



WYSS INSTITUTE

The Science of Digital Fabrication Workshop

Nano-assembly

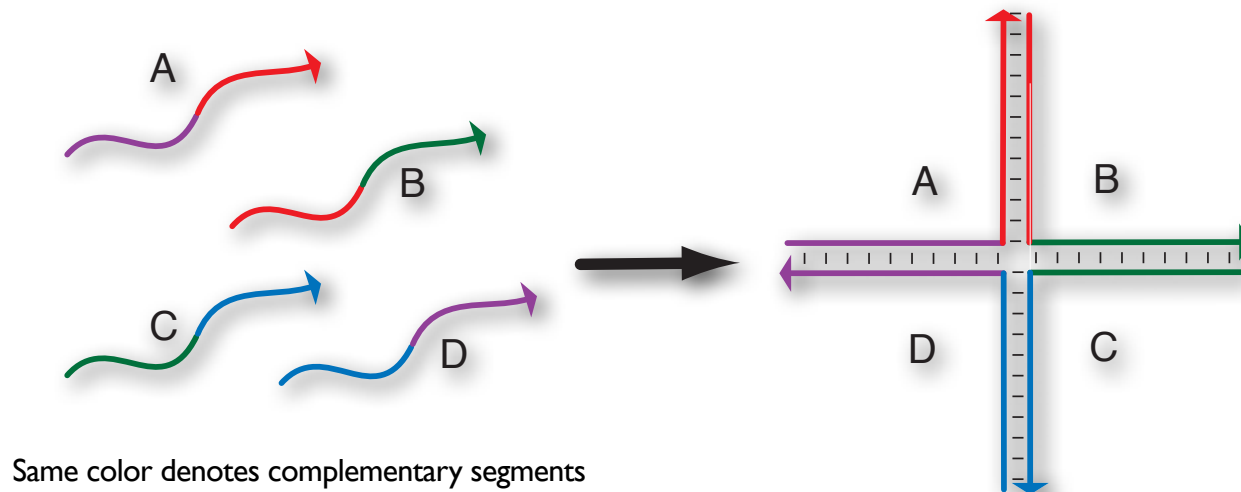
Peng Yin

Department of Systems Biology, Harvard Medical School

Wyss Institute for Biologically Inspired Engineering, Harvard University

March 7th, 2013

Digital fabrication with DNA



N.C. Seeman, *J. Theor. Biol.*, 1982

Simple

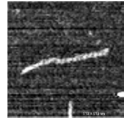
Robust

Designable

DNA nano-structures

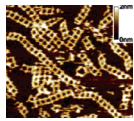
1D ribbons

Rhombus ribbon



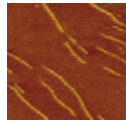
(Mao, Sun & Seeman, 1999)

Nano-track



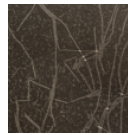
(Park, Yin, Liu, Reif, LaBean & Yan 05)

TX ribbon

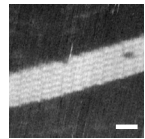


(Li, Park, Reif, LaBean, Yan 03)

Zigzag ribbon



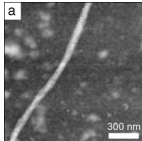
(Schulman, Winfree, 06)



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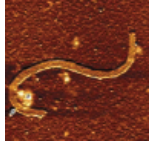
1D tubes

TX-tube



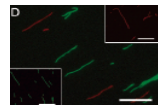
(Liu, Park, Reif & LaBean 04)

4x4 tube



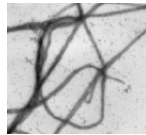
(Yan, Park, Finkelstein, Reif & LaBean 03)

DX tube



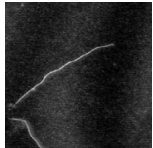
(Rothemund, Ekani-Nkodo, Papadakis, Kumar, Fygenson & Winfree 04)

Chiral DX tube



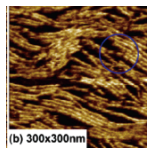
(Mitchell, Harris, Malo, Bath & Turberfield 04)

6-helix bundle



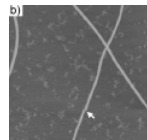
(Mathieu, Liao, Kopatsch, Wang, Mao & Seeman 05)

3-helix bundle



(Park, Barish, Li, Reif, Finkelstein, Yan & LaBean 05)

single-strand DX-like tubes

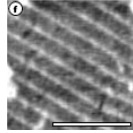


(He, Chen, Liu, Ribbe & Mao 05)

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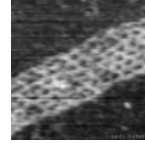
2D lattices

DX lattice



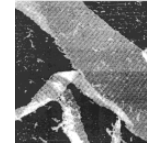
(Winfree, Liu, Wenzler & Seeman 98)

Rhombus lattice



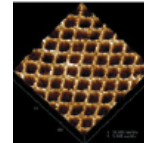
(Mao, Sun & Seeman 99)

TX lattice



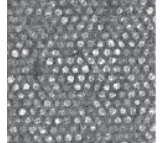
(LaBean, Yan, Kopatsch, Liu, Winfree, Reif, & Seeman 00)

4x4 lattices



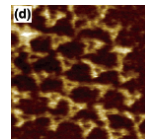
(Yan, Park, Finkelstein, Reif & LaBean 03)

HJ lattice



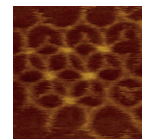
(Malo, Mitchell, Venien-Bryan, Harris, Wille, Sherratt & Turberfield 05)

triangle lattice



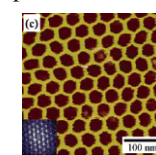
(Liu, Wang, Deng, Walulu & Mao 04)

hexagonal lattice



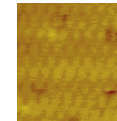
(Chelyapov, Brun, Gopalkrishnan, Reishus, Shaw & Adleman 04)

3 point-star lattices



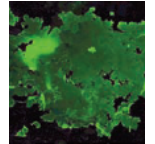
(He, Chen, Liu, Ribbe & Mao 05)

DDX lattice



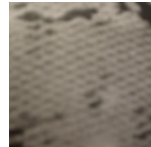
(Reishus, Shaw, Brun, Chelyapov & Adleman 05)

symmetry lattice



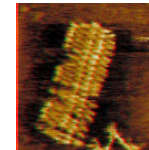
(He, Tian, Chen, Deng, Ribbe & Mao 05)

SAO lattice



(Rothemund 05)

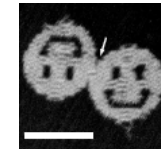
Barcode lattice



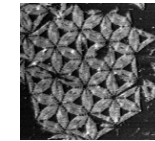
(Yan, LaBean, Feng & Reif 03)

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Origami



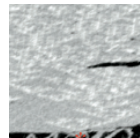
(Rothemund 06)



(Rothemund 06)

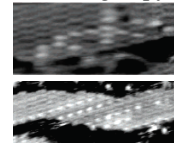
Algorithmic lattice

Sierpinsky triangle



(Rothemund, Papadakis & Winfree 04)

Counting/copying



(Barish, Rothemund & Winfree 05)

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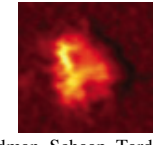
3D

Octahedron



(Shih, Quispe & Joyce 04)

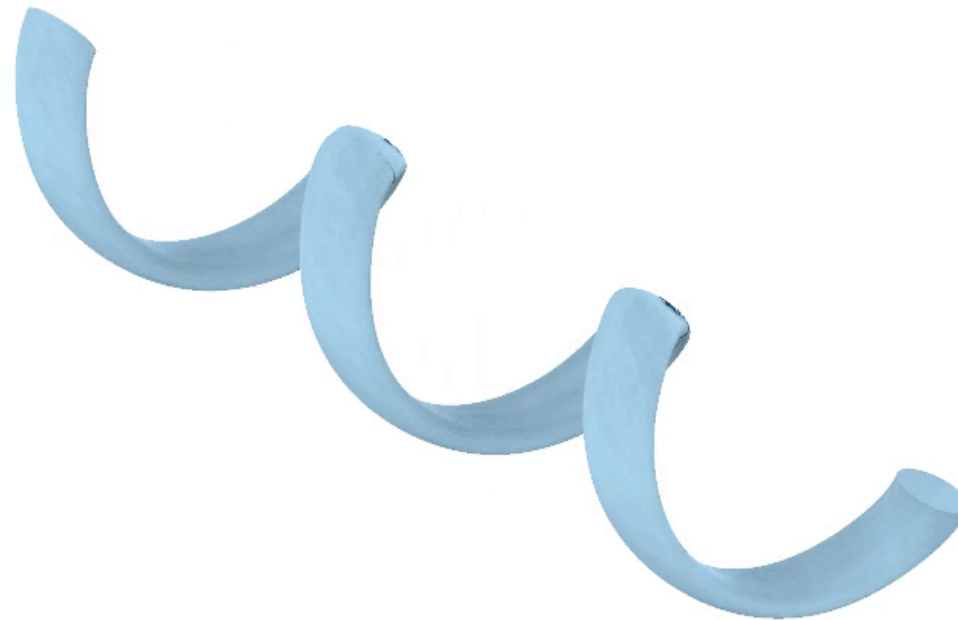
Tetrahedron



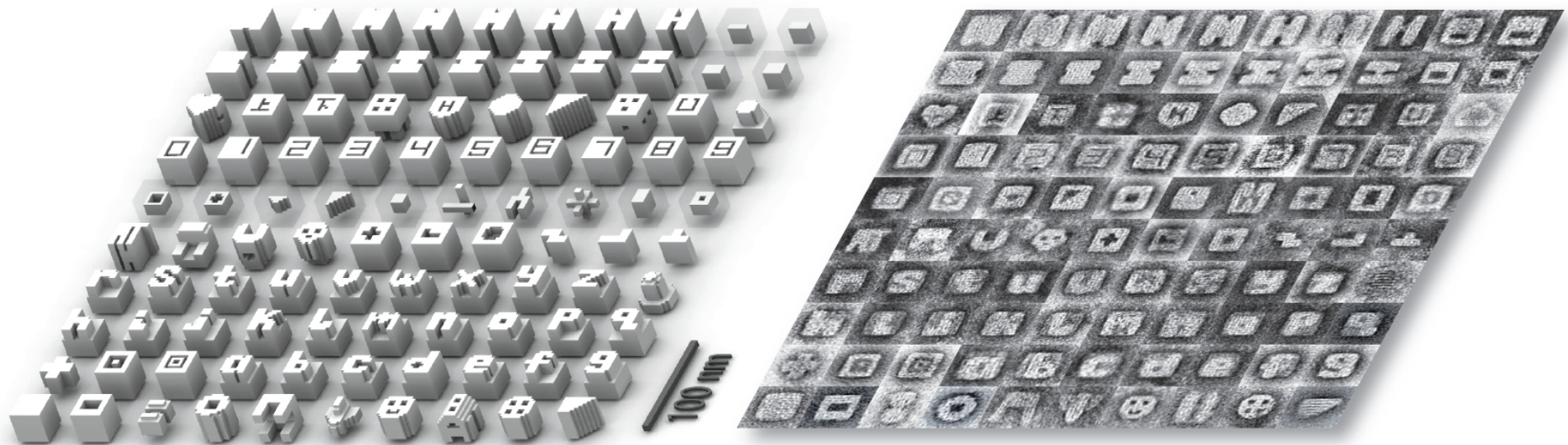
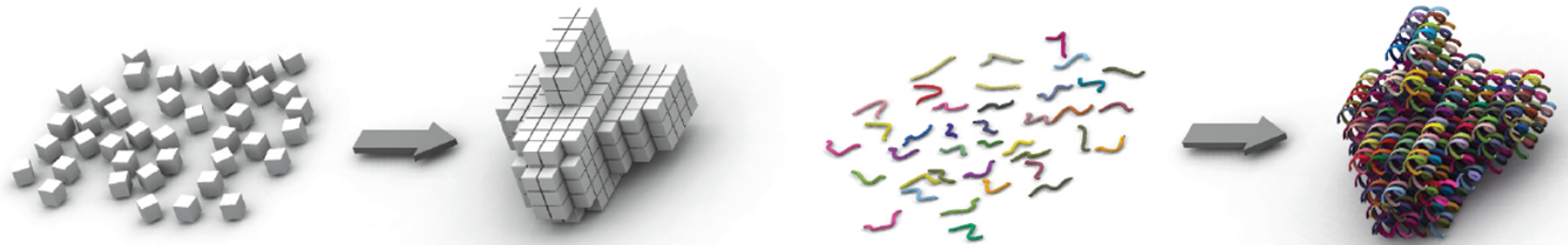
(Goodman, Schaap, Tardin, Erben, Berry, Schmidt & Turberfield 05)

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**Rapid prototyping
with
DNA bricks**



Building 3D structures with DNA bricks



30 November 2012 | \$10

Science

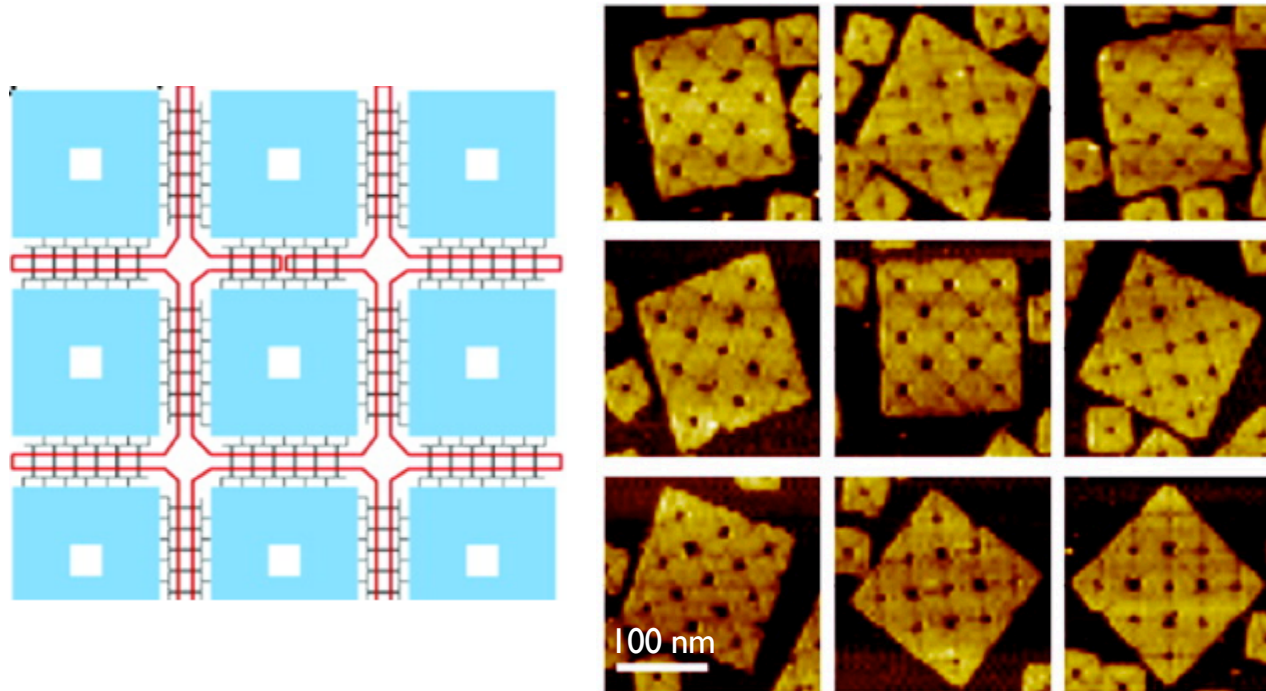


AAAS

Yin lab @ Harvard

Scaling up

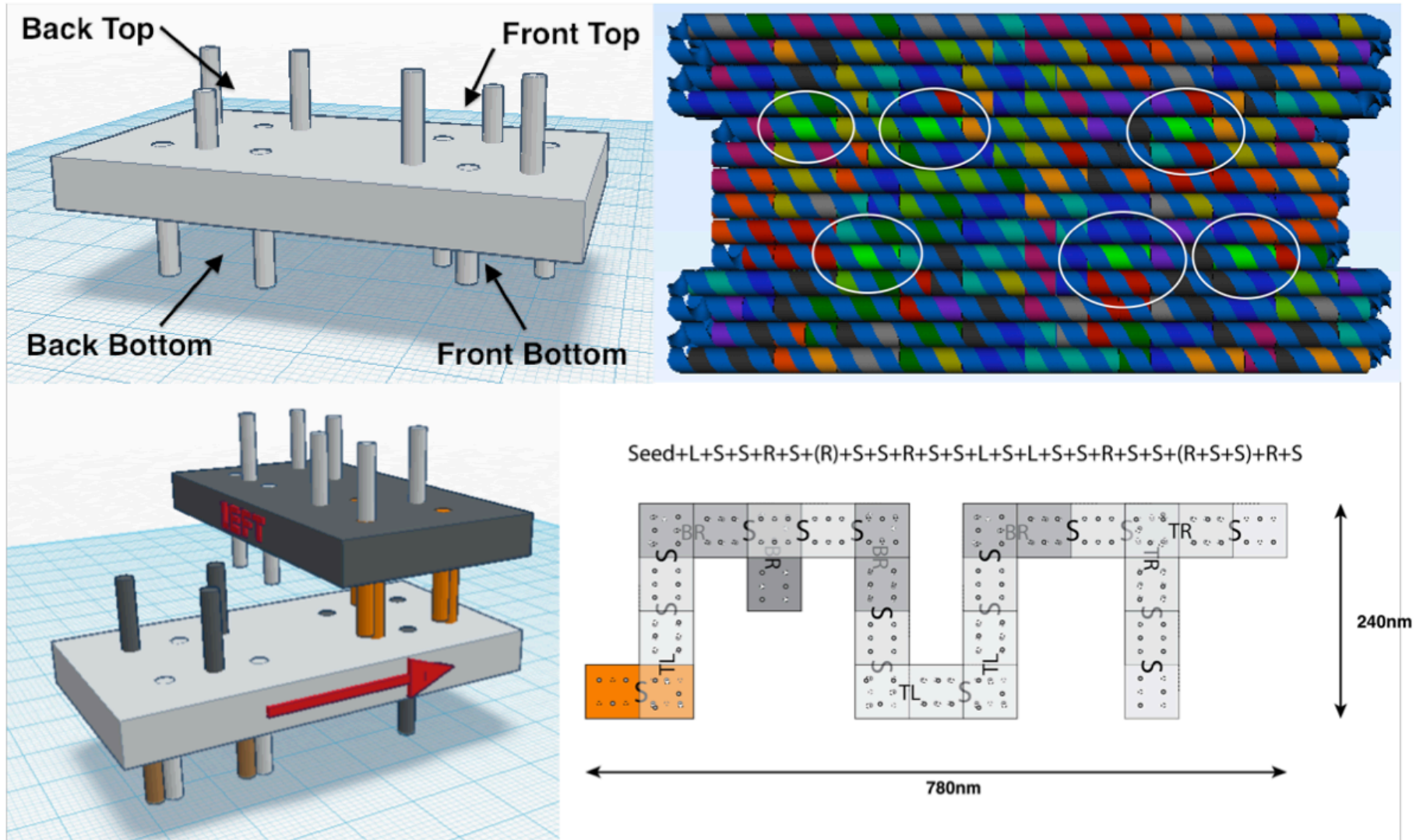
Hierarchical assembly



Zhao Zhao ,Yan Liu *, and Hao Yan * Nano Lett., 2011

Yan lab @ASU

NanoAssembler: iterative, **solid phase** synthesis of geometry



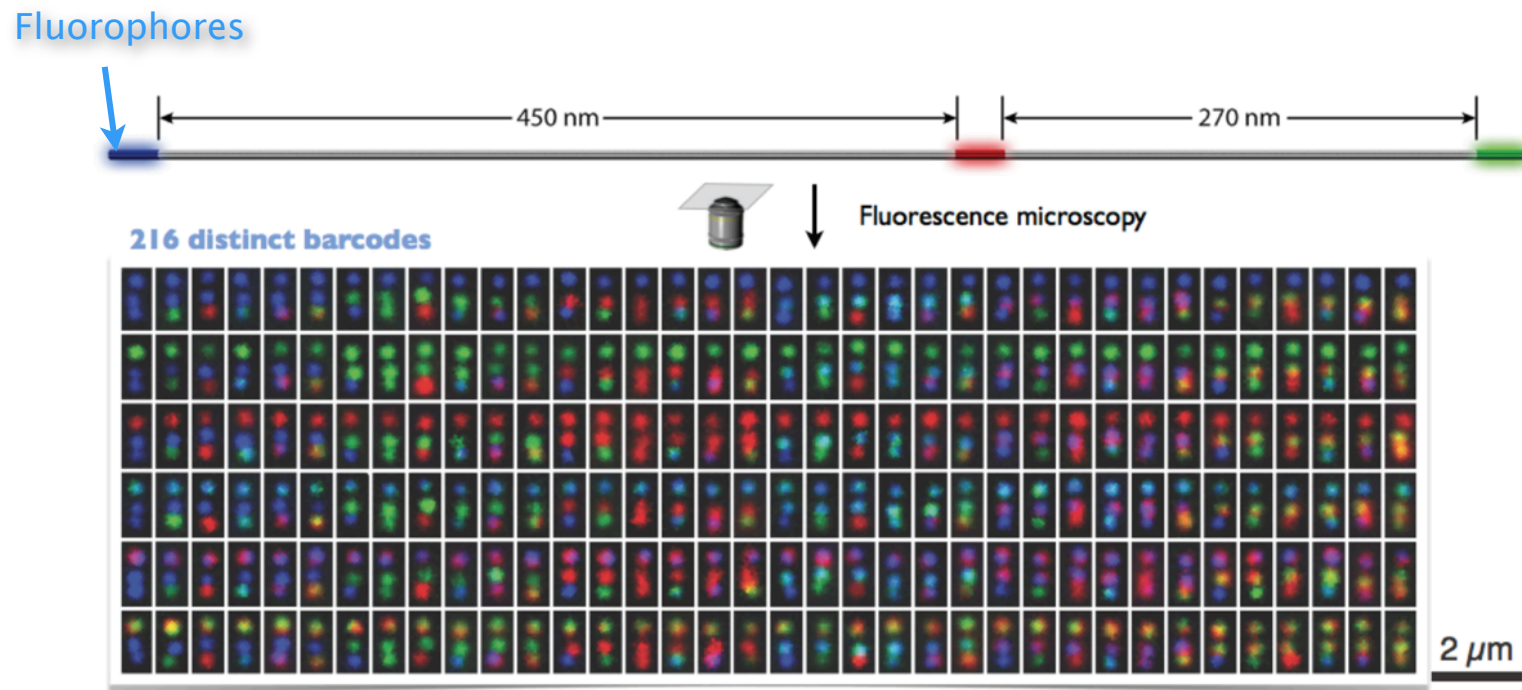
Slide credit: Charles Fracchia

Gershenfeld lab @ MIT

Scaffolds for functional materials

Fluorophores

Fluorescent barcodes for multiplexed imaging

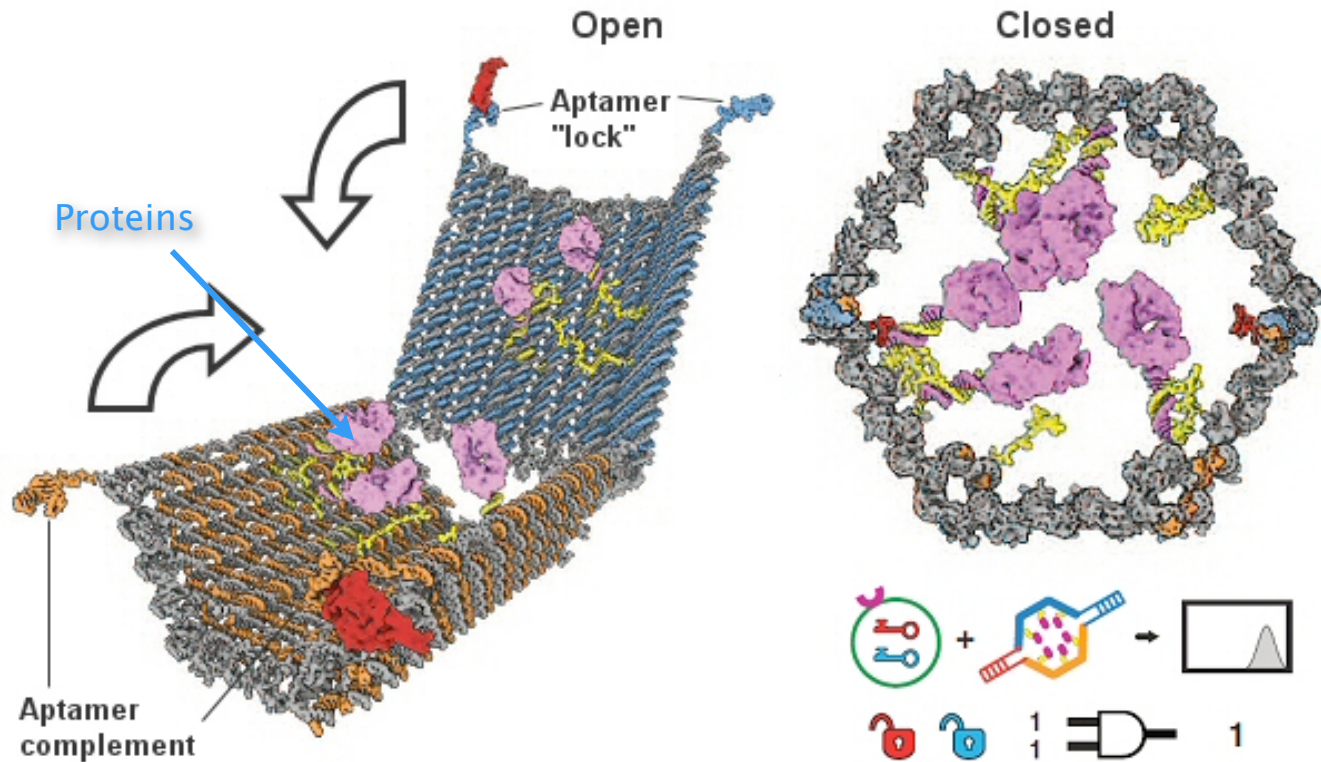


Lin, Jungmann, Leifer, Li, Levner, Church, Shih* & Yin*, *Nature Chemistry* 4:832 (2012)

Church, Shih, Yin labs @ Harvard

Proteins

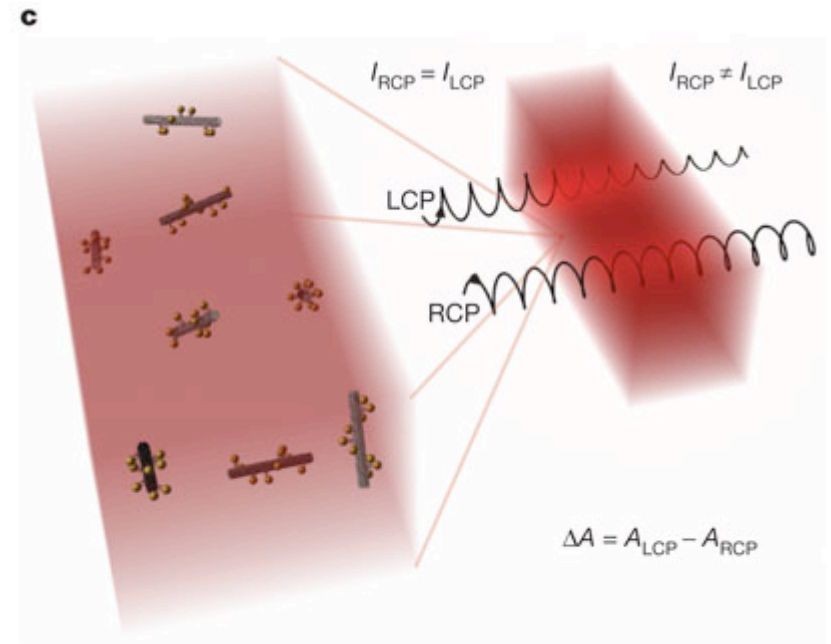
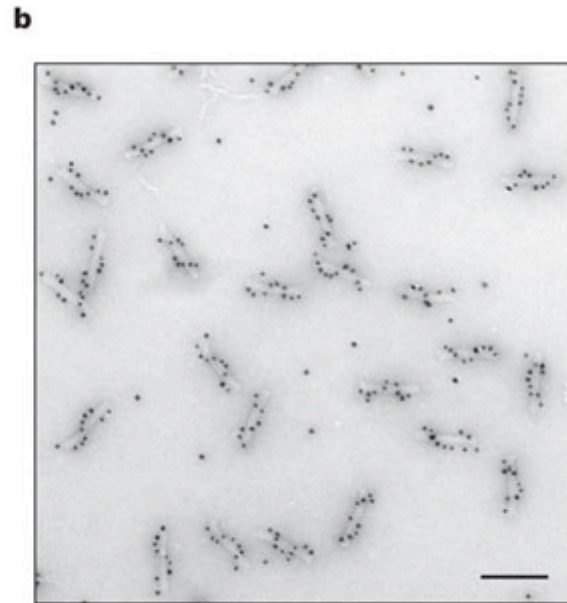
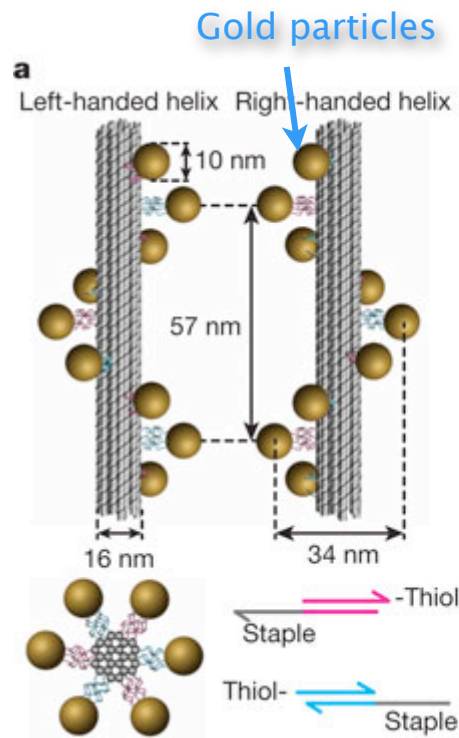
DNA “nanorobot” for targeted delivery



SM Douglas, I Bachelet, GM Church (2012) Science. 335:831

Gold particles

Chiral gold arrays for “Carving light”



Anton Kuzyk et al, Nature 483, 311, 2012

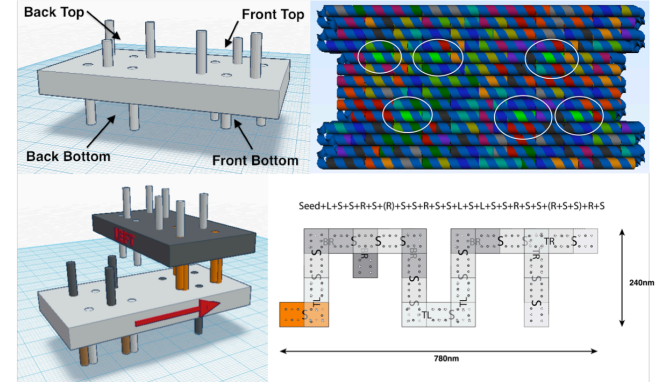
Liedl lab @ LMU

DNA
to
inorganic

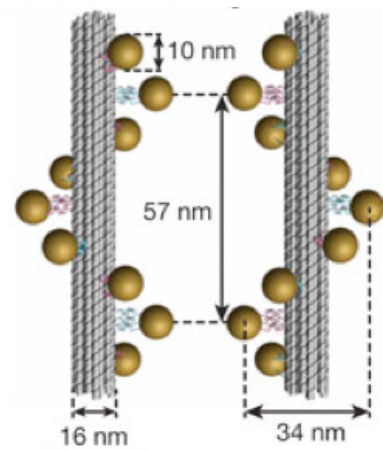
3D nano-printing with DNA bricks



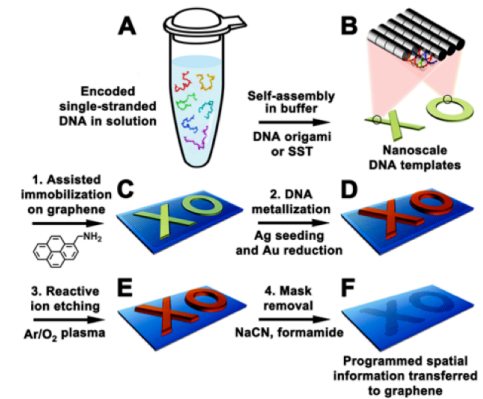
Scaling up



Scaffolds for functional materials



Digital fab of inorganic nano-structures



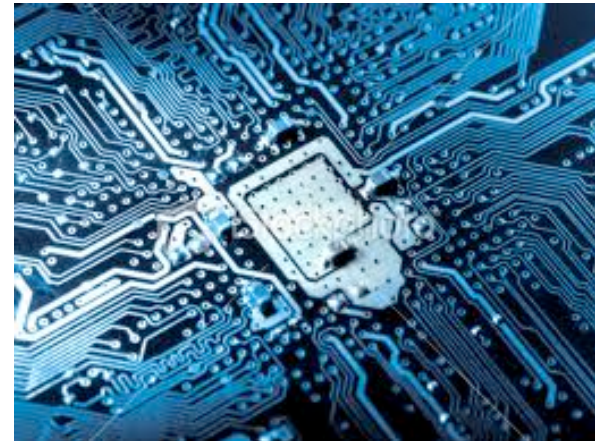
Digital fabrication of functional nano-structures with DNA

ATGGTGAGCAAGGG
CGCCGAGCTGTTCA
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ATCCTGATCGAGCT
GAATGGCGATGTGA
ATGGCCACAAGTTC
AGCGTGAGCGGCGA
GGGCGAGGGCGATG
CCACCTACGGCAAG
CTGACCCCTGAAGTT
CATCTGCACCACCG
GCAAGCTGCCTGTG
CCCTGGCCACCCT
GGTGACCACCTGA
GCTACGGCGTGCAG
TGCTTCTCACGCTA
CCCCGATCACATGA
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TACCAGCAGAATAC
CCCCATCGGGCGATG
GCCCTGTGCTGCTG
CCCGATAACCACTA
CCTGTCCACCAGCA
GCGCCCTGTCCAAG
GACCCCAACGAGAA
GCGCGATCACATGA
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CATCACCACGGCA
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Digital fabrication by nature: **Genome** for a whale



Digital fabrication by us: **Genome** for a computer?



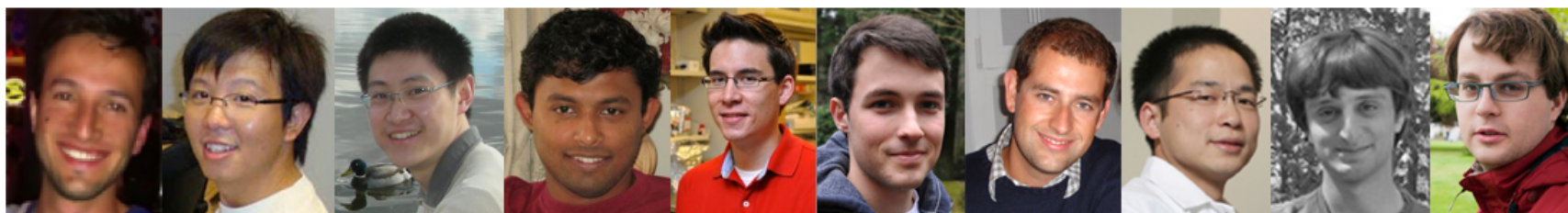
“Grow” a computer using DNA?

Acknowledgements

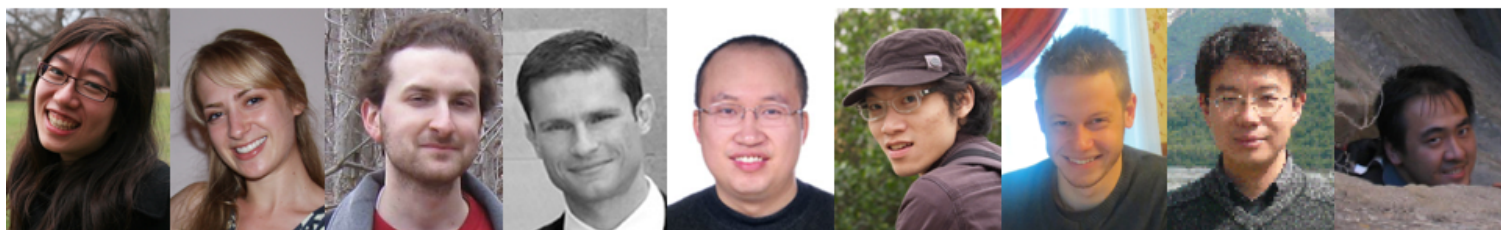


molecular-systems.net

Molecular Systems Lab at Harvard



Avendano Chen Dai Gopalkrishnan Green Grun Jungmann Ke Marblestone Myhrvold



Ong Pastuszak Sadowski Schaus Sun Wei Wohrstein Yin Zhang



Wyss Institute for
Biologically Inspired Engineering



National Institute of Health
Director's New Innovator Award
NIGMS



National Science Foundation
Faculty CAREER Award
CISE



Office of Naval Research
Young Investigator Program Award
& Biomat. and Bionanotech. Program



Defense Advanced
Research Projects Agency
Young Faculty Award
Living Foundries



Army Research Office
Biochemistry