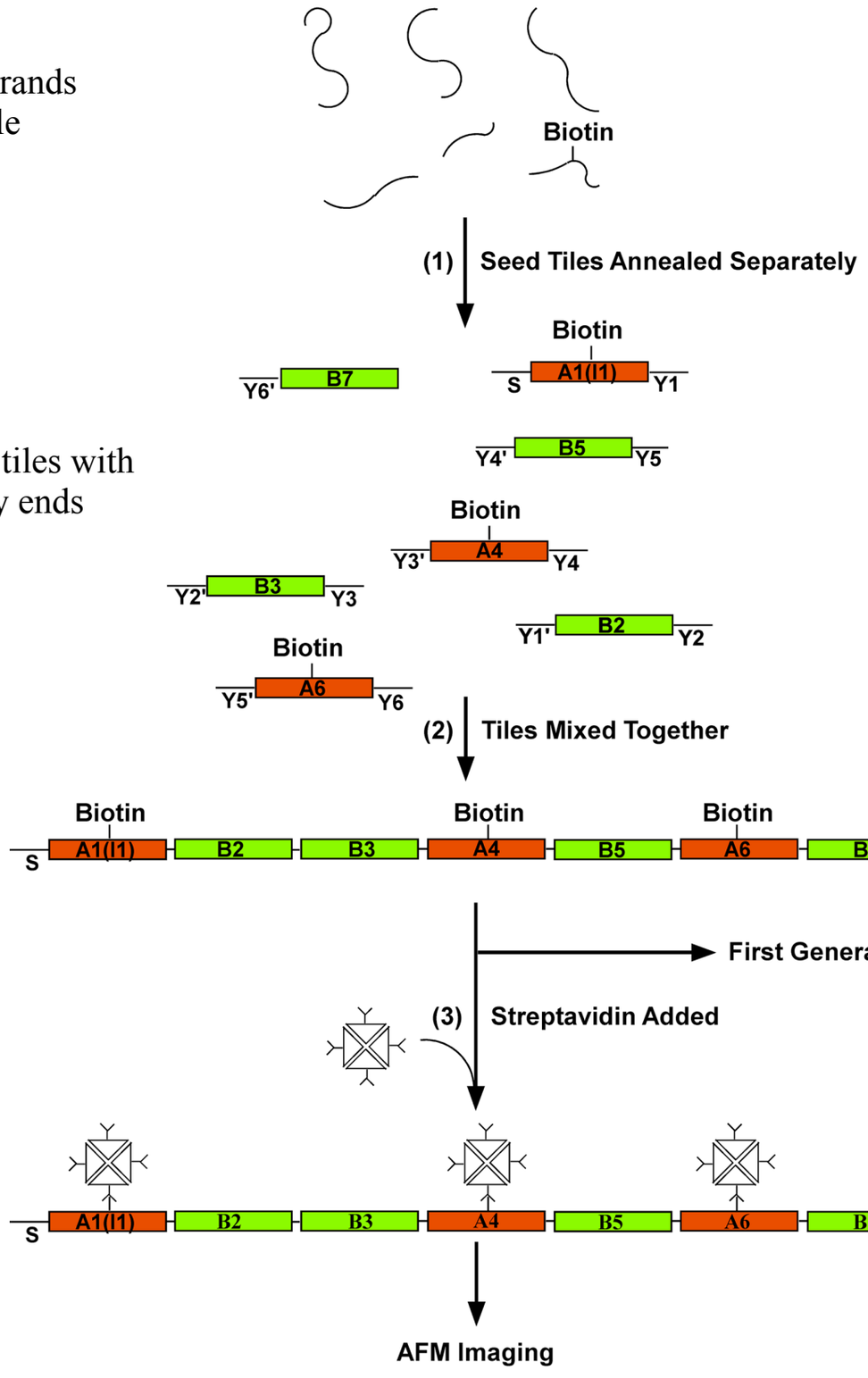
Seed Formation

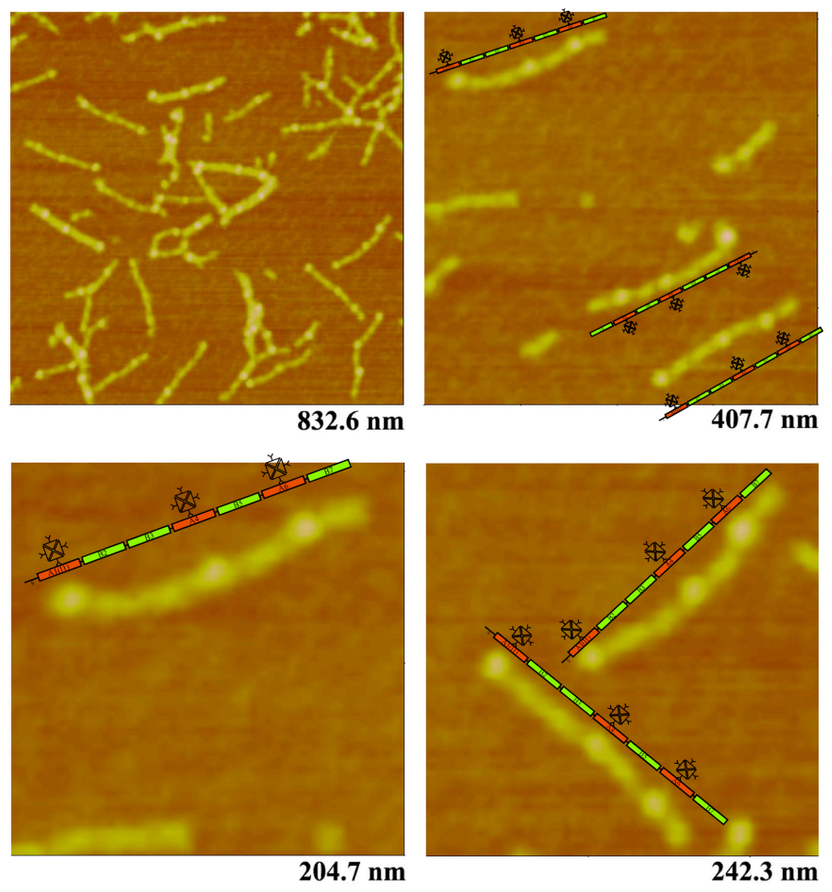
9 DNA strands per tile

7 specfic tiles with sticky ends

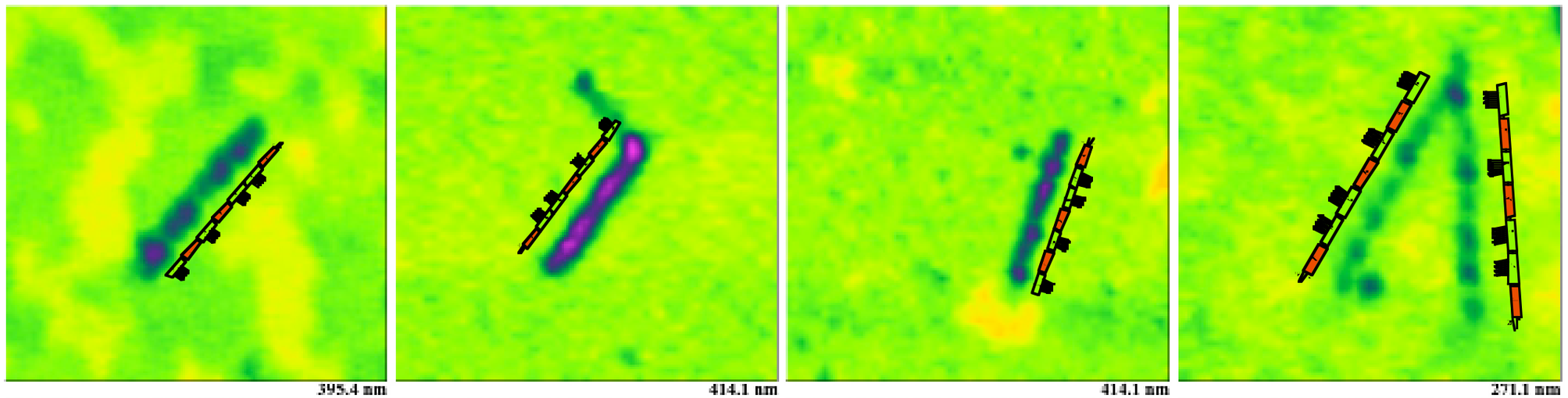
seeds



AFM images of seeds



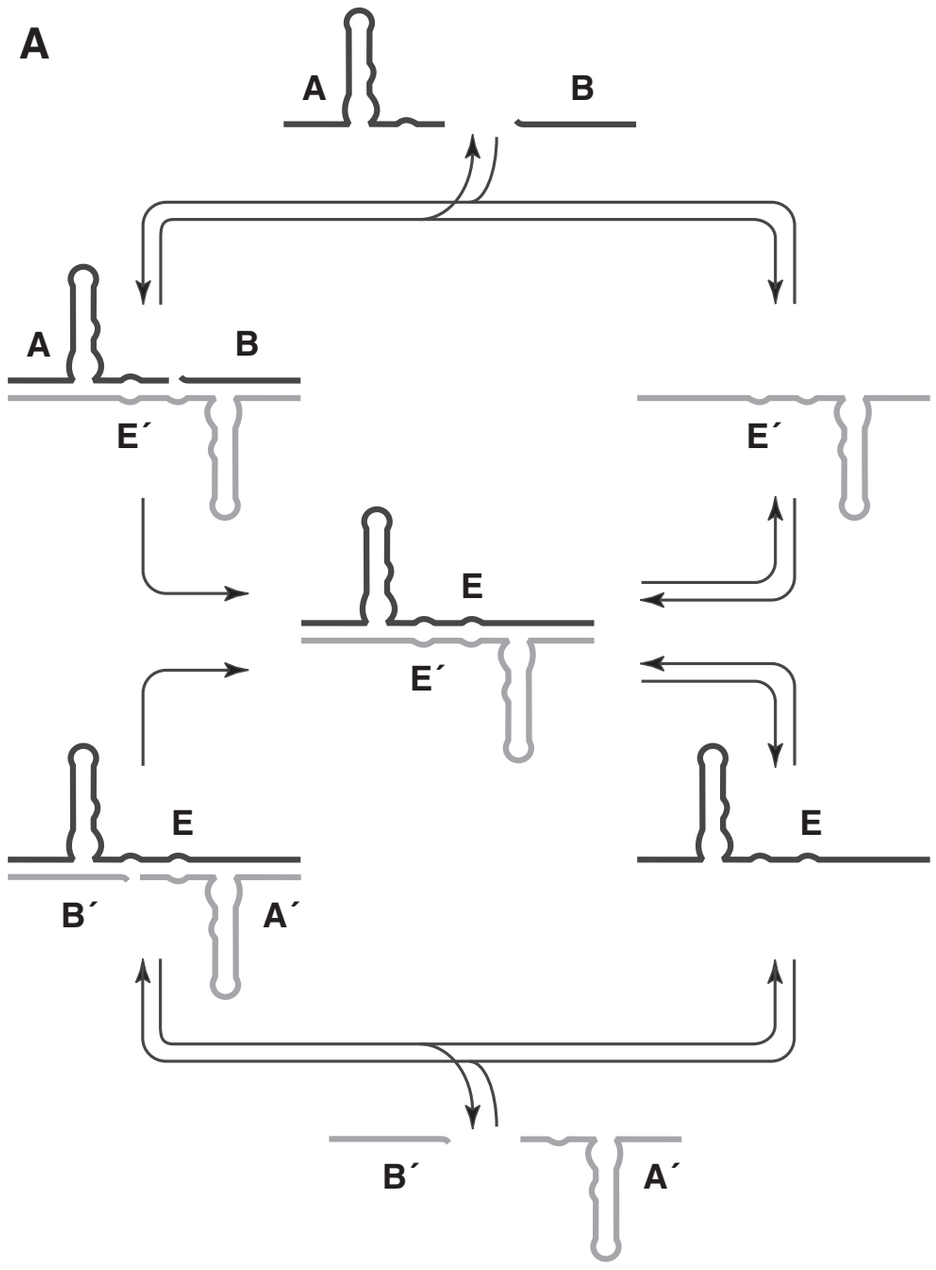
Daughters Labeled with Hairpins ~ 60% yield

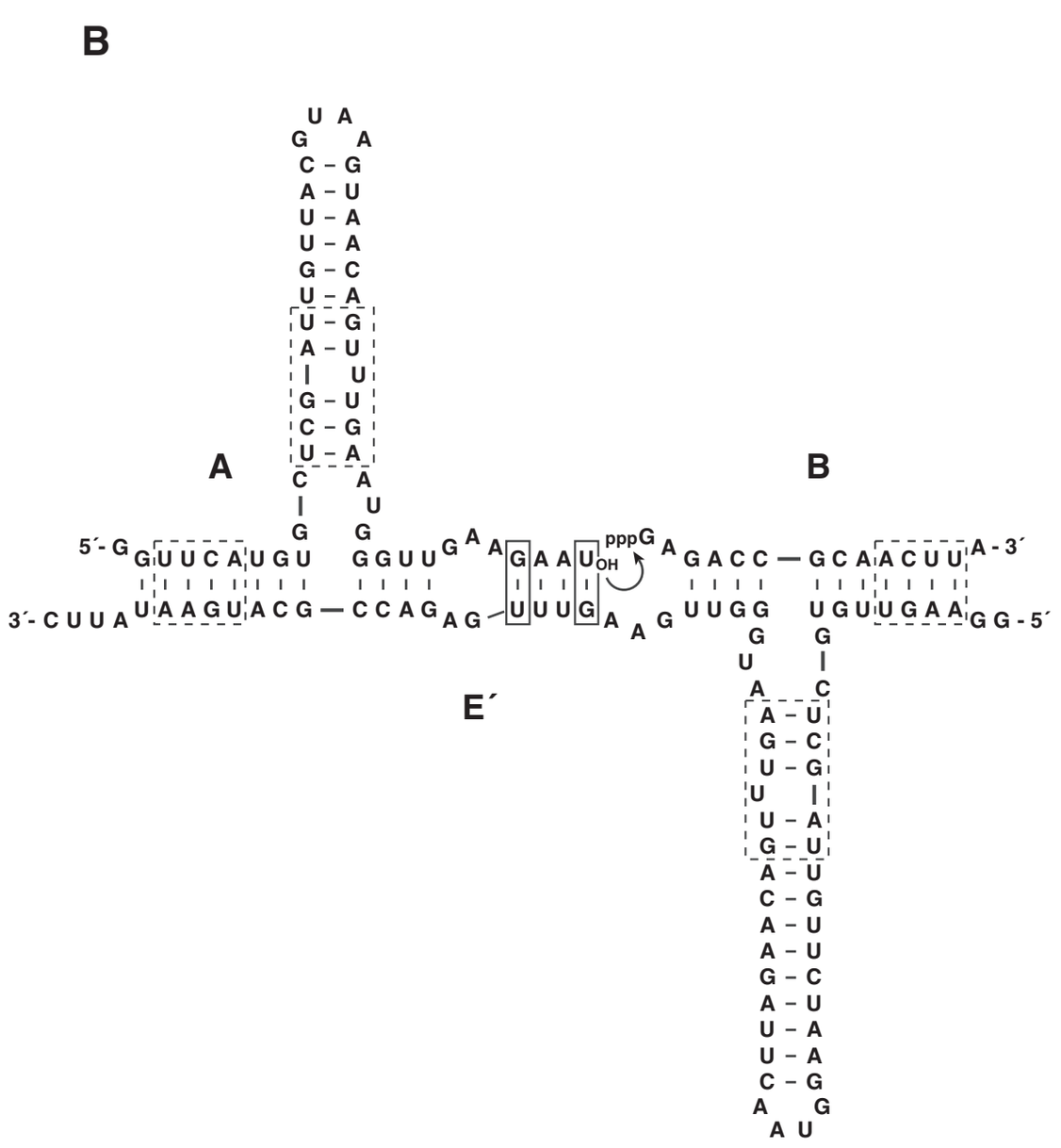


Self-Sustained Replication of an RNA Enzyme

Tracey A. Lincoln and Gerald F. Joyce*

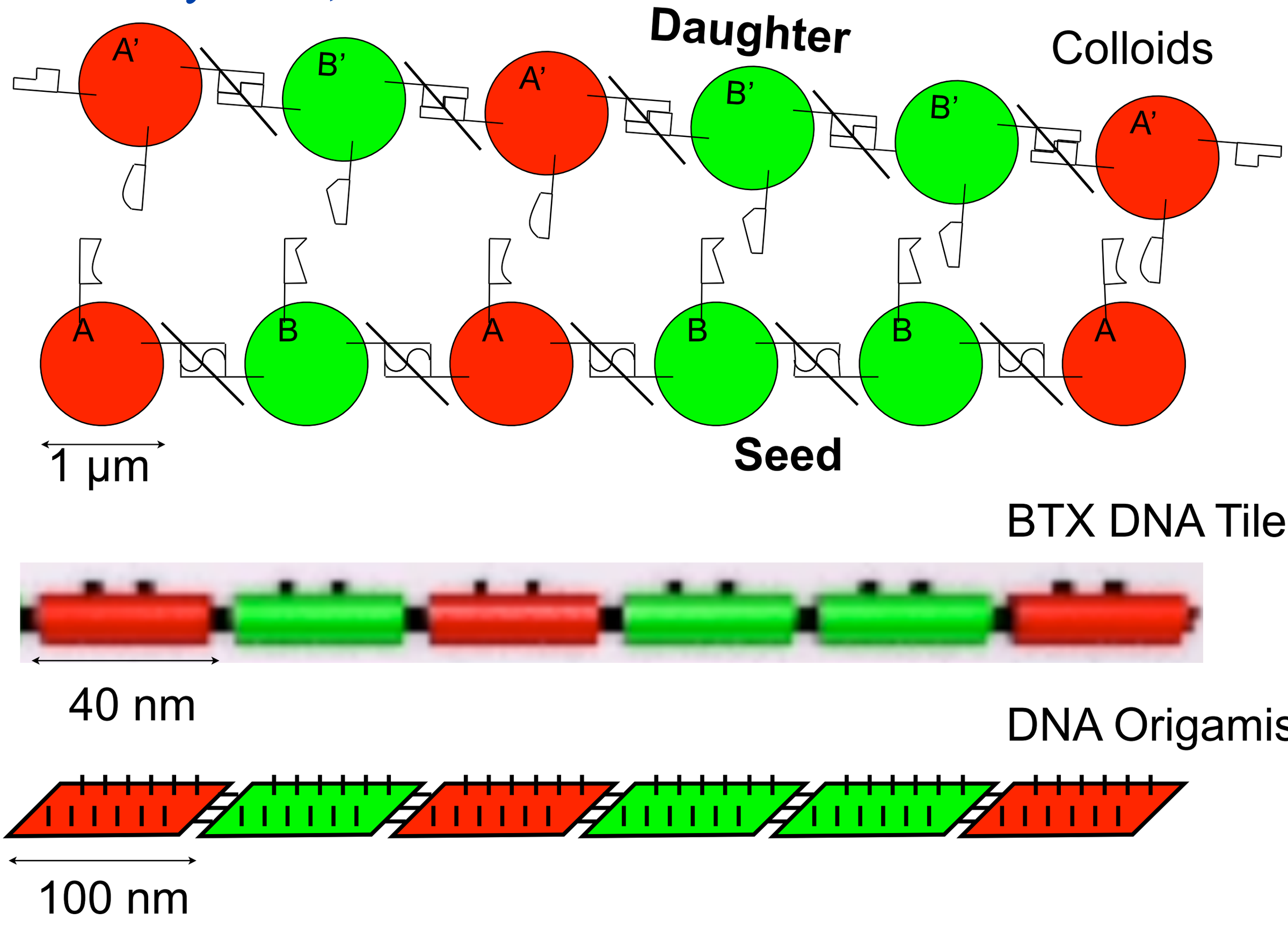
SCIENCE, 323, 1229, 2009





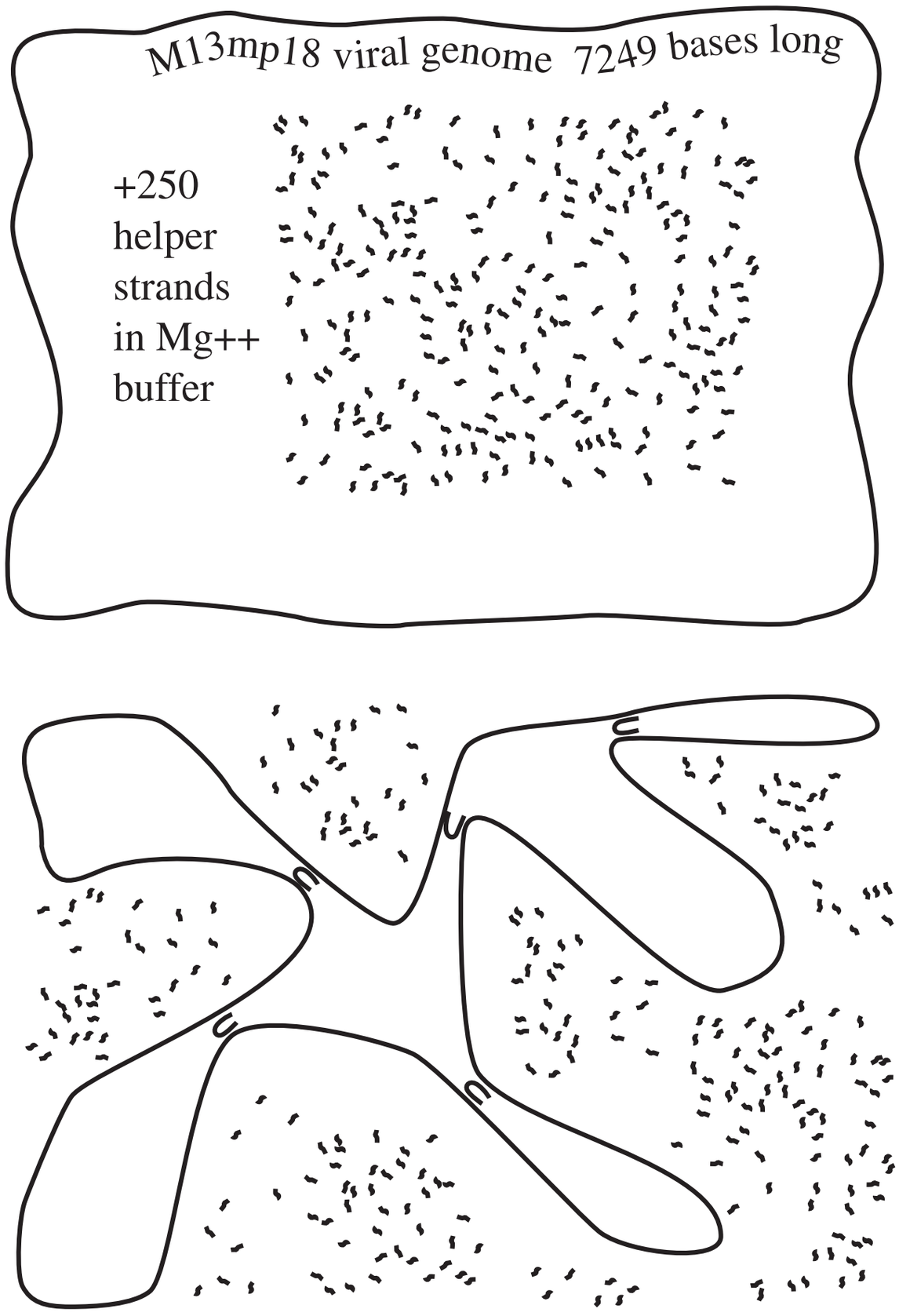
Why don't we try two tiles? And do it with Origamis

Different systems, same idea



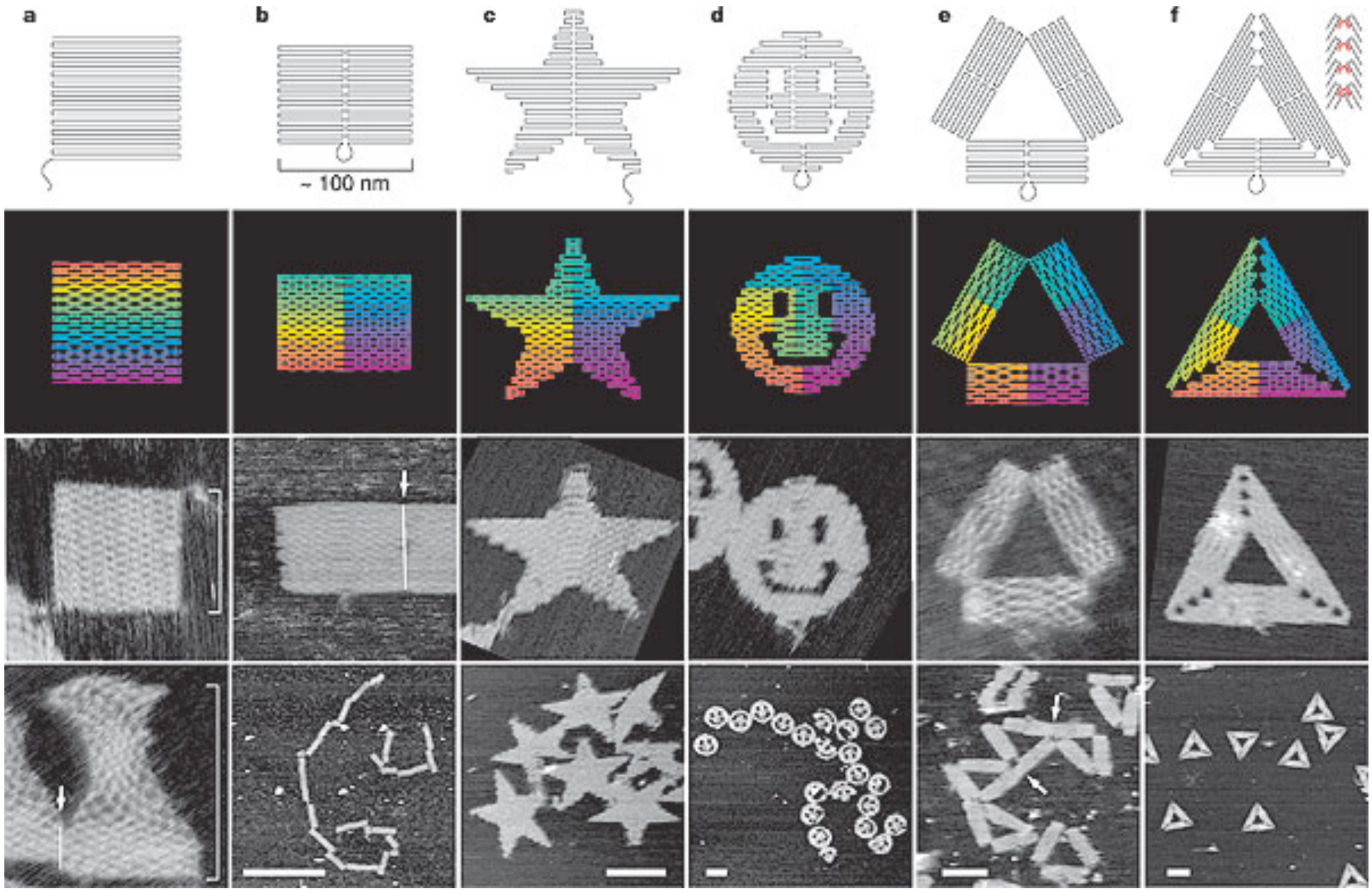
Design of DNA origami

Paul W.K. Rothemund
Computer Science and Computation and Neural Systems
California Institute of Technology, Pasadena, CA 91125
pwkr@dna.caltech.edu

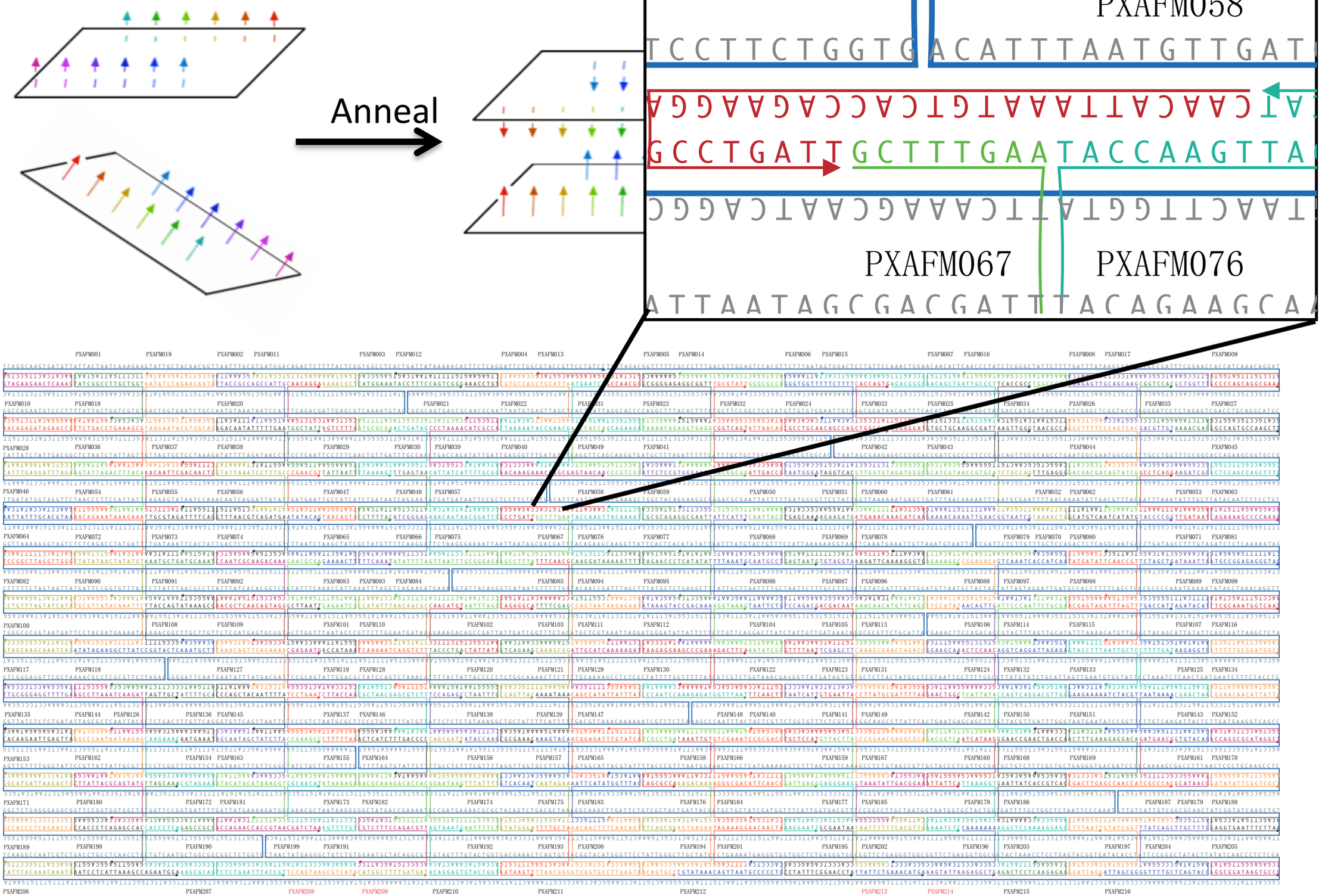


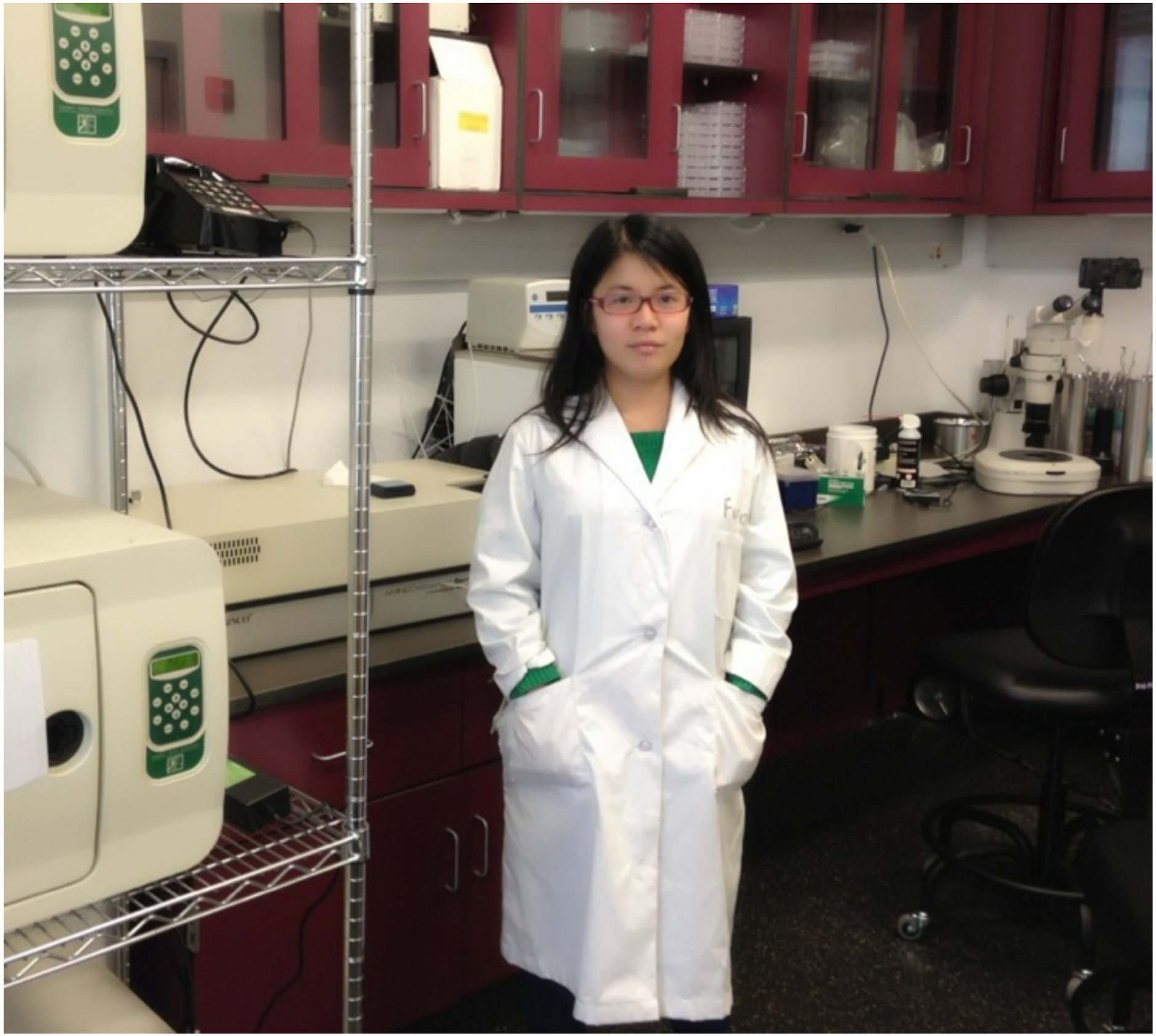
Proceeding
ICCAD '05 Proceedings of the 2005 IEEE/ACM International conference on Computer-aided design
Pages 471-478

Rothemund's DNA Origamis



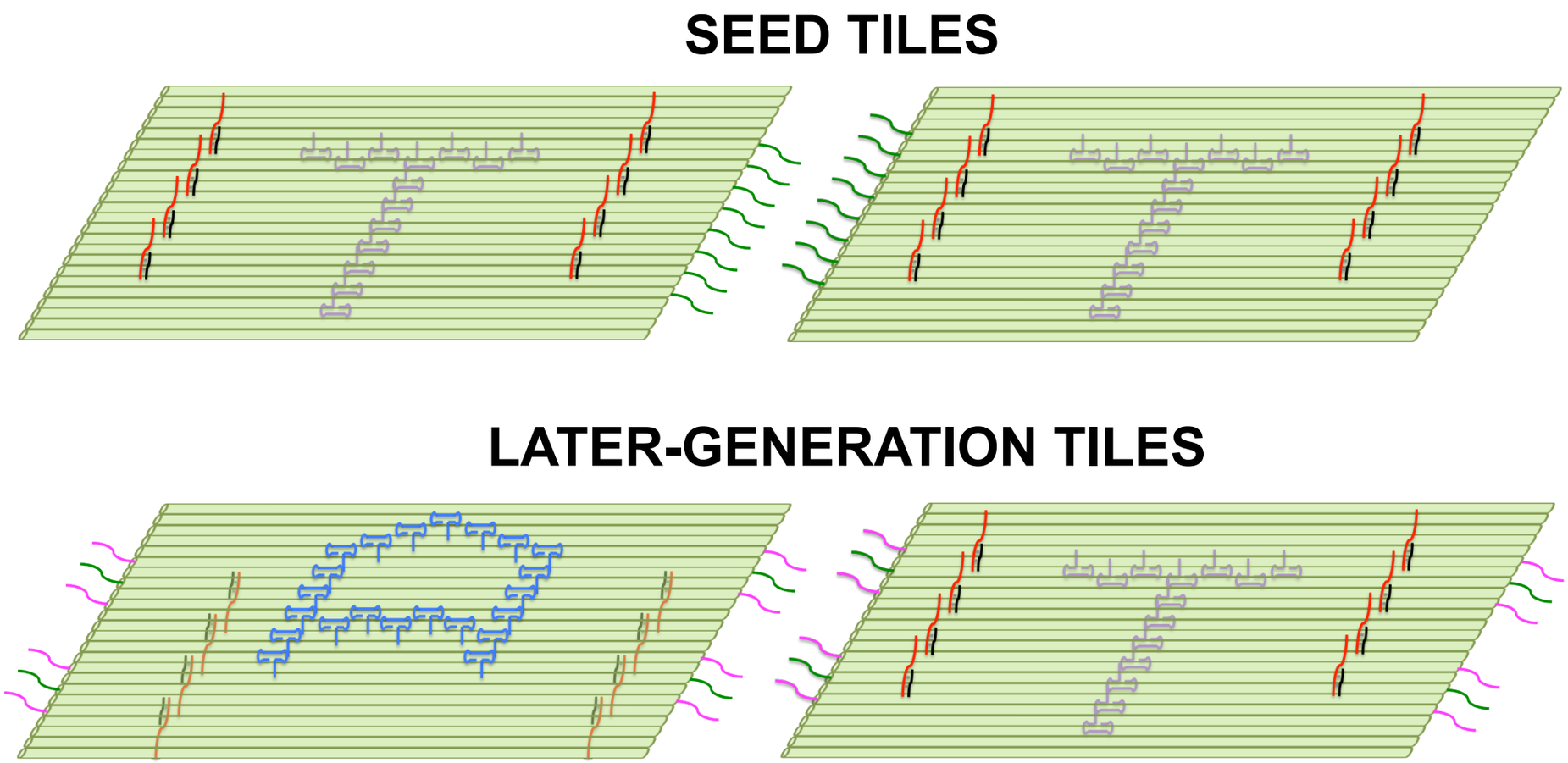
DNA Origami Desig

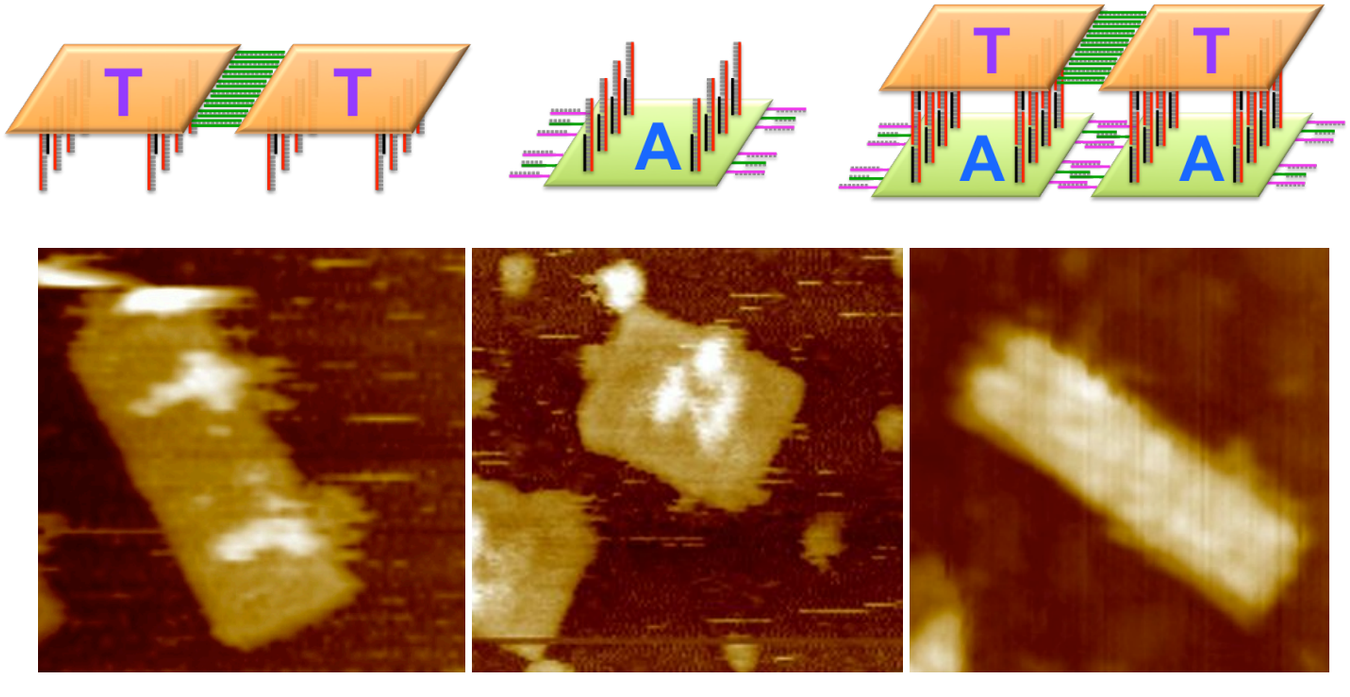




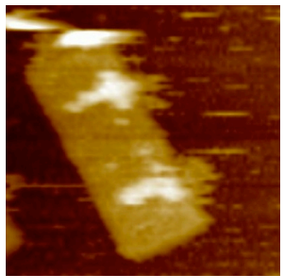
Xiaojin He HKUST/NYU

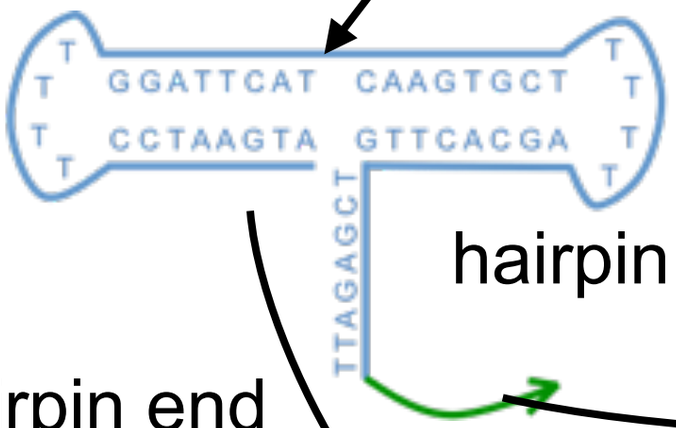
Basic tile set for self-replication





Labelling with letter “T”





hairpin dot

hairpin end

staple end

T-050	ATGAATCCTTTTGGATTCATCAAGTGCTTTTTAGCACTTGTCGAGATTCAGCAAATCGGTCAGT
T-051	ATGAATCCTTTTGGATTCATCAAGTGCTTTTTAGCACTTGTCGAGATTTAGGTCACAATAGGAAC GCCATCATGAGCAAA
T-059	ATGAATCCTTTTGGATTCATCAAGTGCTTTTTAGCACTTGTCGAGATTGGCGAATTAATATATGT GAGTGAATAGAACCC
T-077	ATGAATCCTTTTGGATTCATCAAGTGCTTTTTAGCACTTGTCGAGATTTCATATATAAGCCTCAG AGCATAAATAAAGTA
T-095	ATGAATCCTTTTGGATTCATCAAGTGCTTTTTAGCACTTGTCGAGATTCCGACAAAAAAAATAAT ATCCCATTAAGAGGA
T-112	ATGAATCCTTTTGGATTCATCAAGTGCTTTTTAGCACTTGTCGAGATTAGCCCGAAATAAAAACC AAAATAGCCCAATCC
T-130	ATGAATCCTTTTGGATTCATCAAGTGCTTTTTAGCACTTGTCGAGATTAAAGAGATGGTTTAAT
T-158	ATGAATCCTTTTGGATTCATCAAGTGCTTTTTAGCACTTGTCGAGATTTAAATTGTTCCATTAAA CGGGTAACAGCGCCA
T-176	ATGAATCCTTTTGGATTCATCAAGTGCTTTTTAGCACTTGTCGAGATTAAGACAAACGTAATCAG TAGCGACTTCAGCGG

b

CNVK

T

366 nm

CNVK

T

NC

O

NH

N

O

$R_3'O$

O

N

O

$R_3'O$

$OR_{3'}$

366 nm

NC

O

NH

N

O

$R_3'O$

N

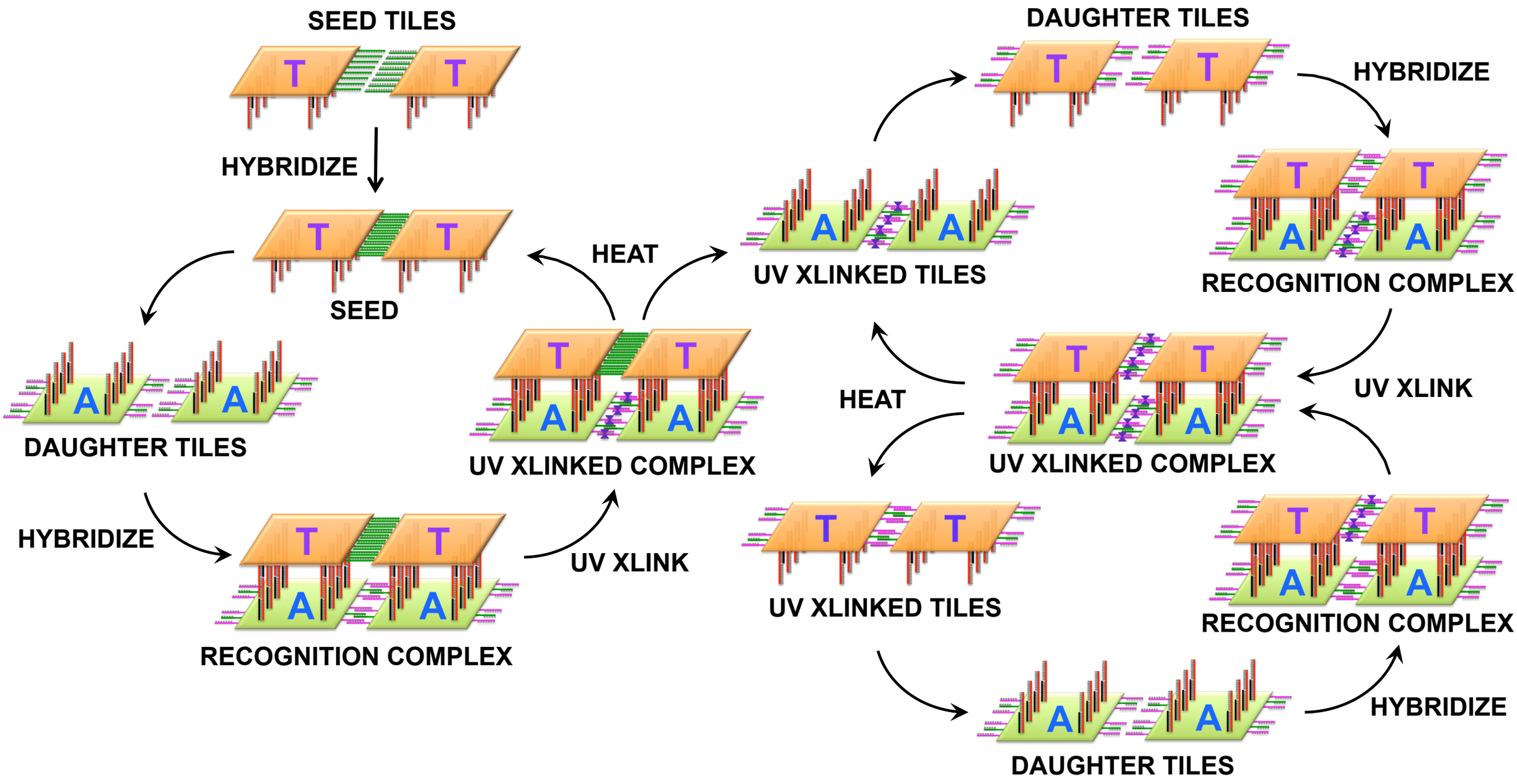
O

O

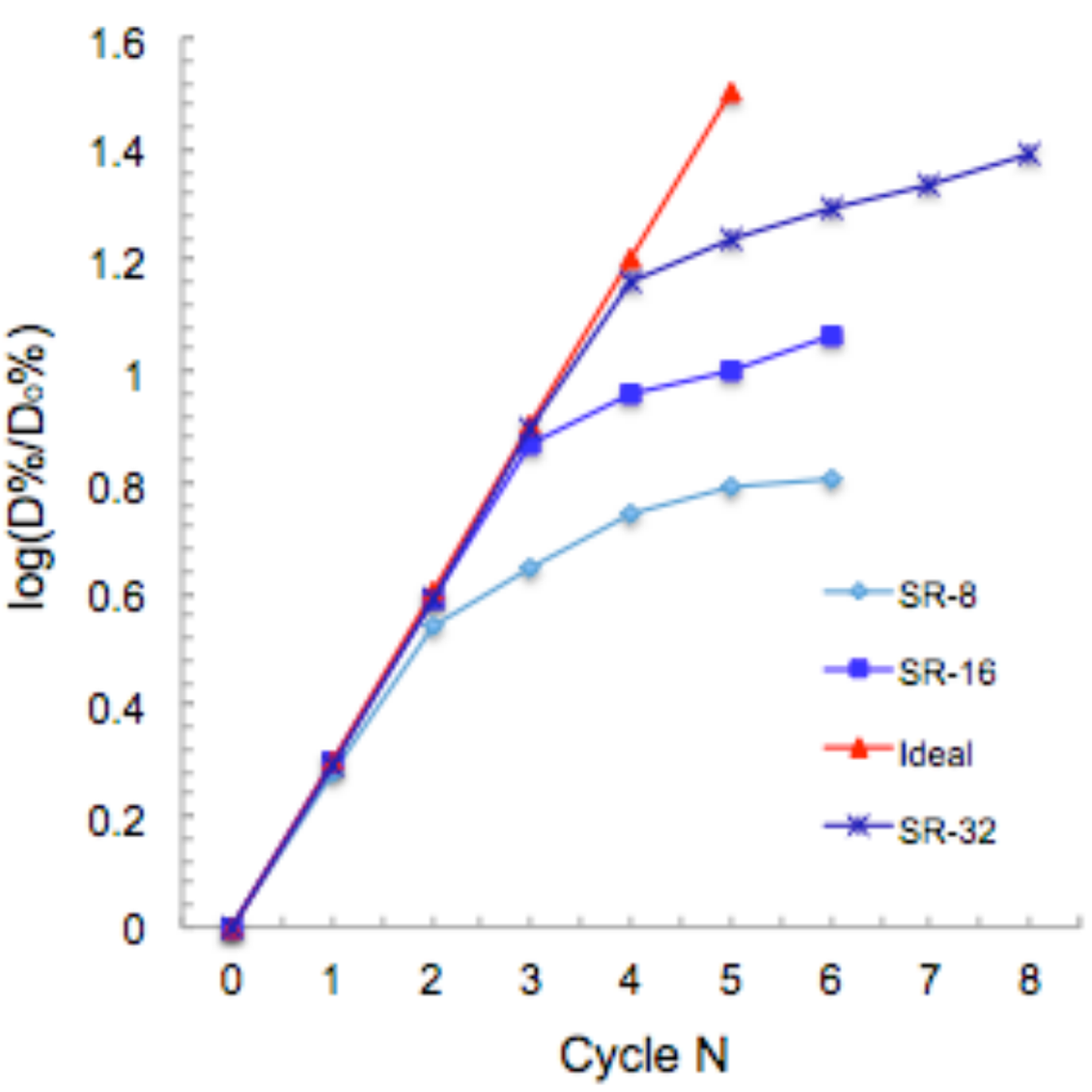
$R_3'O$

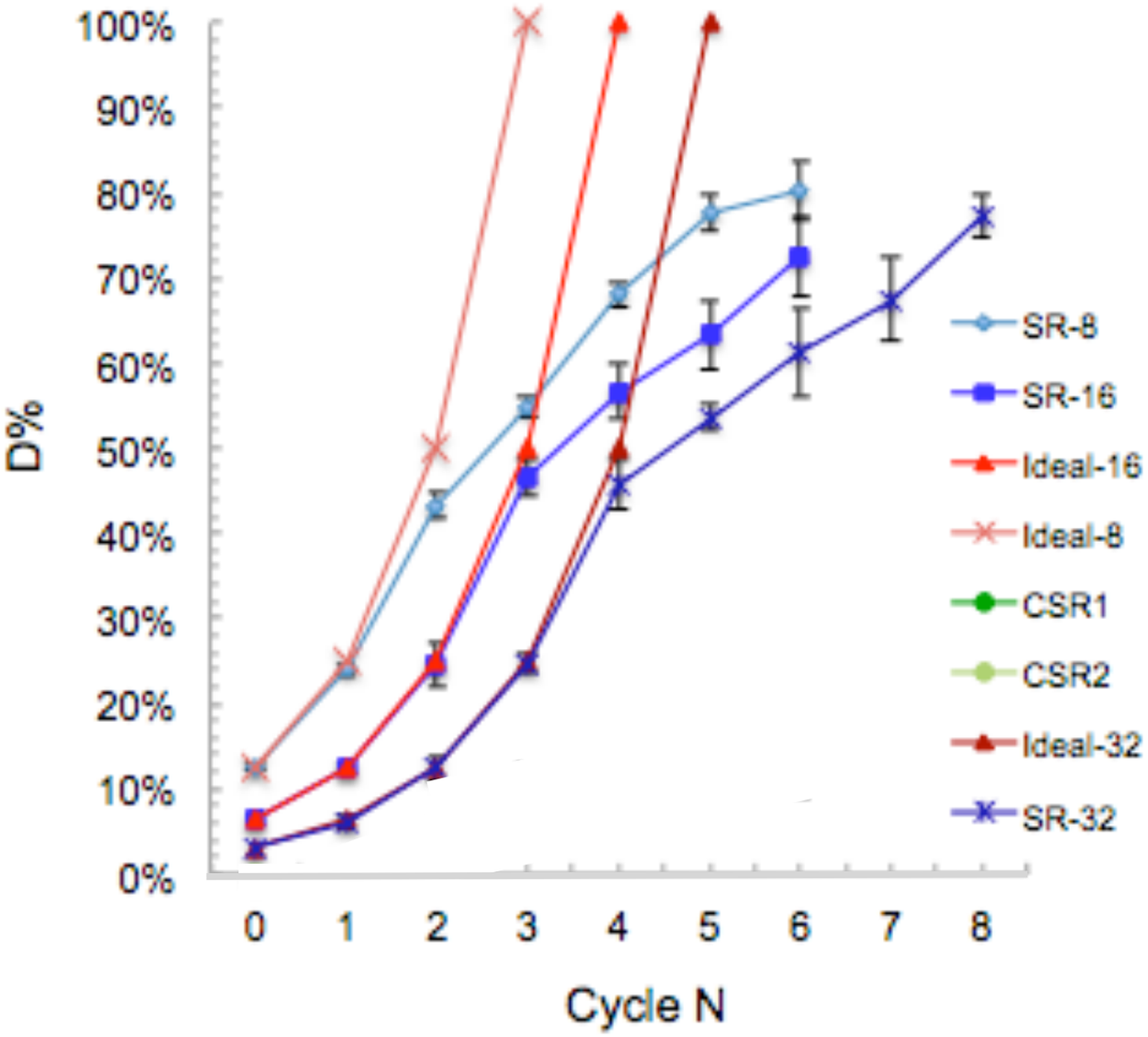
$OR_{3'}$

Replication cycles - cool/UV/heat -repeat



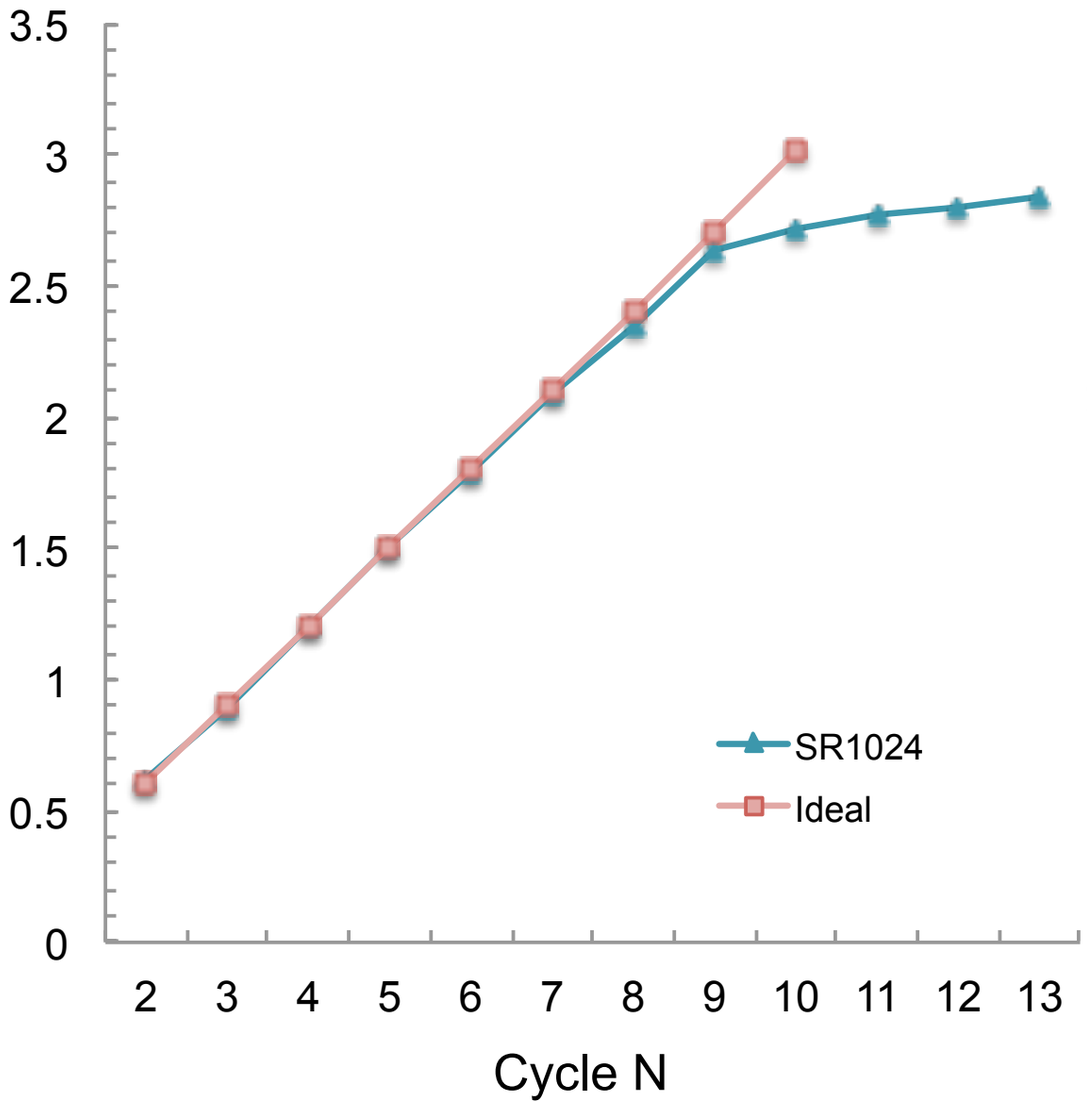
Number of Dimers Doubles each cycle!

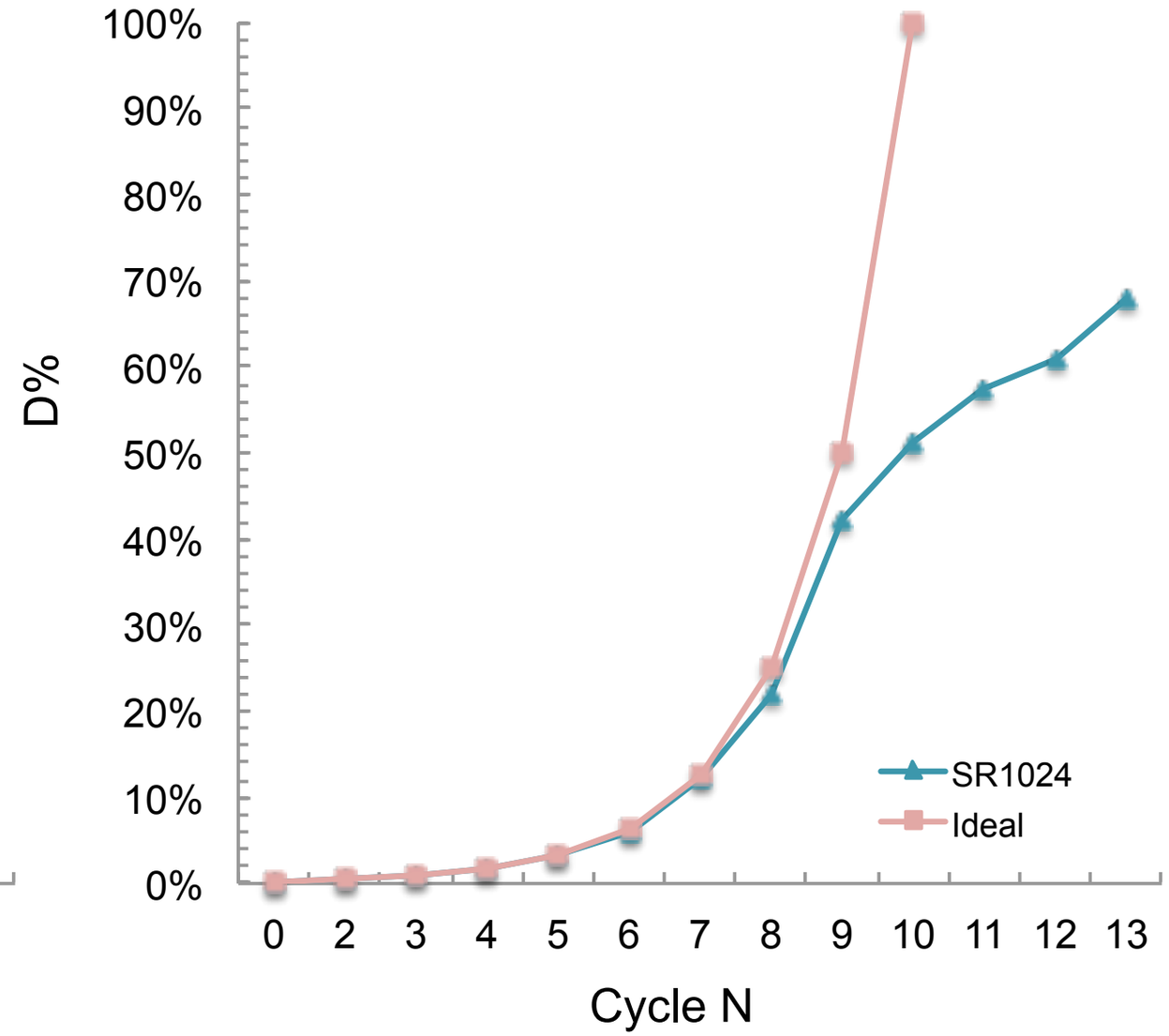




Here’s 500X multiplication of seed

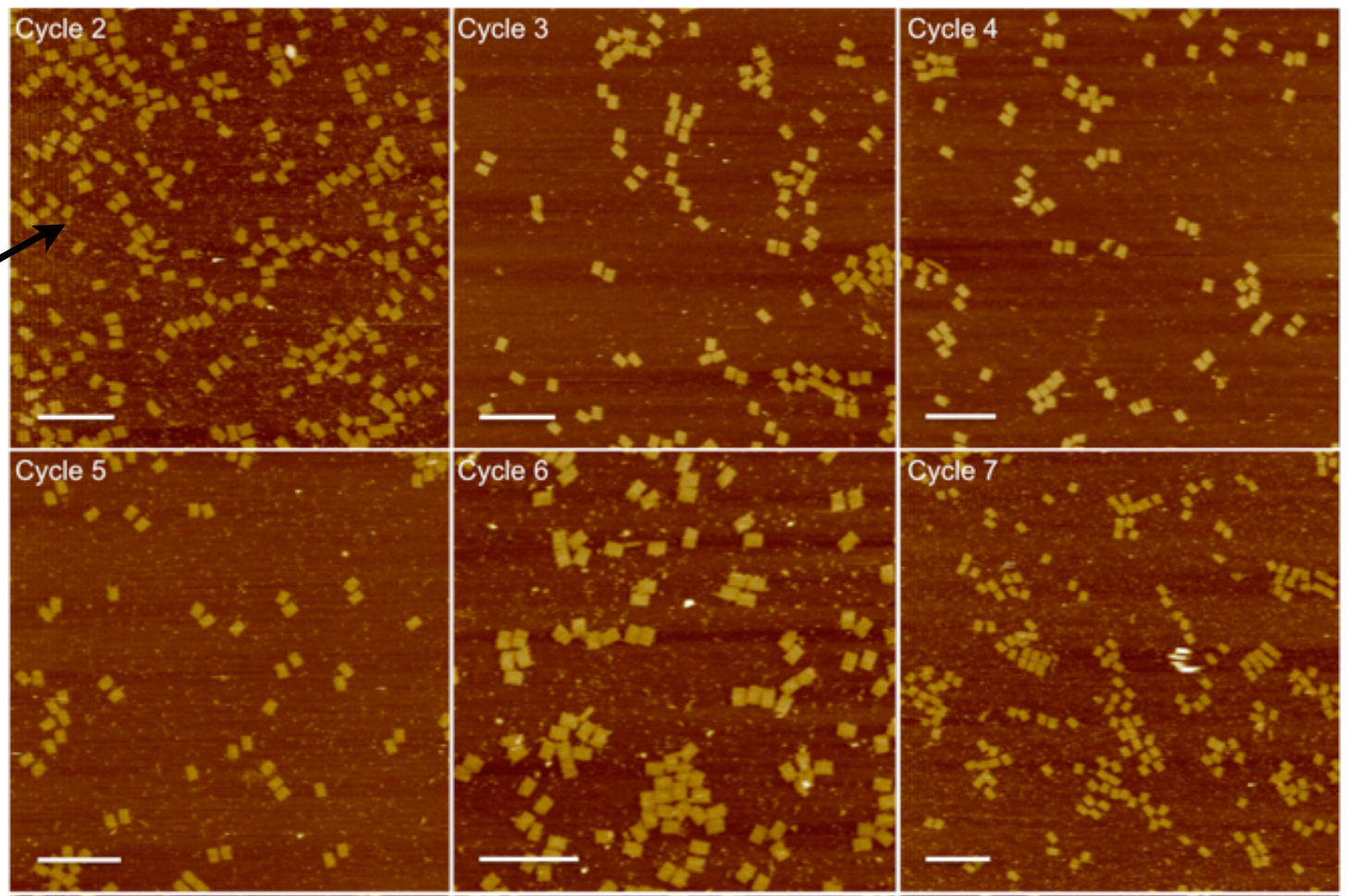
Self-Replication Plot (1:1024)



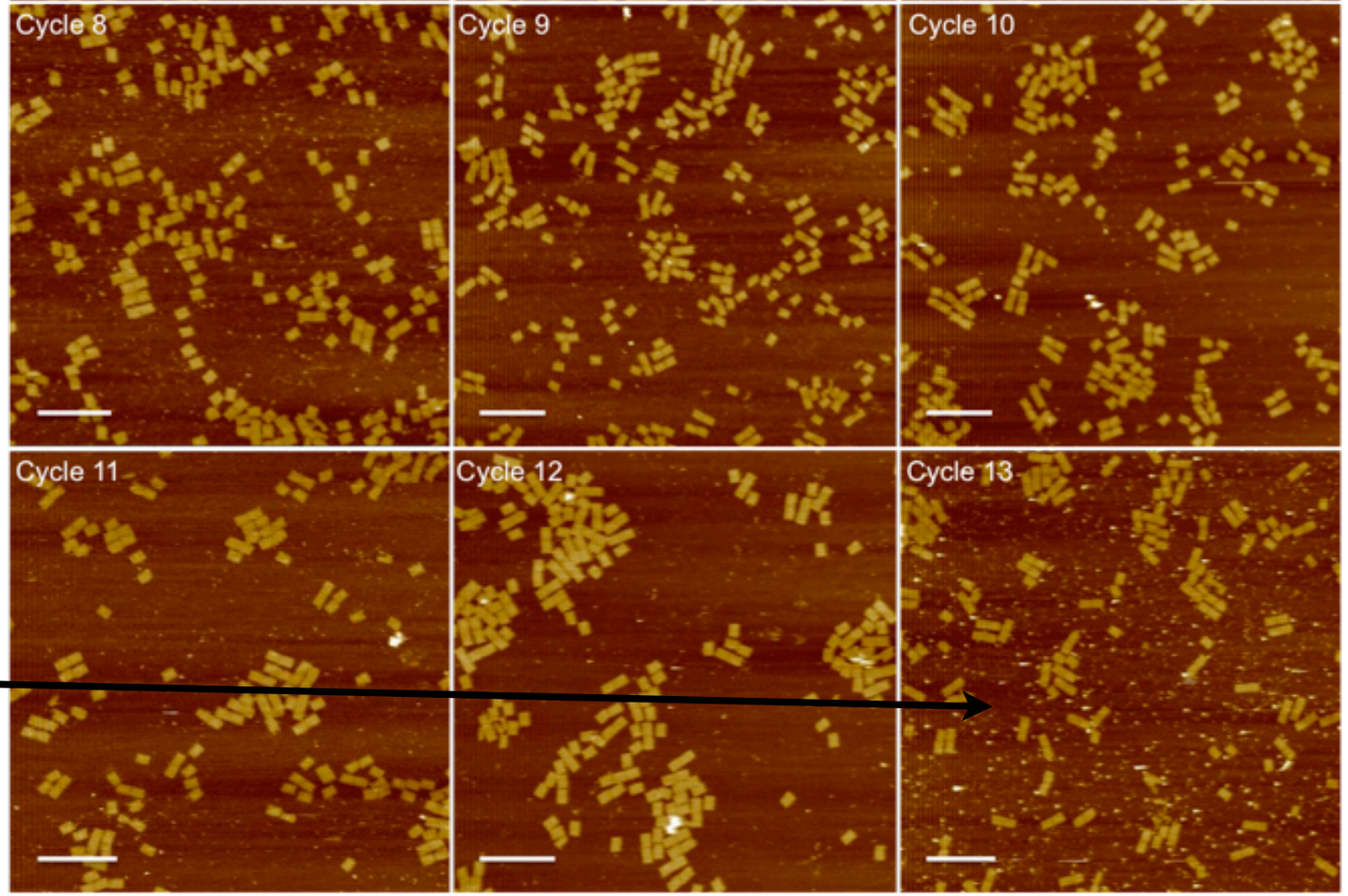


AFM Images of 1024 replication

mostly single tiles

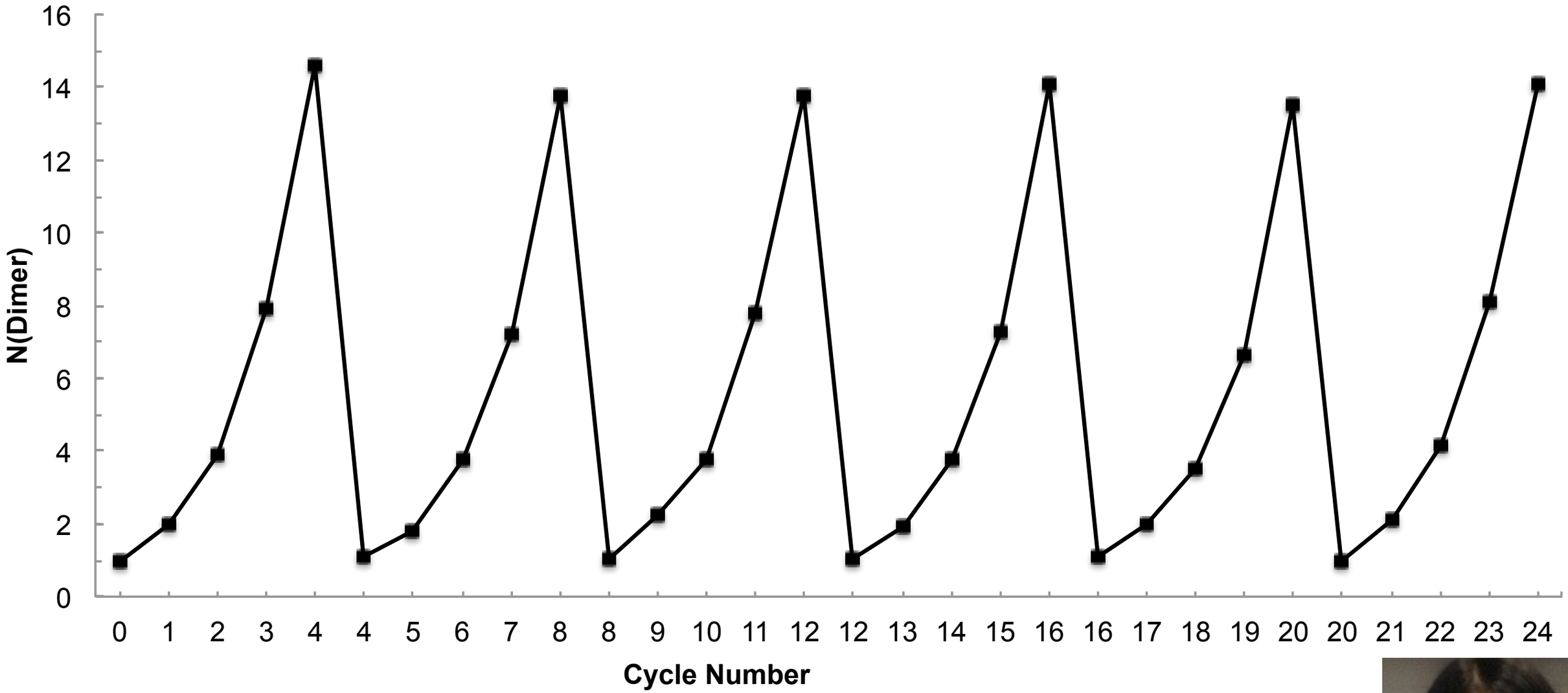


mostly dimer tiles



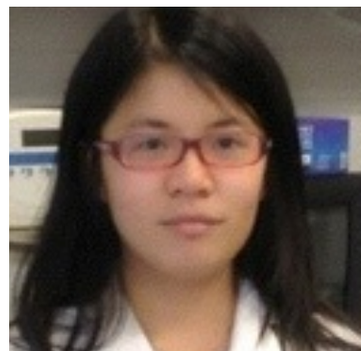
Replication by Serial Dilution

- 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.

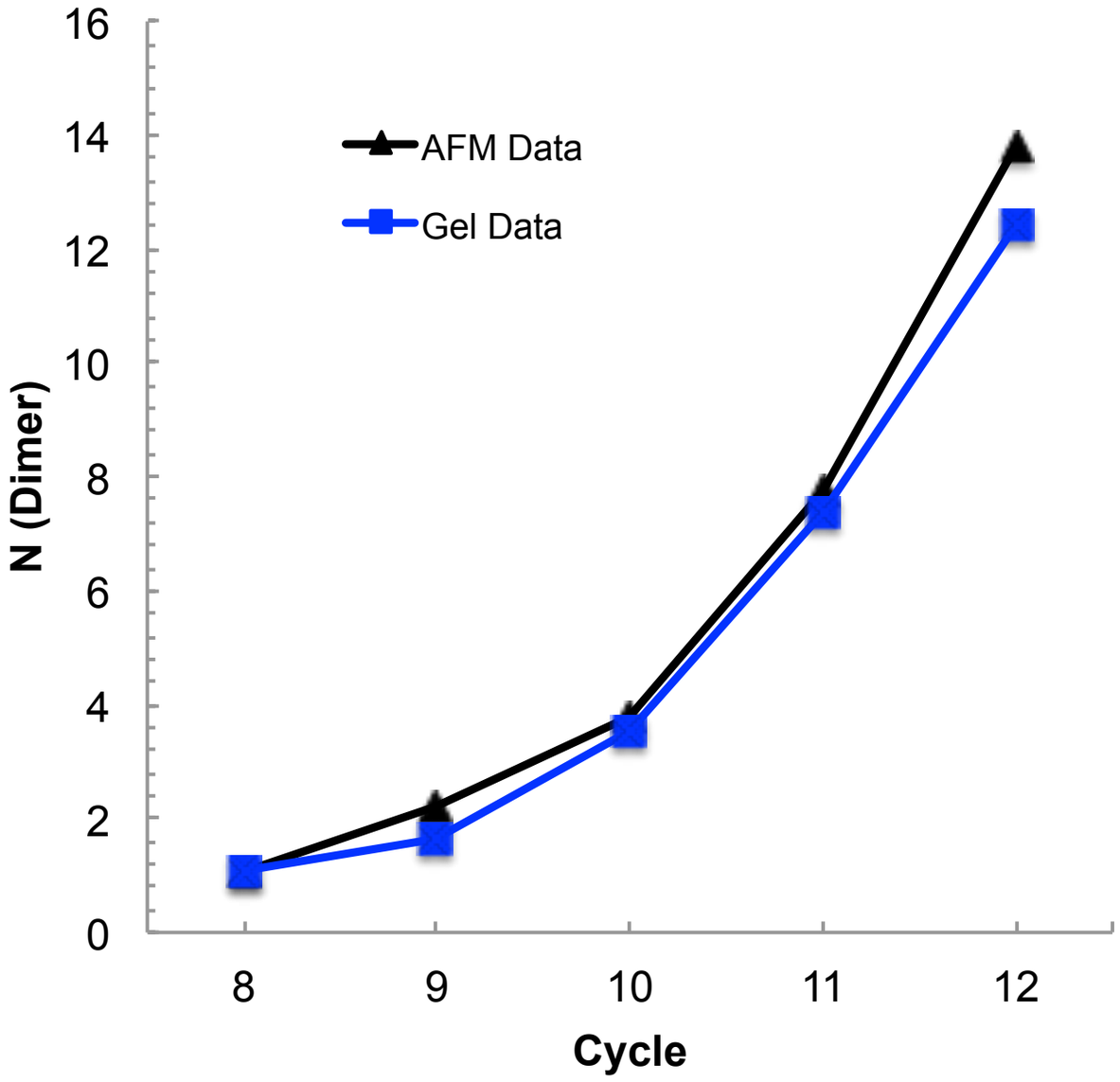


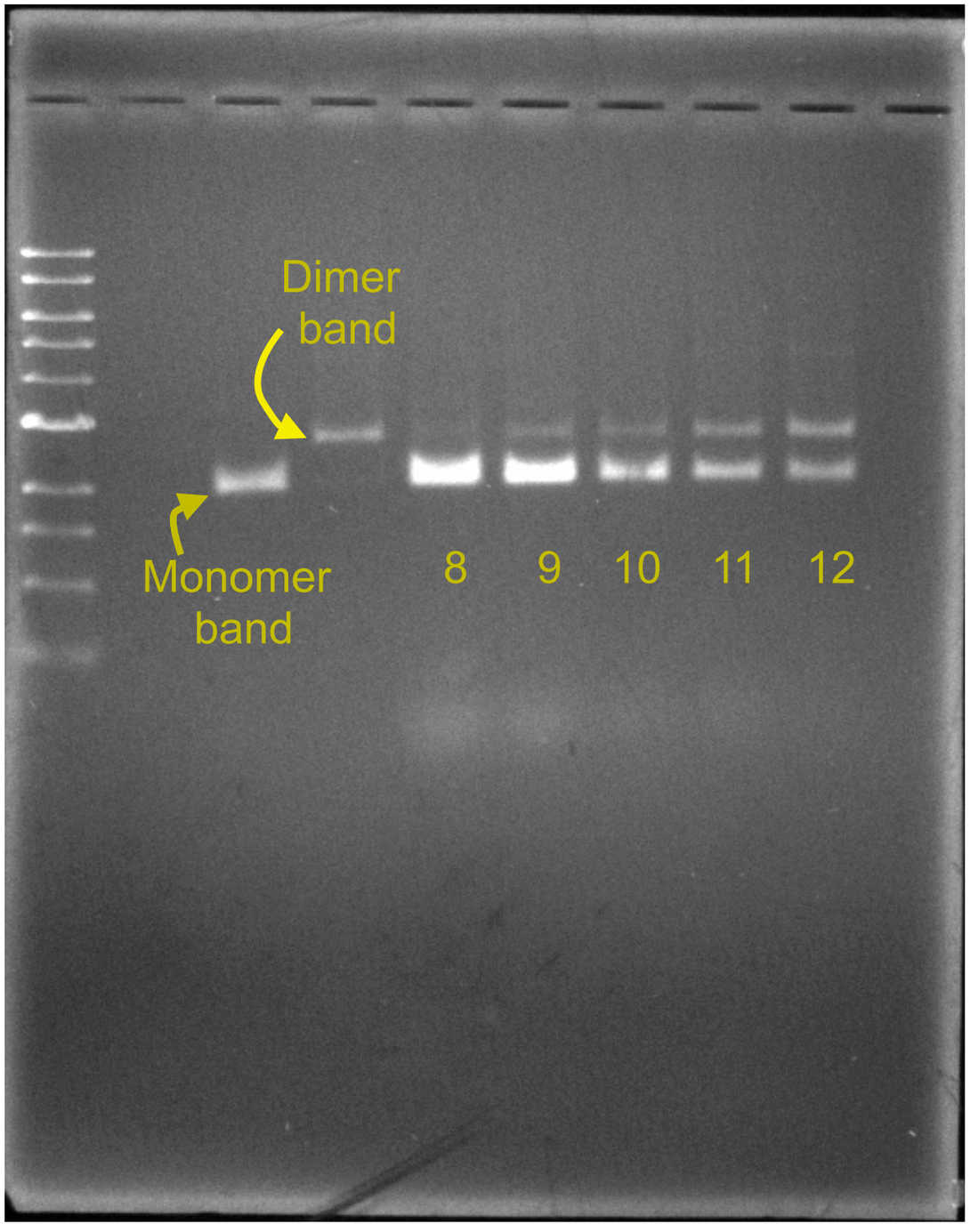
Total Amplification 7.5 million

Xiaojin He

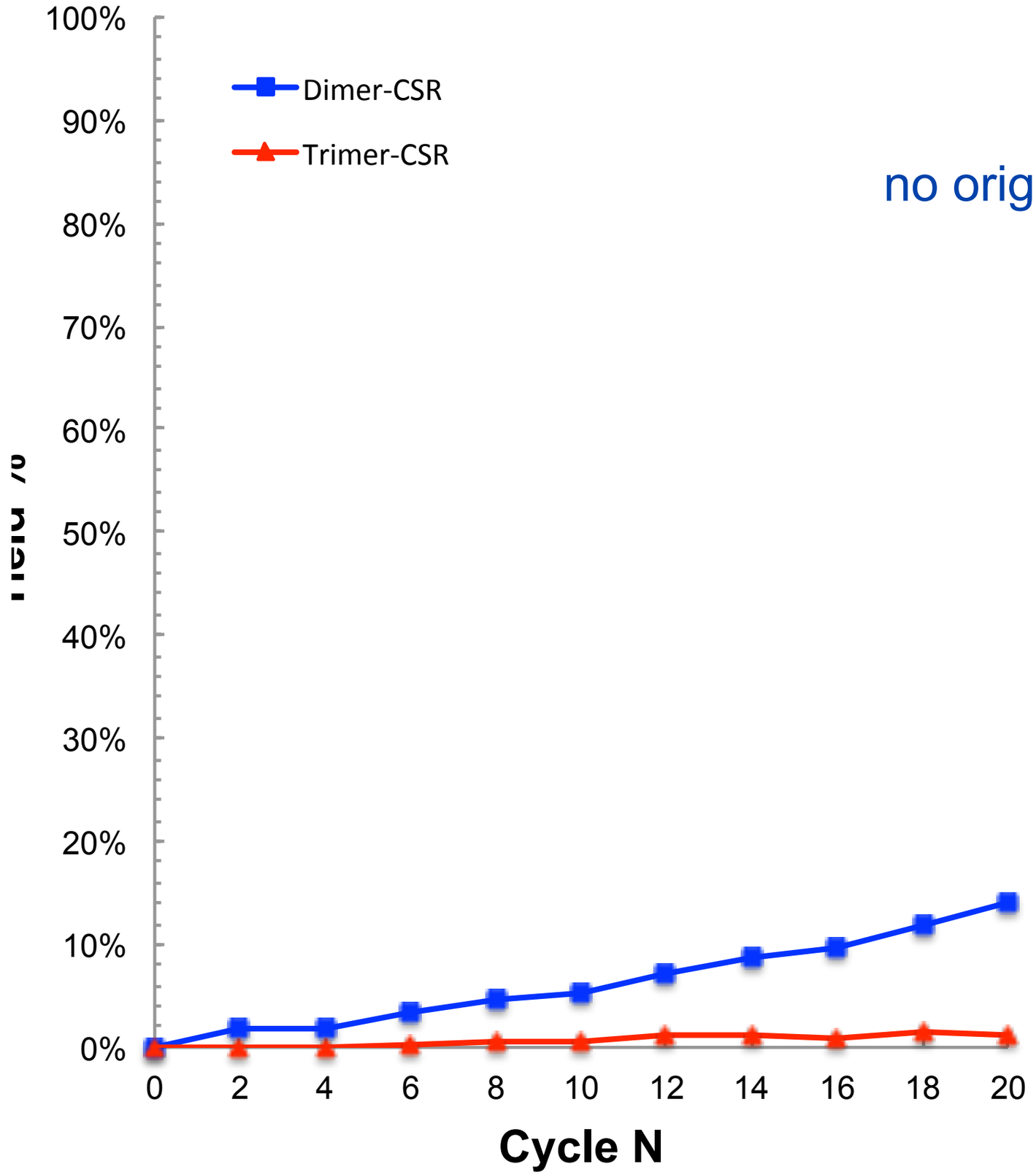


Gel analysis shows same growth as counting Origami





Temperature and light cycles
NO SEED



no origin of life *yet*

Evolution - Wikipedia, the free encyclopedia

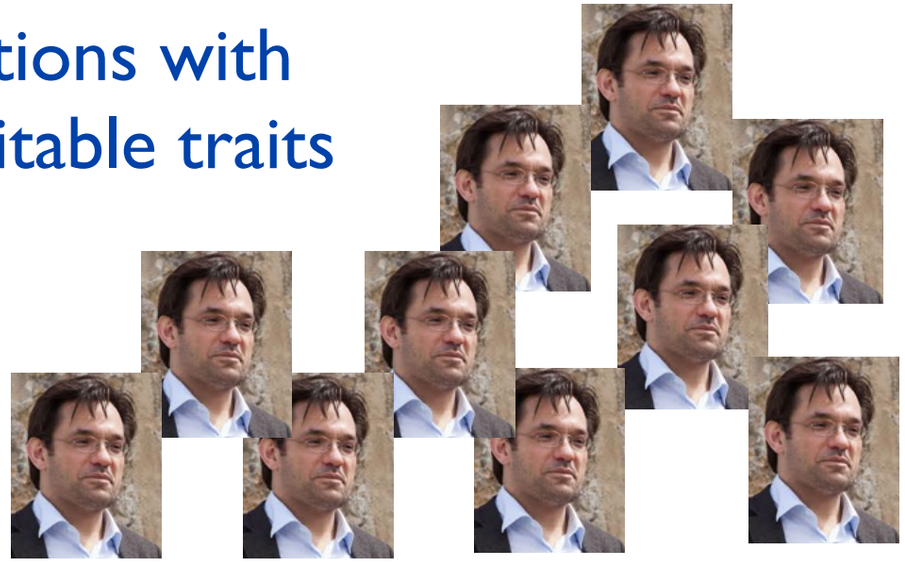
en.wikipedia.org/wiki/**Evolution**

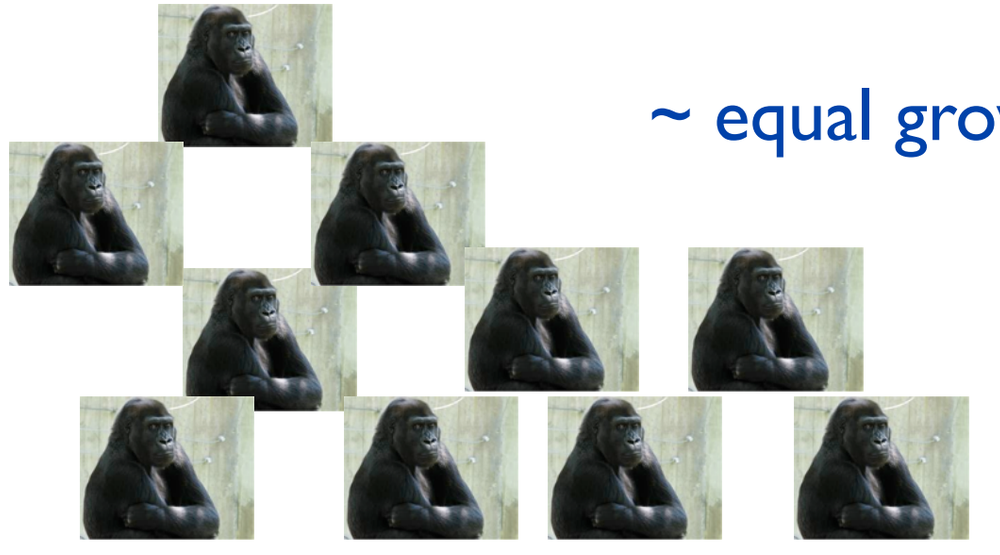
Evolution is the change in the inherited characteristics of biological populations over successive generations. **Evolutionary** processes give rise to diversity at ...

Schematic Evolution

Original Species

Mutations with inheritable traits





~ equal growth

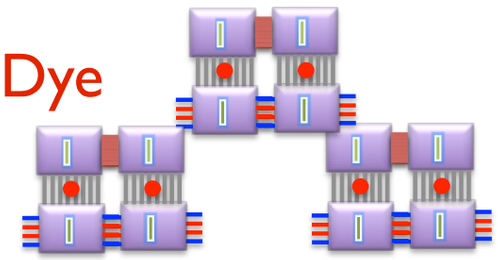
Environment Changes - Fire - need theory of Plasmas - advantage to one species

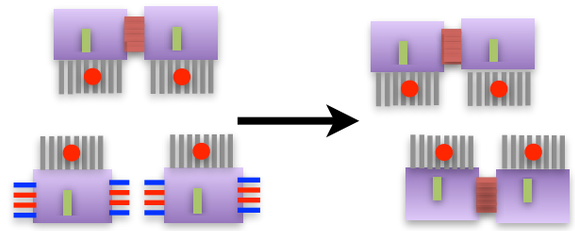
Environment Changes - advantage to one species
growth rate higher - species takes over

Red - Green Origami Evolution

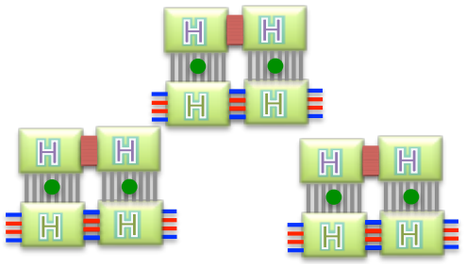
Original Species

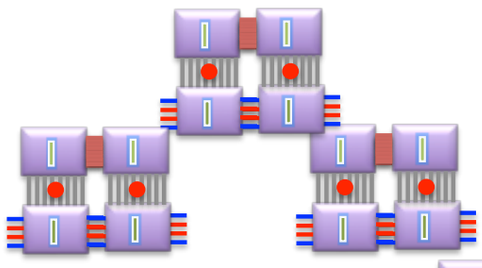
Red Dye





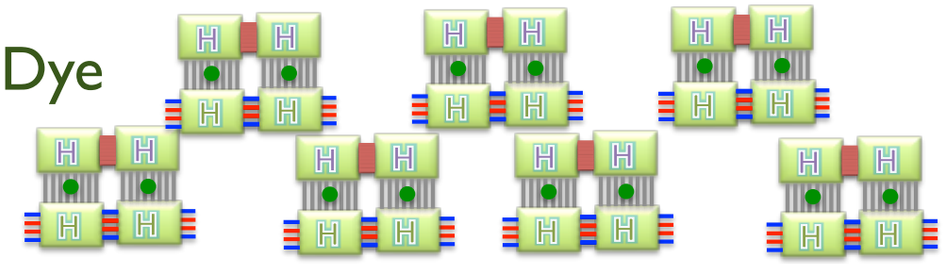
Mutations with inheritable traits

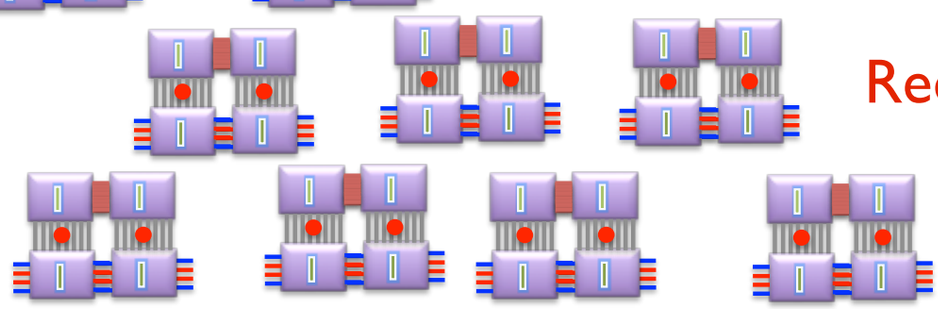




~ equal growth

Green Dye





Red Dye

Environment Changes - Red Light - advantage to one species

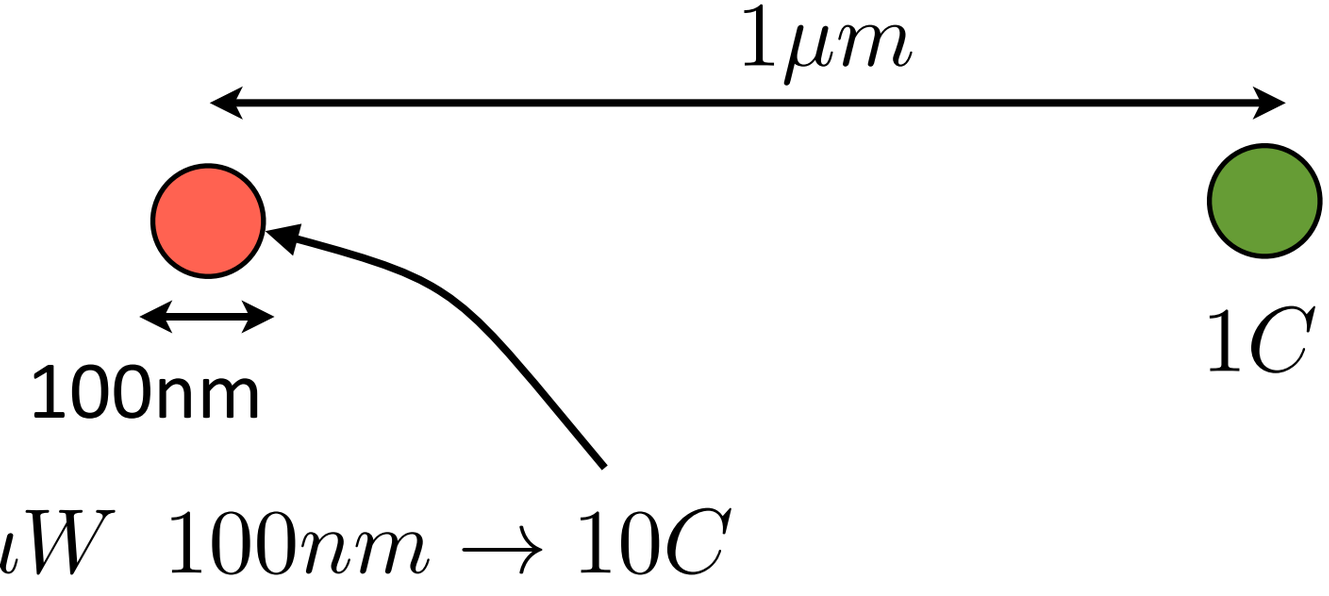
Selection - higher growth rate - Green takes over

Laser Heating of IR Dyes

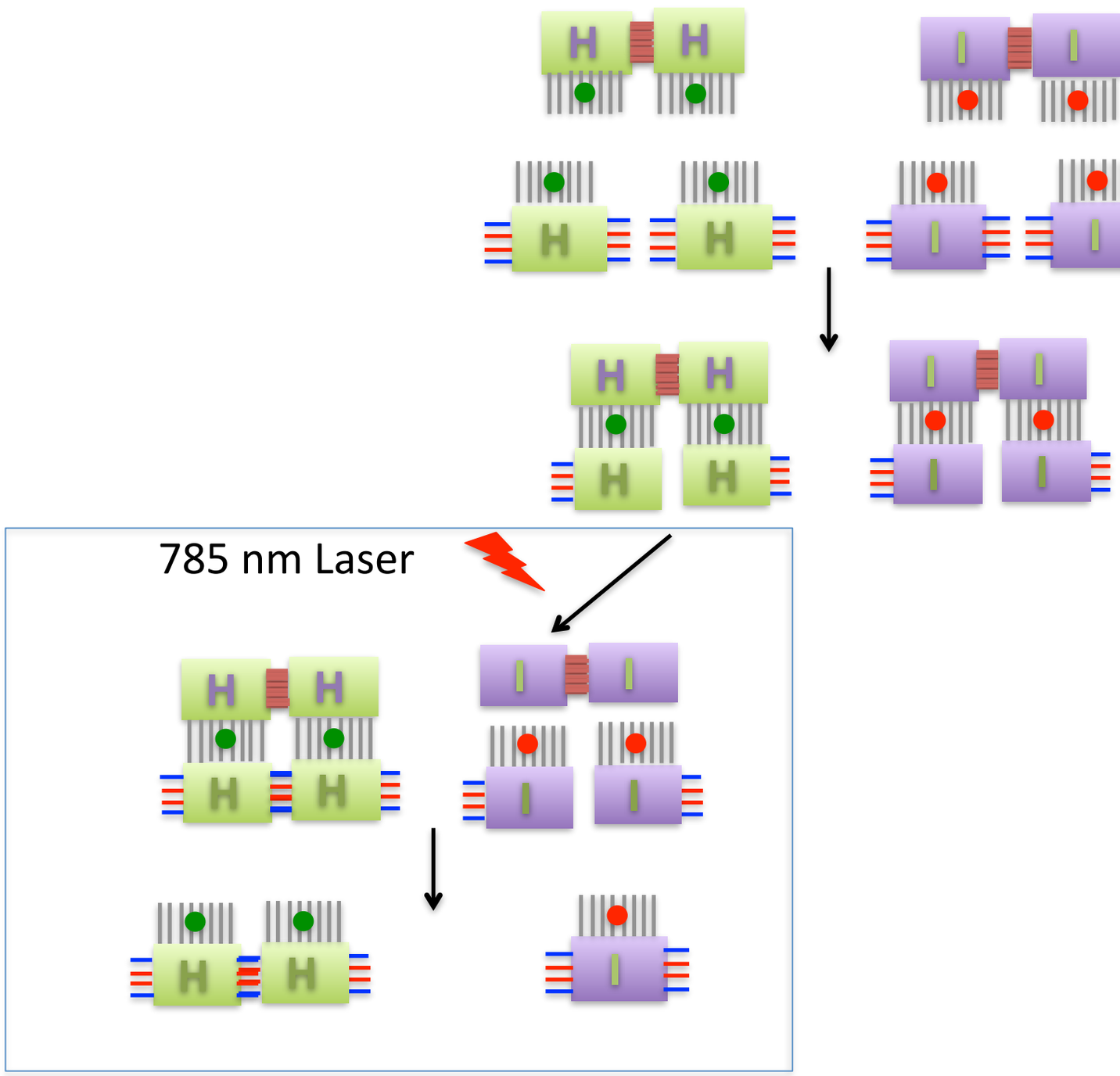
Local heating

$$j_Q \sim \frac{\dot{Q}}{4\pi r^2}$$

$$T = T_0 + \delta T / r$$

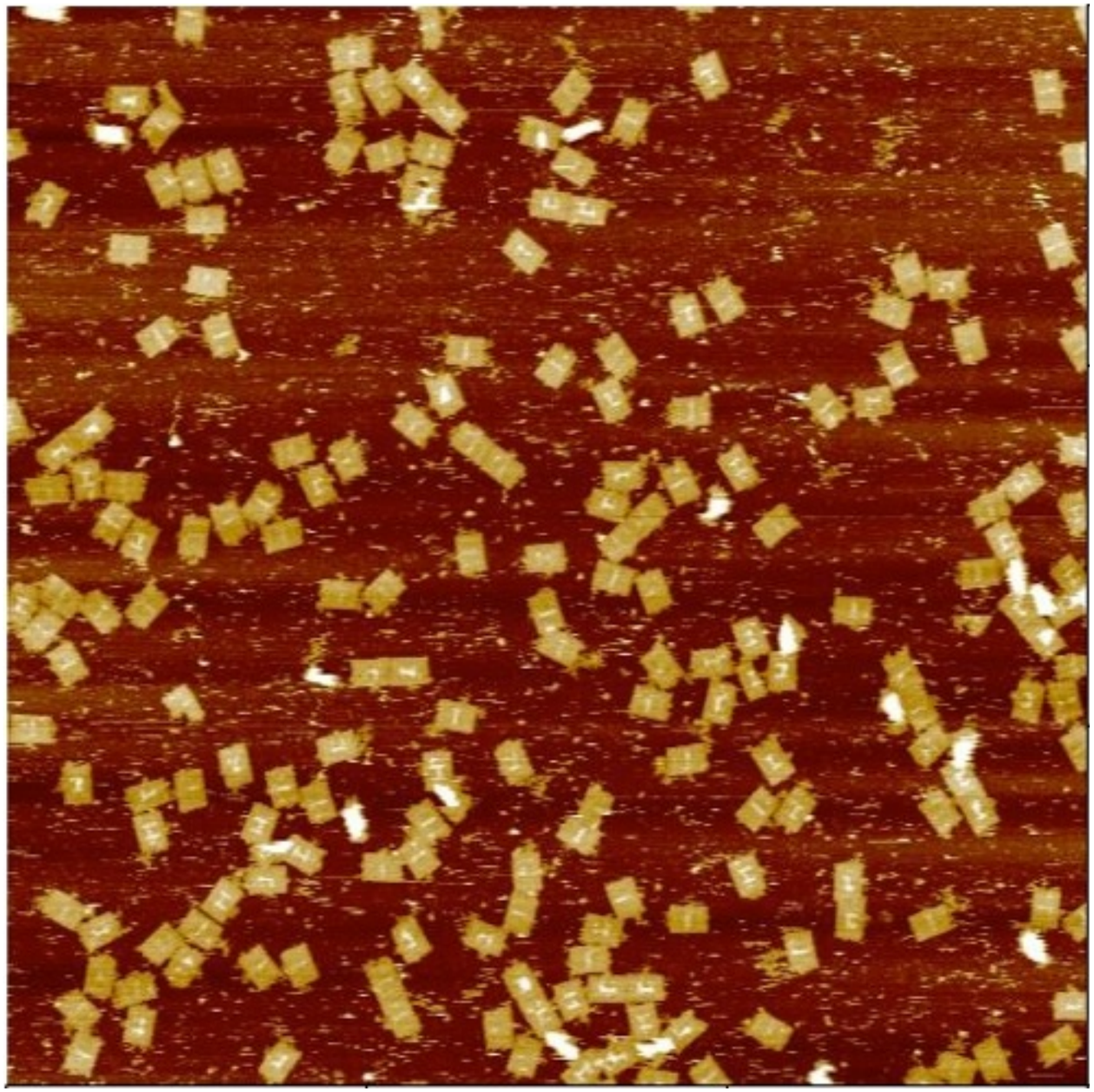


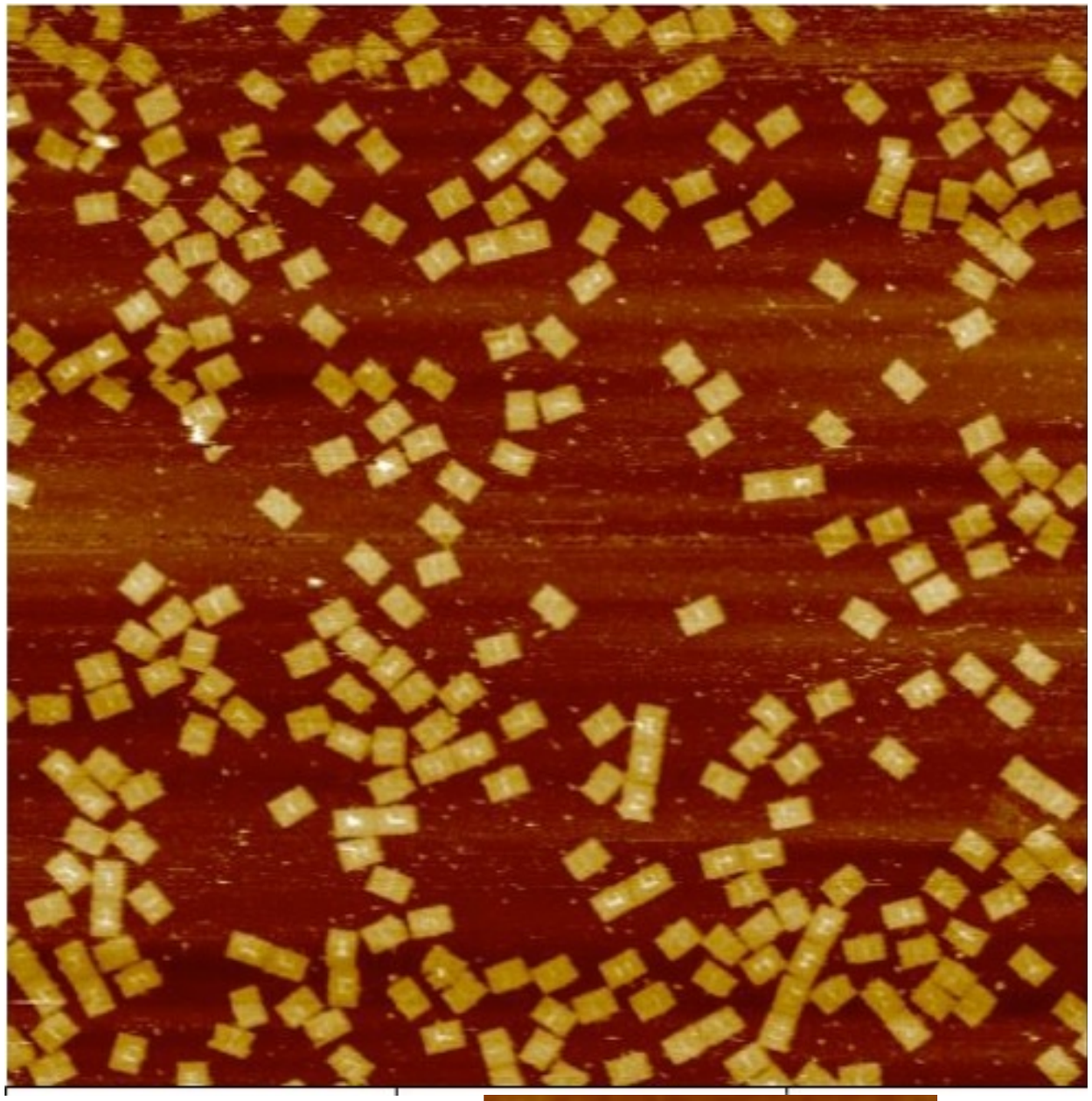
	Seed HH	FG H-2 IR700	SG H-1 IR700	Seed II	FG I-4 IR800	SG I-3 IR800
C 0	1	8	6	1	8	6

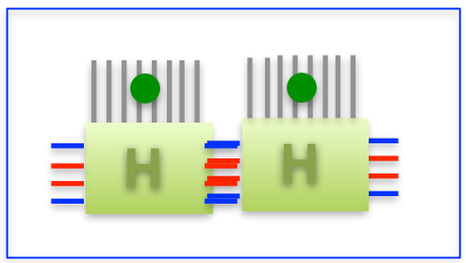


Cycle 2

Cycle 4



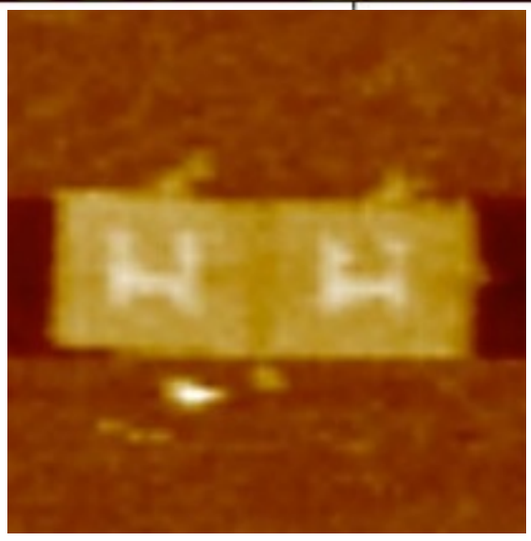


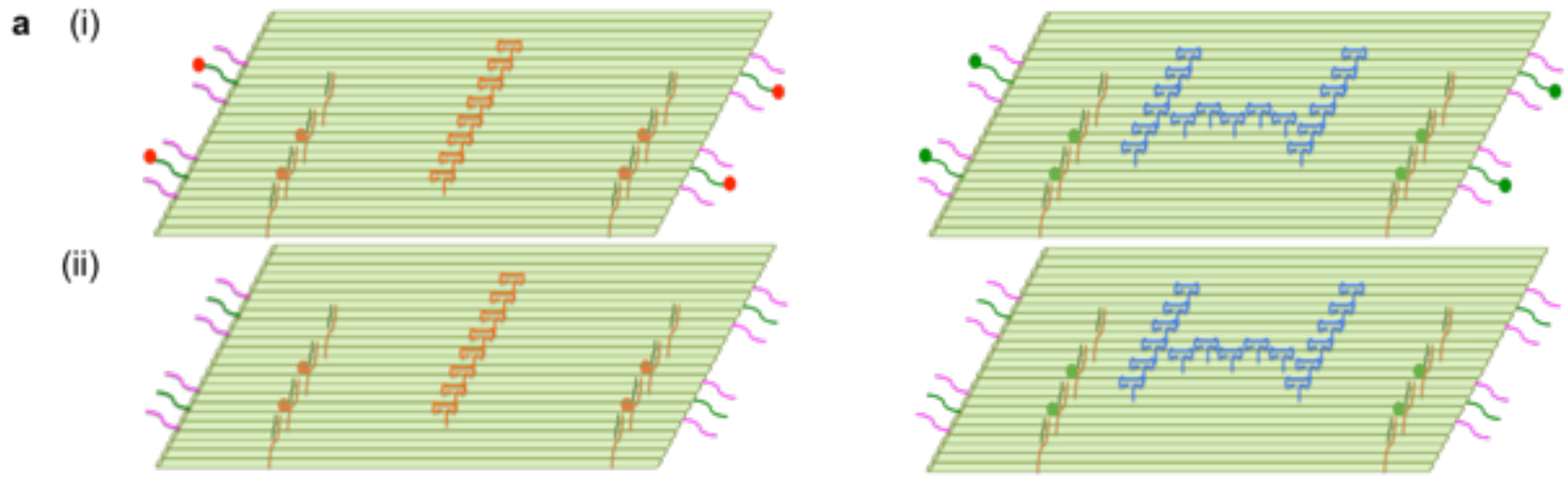


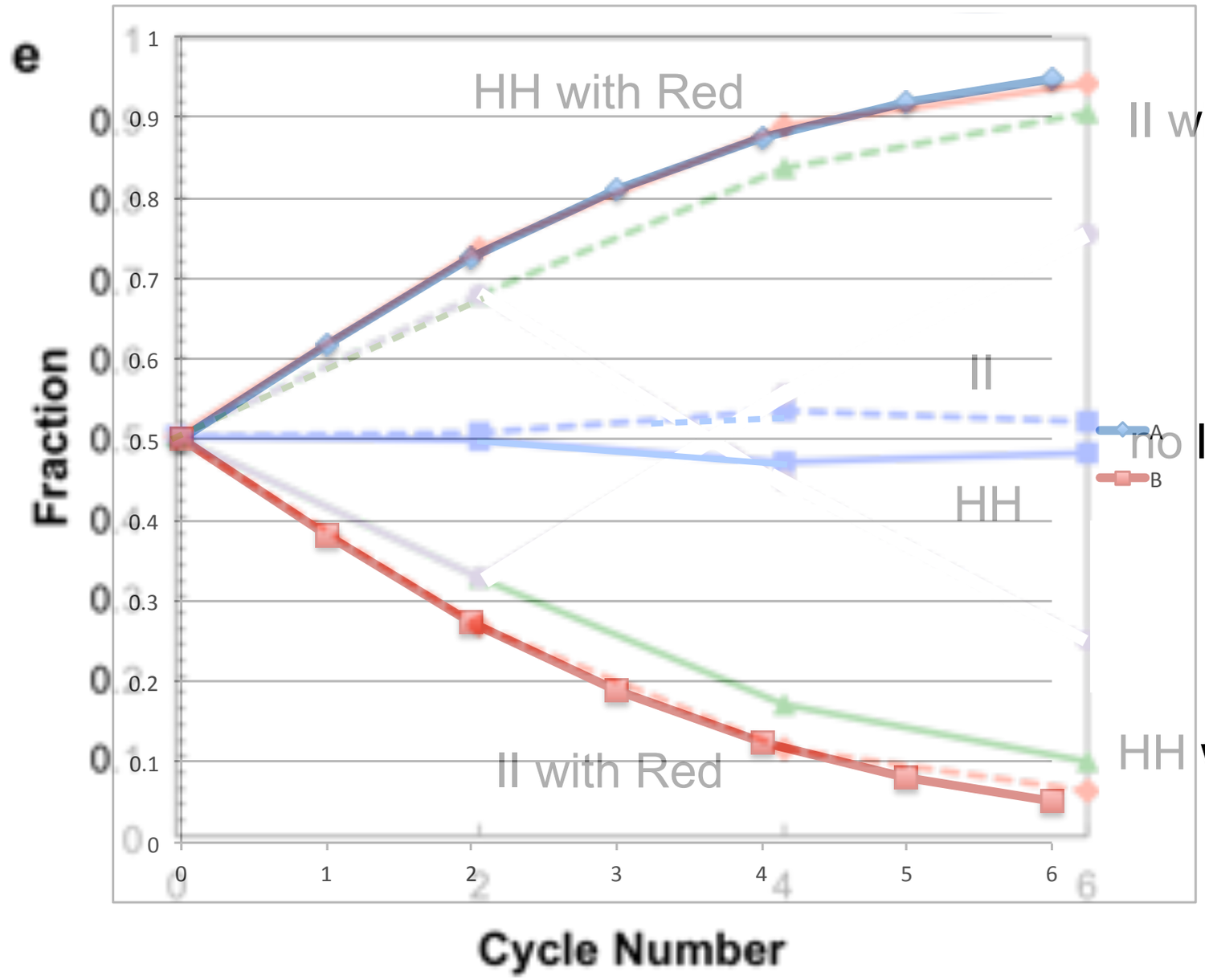
- ~ 4 C: Laser 785 nm for 20 min
- ~ 4 C: Laser 785 nm + UV for 1 h
- After each 2 cycles

1) add monomer H to keep
HH: H-FG: H-SG= 1: 7: 7

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

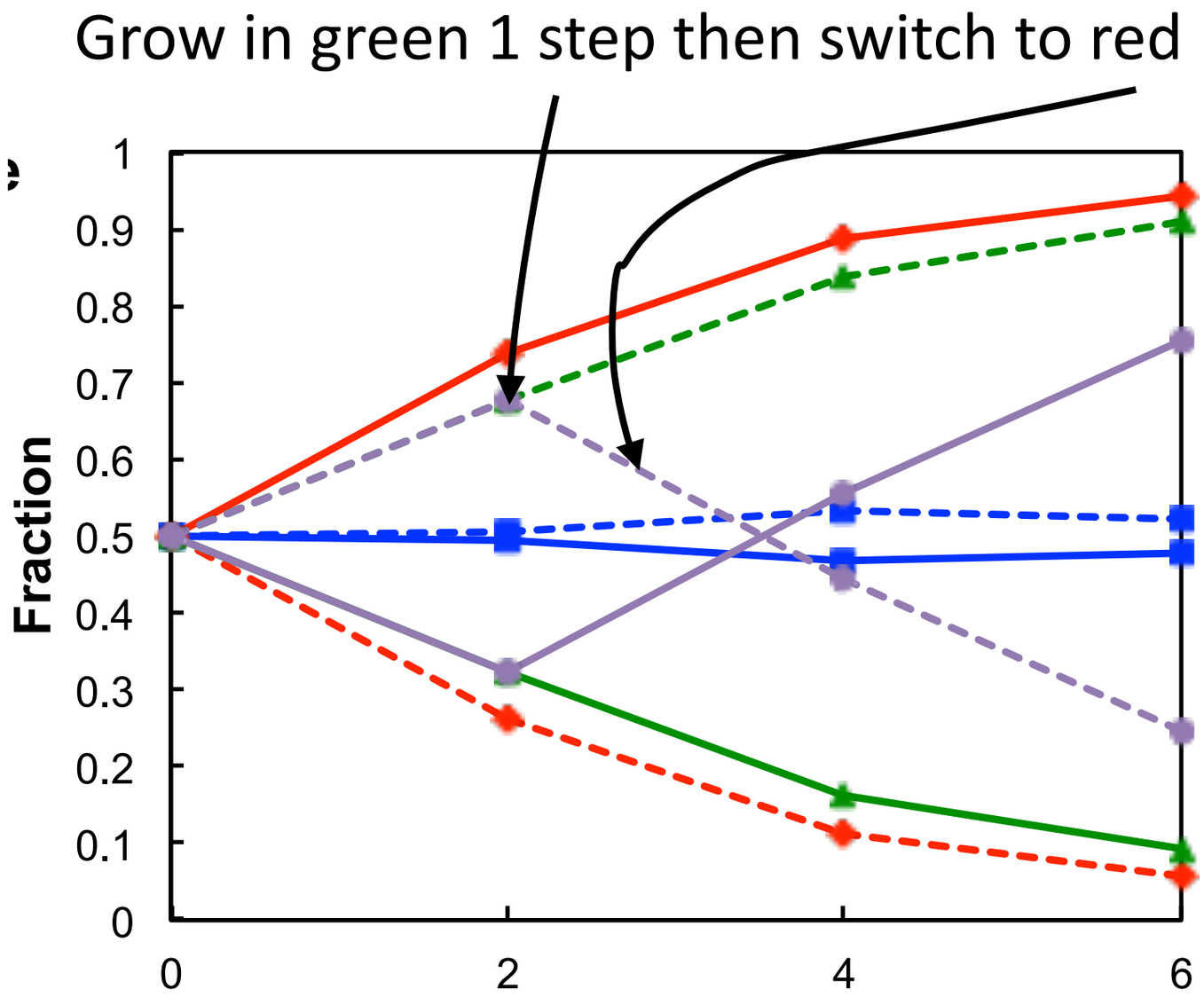






Replication rate
1.2 vs 1.95

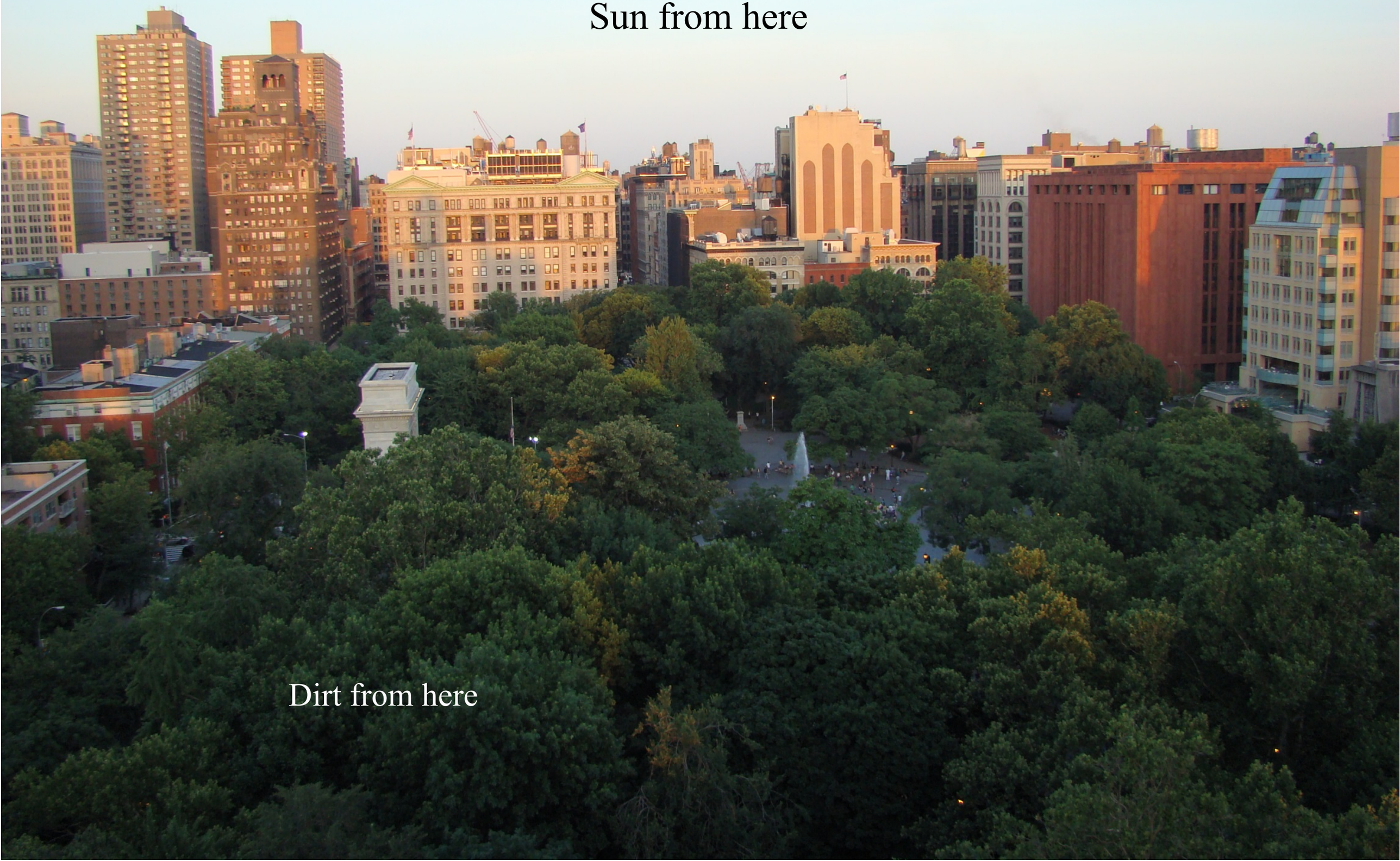
Can reverse selection by switching lights



How about growing it outside?

Roof Top - Washington Sq Park

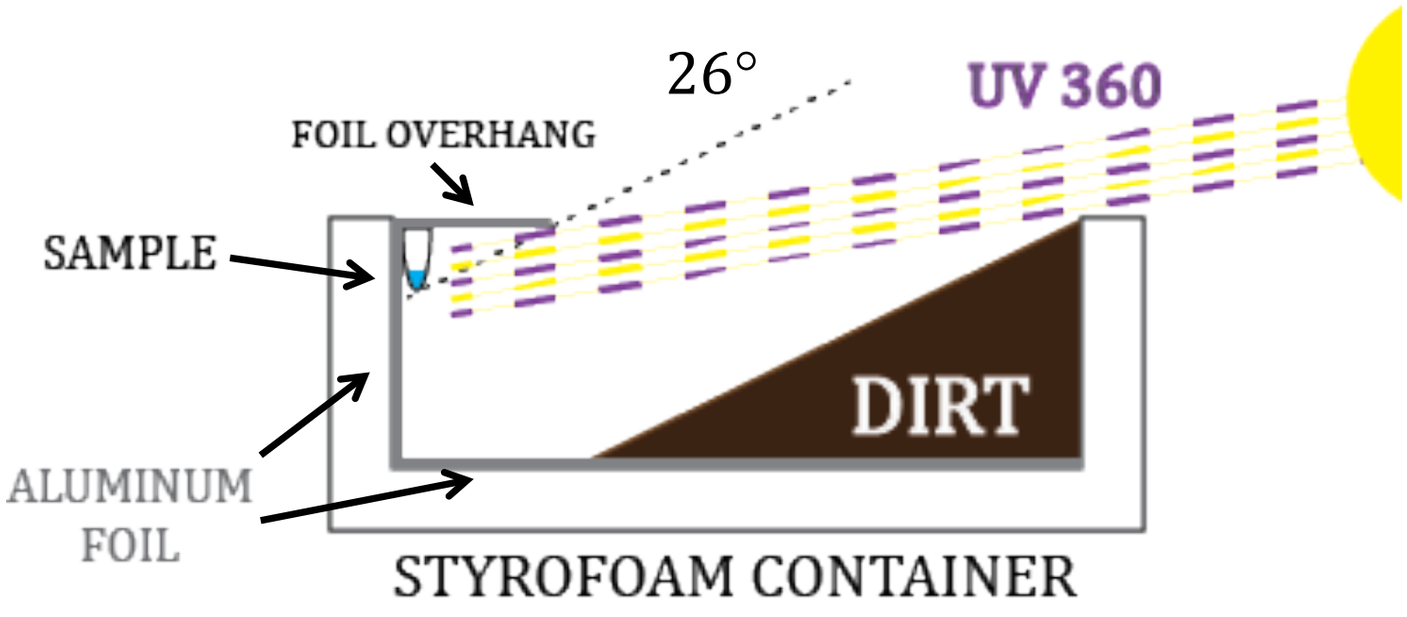
Sun from here



Dirt from here

Roof Top DNA Origami Solar Replicator

After a cold night, rays from the sunrise hit the sample for about 2 hours

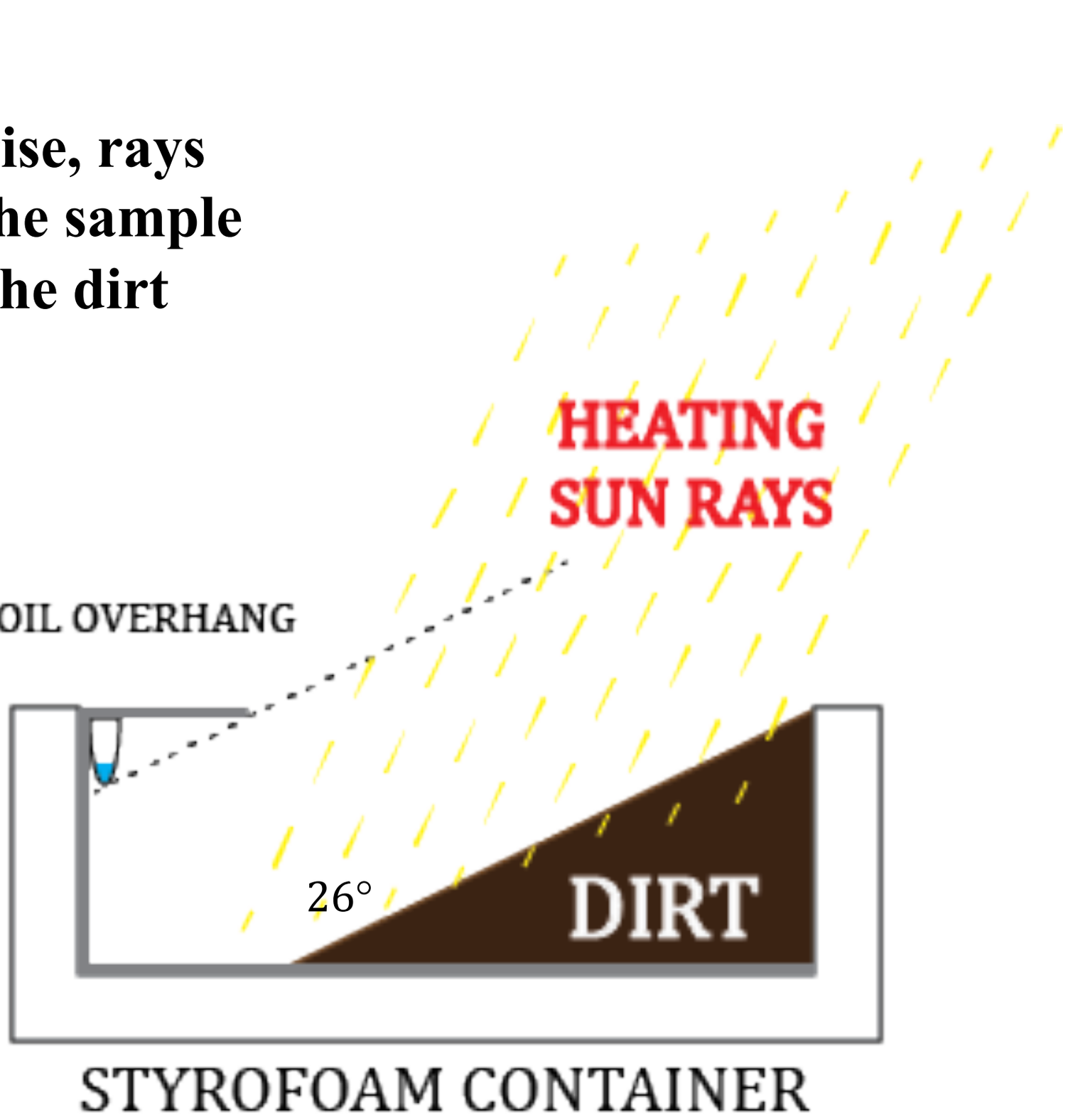


Andrew Bergman

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 –> 0-2C

Dirt Temperature
32-96F -> 0-35C



Original Dimer:Mono Ratio – 1:30

After One Sunny Day:

Control Sample on roof (in Al Foil)

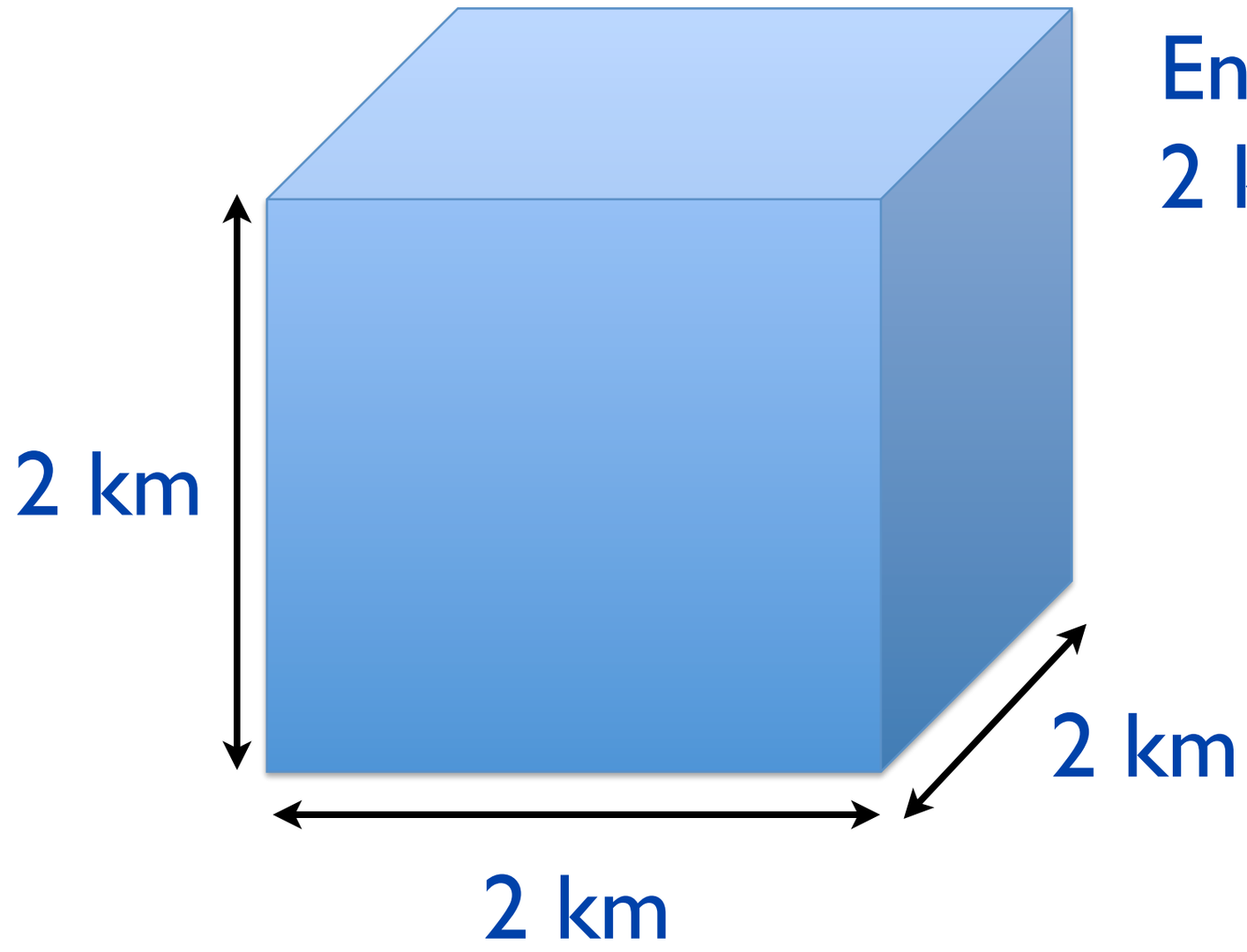
Dimers Remain Same Concentration

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 (ρ_+) > 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
U.S. DEPARTMENT OF ENERGY
Basic Energy Science
GORDON AND BETTY MOORE FOUNDATION