DNA plug-and-play platform

1. Primitives for the bottom-up design. Why DNA?
2. Structures, devices, systems
3. DNA raster fill technique (scaffolded origami)
4. Open source biology, iGEM
What do we need?

• a library of primitives for the bottom-up design on the nanometer scale

• to discover these primitives

• a universal addressable platform to compose these primitives in desirable way

• a proof-of-principle for a much larger composed devices and systems
Why DNA?

• The unique physical, chemical and informational properties of DNA
  – high information storage density
  – self-assembling and replication
    • duplex, triplex, tetraplex, branched junctions
    • template for a molecular optoelectronics
    • DNA cloning and directed evolution toward optimization
  – DNA computation, possibly quantum computation
  – gene engineering, high-throughput DNA synthesis
Emerging technologies based on DNA synthesis

DNA synthesis

Blue Heron, Codon Devices – price $0.85-$1.60/bp
GENION: (8 x 15000 x 60)/2 = 3.6 x 10^6 = 3.6 Mbp

Structural DNA

Multi-stranded origami (Nadrian Seeman)
Scaffolded origami (Paul Rothemund)
Single-stranded origami (William Shih)

Functional DNA

Refactoring (Drew Endy)
Foundation technologies (Craig Venter)
Structures

- DNA templates direct the growth of semiconductor crystals and metal wires
- DNA fragments assemble virus, carbon nanotubes, and colloidal particles
- 1D tracks, 2D grids, and 3D scaffolds are templates for programmable selfassembly
- ordered arrays of tiles as a result of algorithmic selfassembling
Nucleic acid guided assembly


*Ng, Bergstrom* Nano Lett 5(1):107-111, 2005
1D tracks, 2D grids, 3D structures (cube and clonable octahedron)


Devices

• DNA control of mechanical movement by hybridization
  – nanomechanical switches
  – DNA-based nanoactuator with arms
  – DNA biped walking nanomachine
  – tweezers for DNA-templated coupling reactions
DNA nanomachines


Sherman, Seeman *Nano Lett* 4(7):1203-1207, 2004

Systems

- fabrication by selforganization
- nanoscale platform for multifunctional devices

- smart nanoparticles would comprise
  - a magnetic core,
  - alternative NA scaffold, and
  - the functional shell including
    - molecular sensors,
    - logics, and
    - actuators
DNA raster fill technique


1. Fill the shape
2. Draw the raster
3. Add helper strands
4. Merge helper strands
A helical representation

Map of twists

A dumbbell hairpin label
Strands drawn as helices
DNA design and folding

multishapes.m output changes from 90 °C to 20 °C
Different DNA origami shapes
Patterning and combining
Programmable assembling and self-healing Wang tiles

Self-assembled demultiplexers can address a memory. Cook et al., in DNA Computers 9, LNCS 2943:91-107, 2004

Open Source Biology
http://parts.mit.edu/registry/index.php/Main_Page
The aim of Synthetic Biology is genetic robots and orthogonal life

- The designed fragments of DNA could be seen as a kind of genetic programs and parts of genetic robots
- These genetic computer programs could be introduced into living cells in order to control their processes
- … and to enhance their possibilities

- Artificial chemistry and simple genetic logic in poor environment which will be tractable for a numerical simulation
Biological engineering

Engineering Escherichia coli to see light

These smart bacteria 'photograph' a light pattern as a high-definition chemical image.

Anselm Lenska* 1, Aaron A. Cavalli 1, Jeffrey J. Tahor 1, Zachary Beach Simpson 1, Laura A. Lovery 1, Matthew Levy 1, Eric A. Davidson 1, Alexander Gouzevitch 1, Andrew R. Gilchrist 1, Edward M. Marcotte 1, Christopher A. Voigt 1,2*

Emerging Properties of Reduced-Genome Escherichia coli

Gyorgy Pósfai,1,2,4 Guy Prunetti III 1,2,4, Tamas Fehér 1, David Frisch 1,4 Guenter M. Keil 1, Kupa Unzenhofer 1, Vitaliy Kolesnychynchenko 1,4,5,6 Raffy Saki 1,2,7, Sinauk S. Sharma 1,3, Monika de Aruda 1, Valerie Burland 1,3, Sarah W. Harcus 1, Frederick R. Blattner 1,2,4,5,6,7

Combining two genomes in one cell: Stable cloning of the Synechocystis PCC6803 genome in the Bacillus subtilis 168 genome

Mitsuhisa Hayashi 1, Kenji Takebe 1, Maki Ikeda 1, and Kyoko Fujiga 2


Available online at www.sciencedirect.com

Biological engineering