale resolution [6].

Implementation

Send your request to a DNA synthesizing company such as fab in Heidelberg. You will get 2 bottles: 1 with the scaffold DNA, the other full of staples in 1xTAE (pH 7.8-8.4) buffer with 10 mM MgAc.

Get the following equipment: pipettes, gradient thermocycler, AFM, mica.

Mix the scaffold and staple DNAs in 1/10 (IM) proportion (2 x 50 μL).

Warm to 92°C and program the cooling down to room temp 20°C, over 16 hours.

Clean the mica and place 5 μl droplet on the mica. Image with AFM, landslay eureka!

Methods of analysis

1. DNA folding (electrophoresis in the polyacrylamide gel)
2. 2D structures
3. Nanopacket
4. Fluorescence

Conclusions

1. We designed a lot of creatures from DNA. You’ll see!
2. We realized the DNA-synthesis is a bottle-neck of DNA-nanotechnology.
3. We weren’t able to create “self-replicating” staples and Artificial Life was not created this time. We’ll try again.
4. We won’t design the Artificial Life in a tube, rather in the DATABASE. We’ll only manipulate DNA by a mouse, next by modeling, and then we’ll bring it into the lab...

Future projections

Unconventional computing, cryptography, nanoelectronics, nanoptics, nanosensors, drug delivery systems, and smart nanomaterials all are the potential applications for near future.

References


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