Seed Formation

9 DNA strands per tile

(1) Seed Tiles Annealed Separately

Biotin

Y6 B7

S A3(11) Y1

Y4 B5 Y5

(2) Tiles Mixed Together

Biotin

Y3 A4 Y4

Y1 B2 Y2

Biotin

Y9 A6 Y6

7 specific tiles with sticky ends

(3) Streptavidin Added

First Generation

seeds

Biotin

A1(11) B2 B3

Biotin

A4 B5 A6

Biotin

A7

AFM images of seeds

AFM Imaging
Daughters Labeled with Hairpins ~ 60% yield
Why don’t we try two tiles? And do it with Origamis
Different systems, same idea

Seed

1 µm

Daughter

DNA Origamis

40 nm

Colloids

BTX DNA Tiles

100 nm
Design of DNA origami

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Proceeding
ICCAD '05 Proceedings of the 2005 IEEE/ACM International conference on Computer-aided design
Pages 471-478
Rothemund’s DNA Origamis

[Diagrams of various DNA origami structures, including a linear array, a star, a smiley face, a triangle, and others.]
Xiaojin He       HKUST/NYU
Basic tile set for self-replication

SEED TILES

LATER-GENERATION TILES

Basic tile set for self-replication
Labelling with letter “T”

<table>
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<tr>
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<th>T-050</th>
<th>T-051</th>
<th>T-059</th>
<th>T-077</th>
<th>T-095</th>
<th>T-112</th>
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**Hairpin Dot**
- T
- T
- T

**Hairpin End**
- T
- T
- T

**Staple End**
- T
- T
- T

**Cycle Number**
- 0
- 2
- 4
- 6
- 8
- 10
- 12
- 14

**SR1024**
- SR32
- SR16
- TC

**Dimer Amplification (N)**
Replication cycles - cool/UV/heat -repeat
Number of Dimers Doubles each cycle!
Here’s 500X multiplication of seed

Self-Replication Plot (1:1024)

Cycle N

D%
AFM Images of 1024 replication

mostly single tiles

mostly dimer tiles
Replication by Serial Dilution

- Use the self-replicated sample (ratio: 1:32) after four cycles
- Allow approximately 14-fold amplification before transferring ~6% of the mixture to a new reaction tube that contained a fresh supply of monomers.

Total Amplification 7.5 million
Gel analysis shows same growth as counting Origami
Temperature and light cycles
NO SEED

no origin of life yet
Evolution - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/Evolution

Evolution is the change in the inherited characteristics of biological populations over successive generations. Evolutionary processes give rise to diversity at ...
Schematic Evolution

Original Species

Mutations with inheritable traits ~ equal growth

Environment Changes - Fire - need theory of Plasmas - advantage to one species

Environment Changes - growth rate higher - species takes over
Red - Green Origami Evolution

Original Species

Mutations with inheritable traits

Environment Changes - Red Light - advantage to one species

Selection - higher growth rate - Green takes over
Laser Heating of IR Dyes

Local heating

\[ jQ \sim \frac{Q}{4\pi r^2} \]

\[ T = T_0 + \frac{\delta T}{r} \]
Cycle 2

-~ 4 C: Laser 785 nm for 20 min
-~ 4 C: Laser 785 nm + UV for 1 h
-After each 2 cycles

1) Add monomer H to keep
2) Add Monomer I to keep
   (2*HH+ H): (2*I+ I) = 1: 1

Cycle 4
Replication rate 1.2 vs 1.95
Can reverse selection by switching lights

Grow in green 1 step then switch to red
How about growing it outside?
Roof Top - Washington Sq Park

Sun from here

Dirt from here
After a cold night, rays from the sunrise hit the sample for about 2 hours.
As the sun continues to rise, rays are blocked from hitting the sample and now serve to heat the dirt

Why Dirt?
Ambient temperature
32-36F \(\rightarrow\) 0-2C

Dirt Temperature
32-96F \(\rightarrow\) 0-35C
Original Dimer:Mono Ratio – 1:30

After One Sunny Day:

Control Sample on roof (in Al Foil)

*Dimers Remain Same Concentration*

Sunny Sample

*Dimers Doubled*
DNA as a functional material

Now much DNA is there?

Enough to fill a cube 2 kilometers on a side

Enough to build 200 cities the size of New York
Summary

• Dynamic Clustering when flux in \((\rho^+)\) > flux out

• **DNA is a great structural material**
  - specific, controllable, reversible, or permanent bonds

• 1st? Artificial Self-replicating system with:
  - design flexibility
  - autonomous offspring
  - no enzymes
  - exponential growth (great way to make zillions of nanodevices)
  - uses only temperature and light mimicking daily cycles
  - replicates information and structure
  - 1: 7,500,000 and growing

• Next:
  - evolution
  - without nucleic acids

Keck Foundation
NYU NSF MRSEC

Basic Energy Science