Technische Universität München

Molecular programming with DNA: DNA-based nanoassembly and synthetic biochemical circuits

Friedrich C. Simmel

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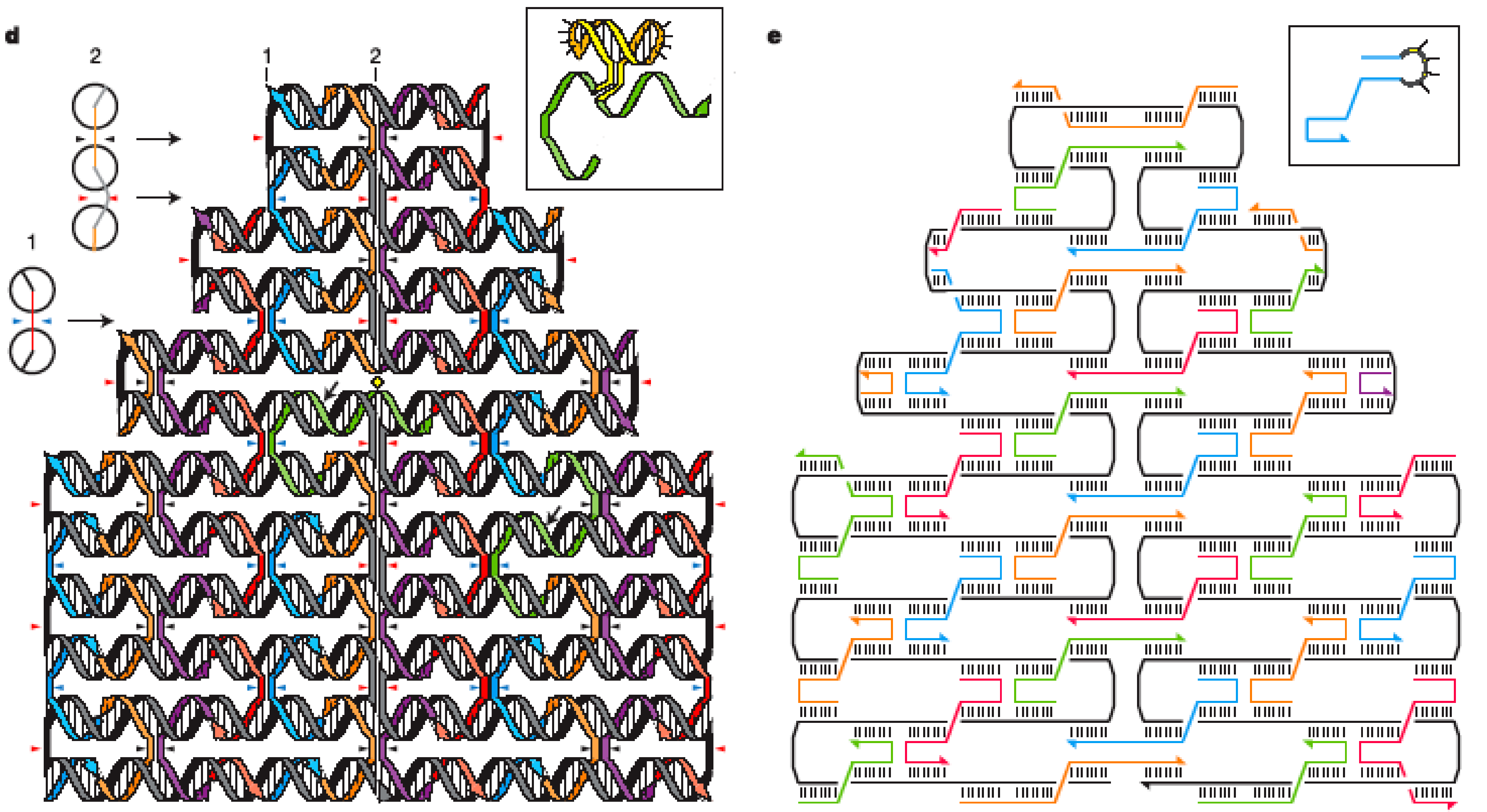
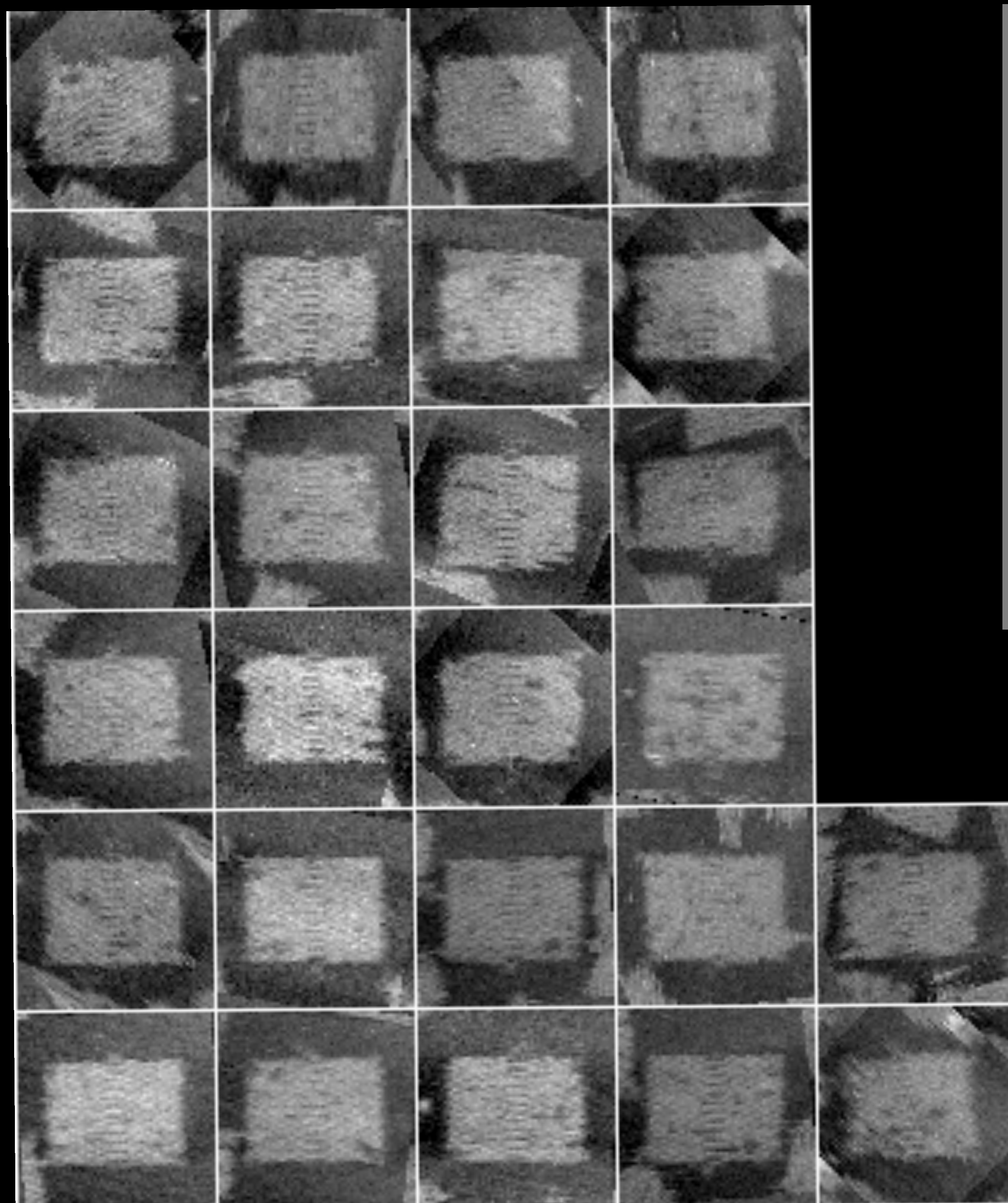
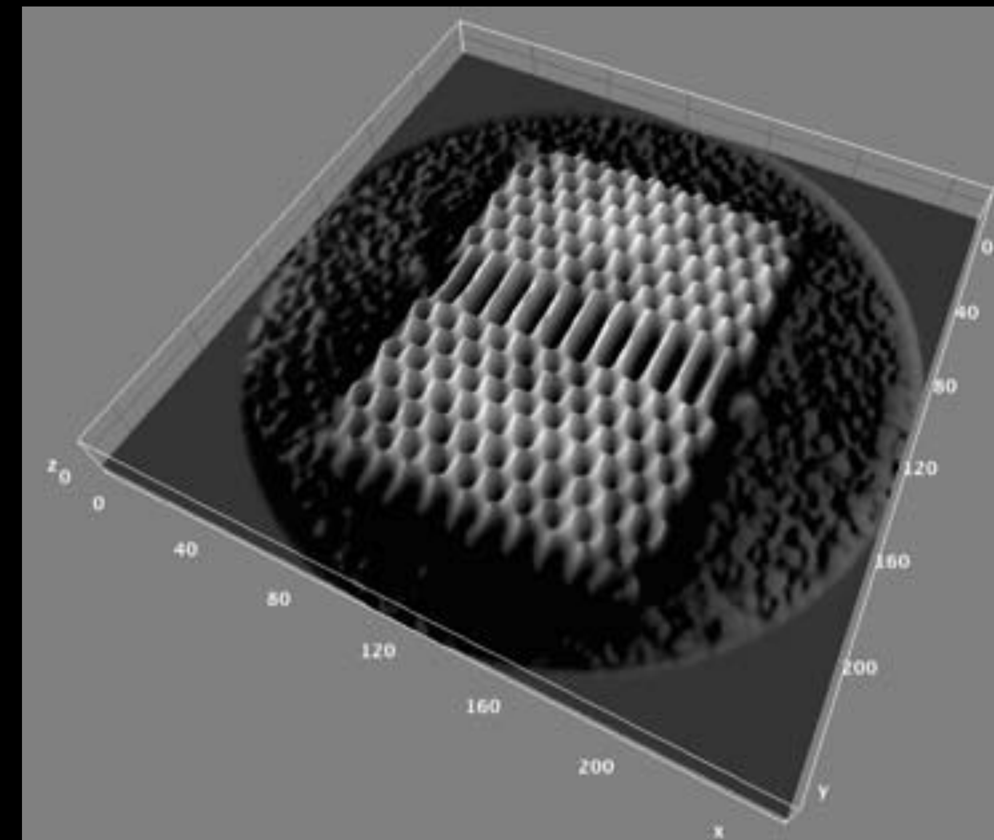
1. Nanostructures & nanodevices

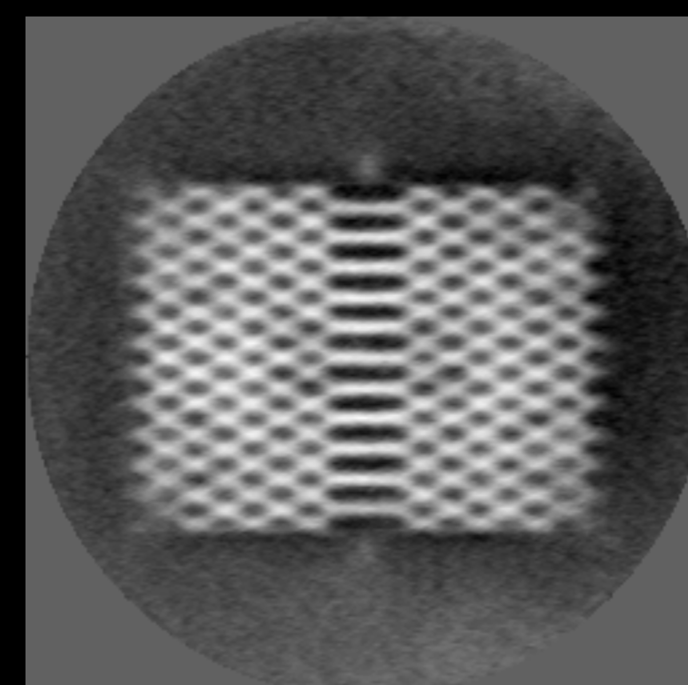
DNA origami

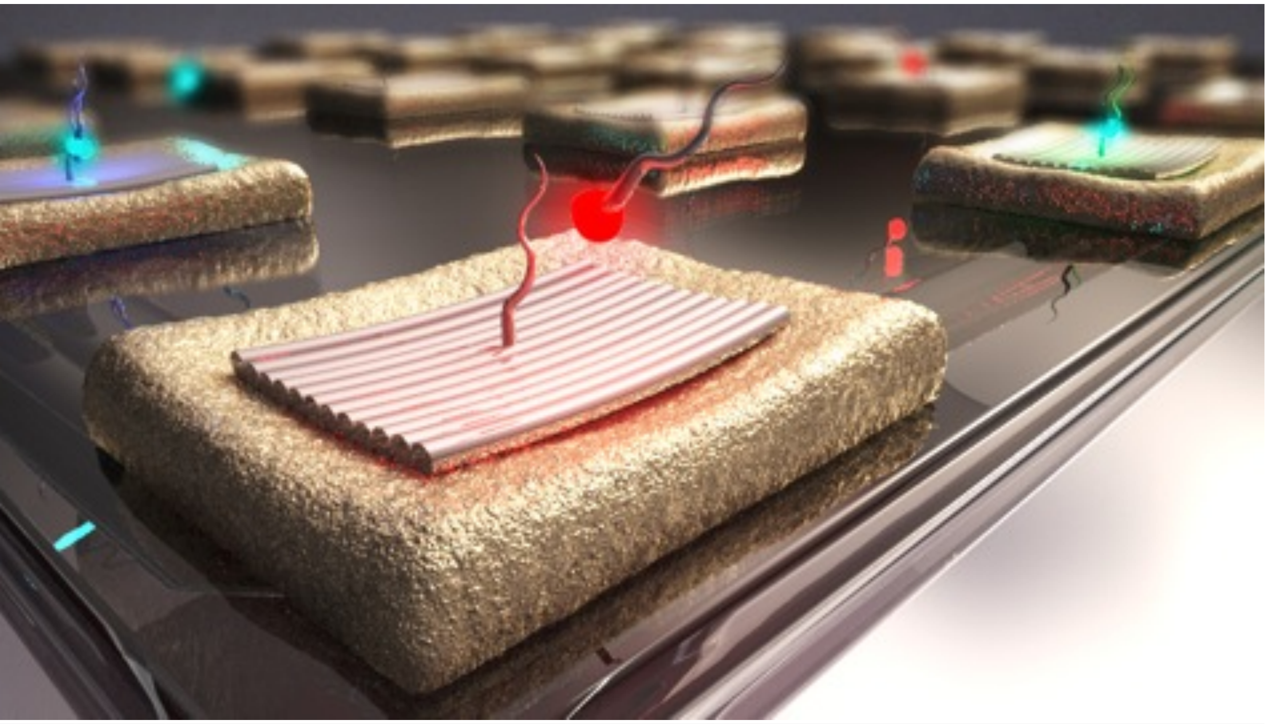


Rothemund, P. W. K., Nature 440: 297 (2006)




0
40
80
120
160
200
x
Y
z





DNA strand displacement on lithographic DNA origami arrays

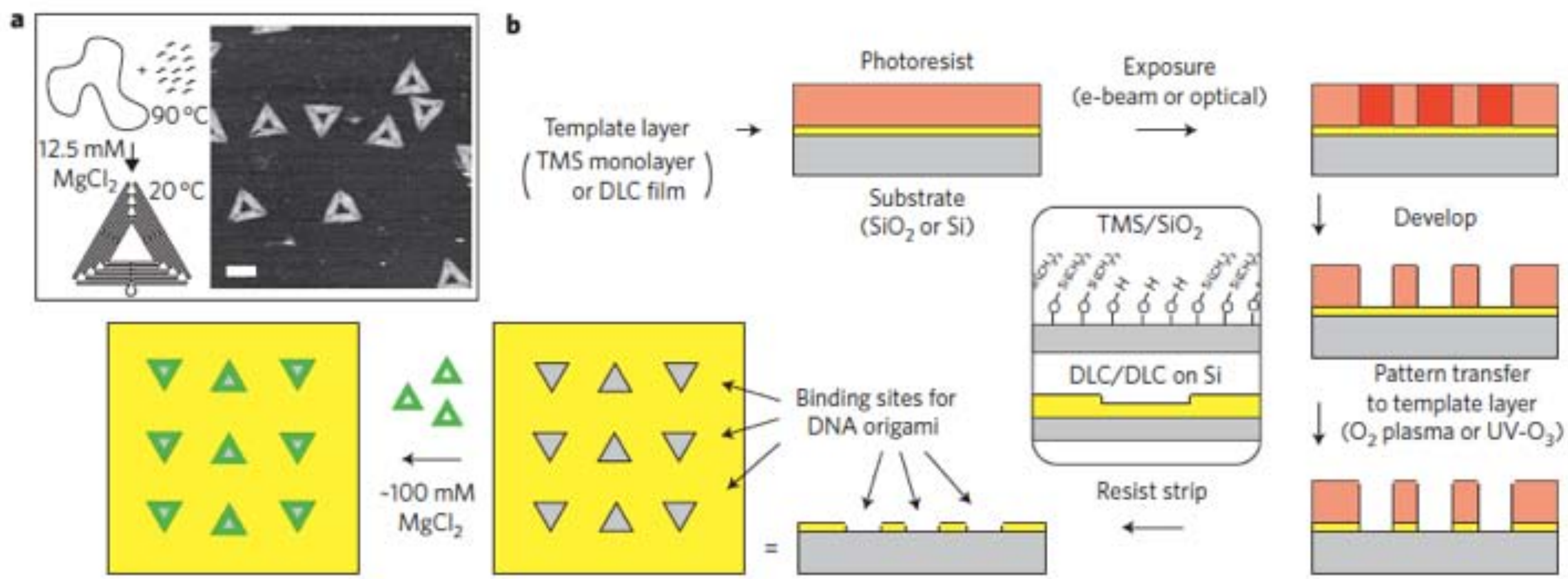
Max Scheible, Günther Pardatscher, Anton Kuzyk

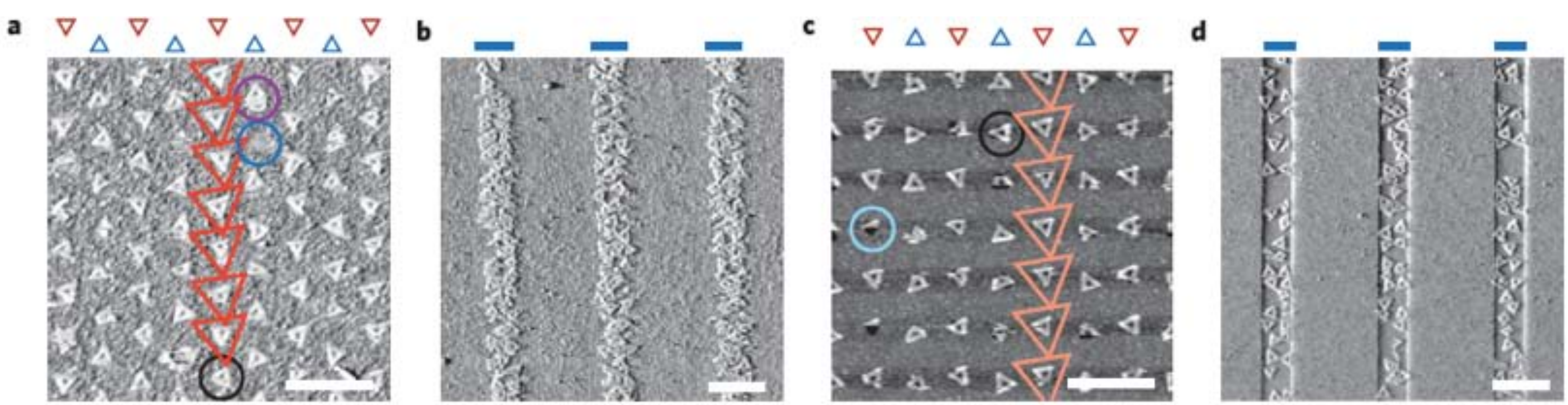
M. B. Scheible, G. Pardatscher, A. Kuzyk, F. C. Simmel, *Nano Lett.* **2014**, *14*, 1627-1633.

Bridging the scales with lithography

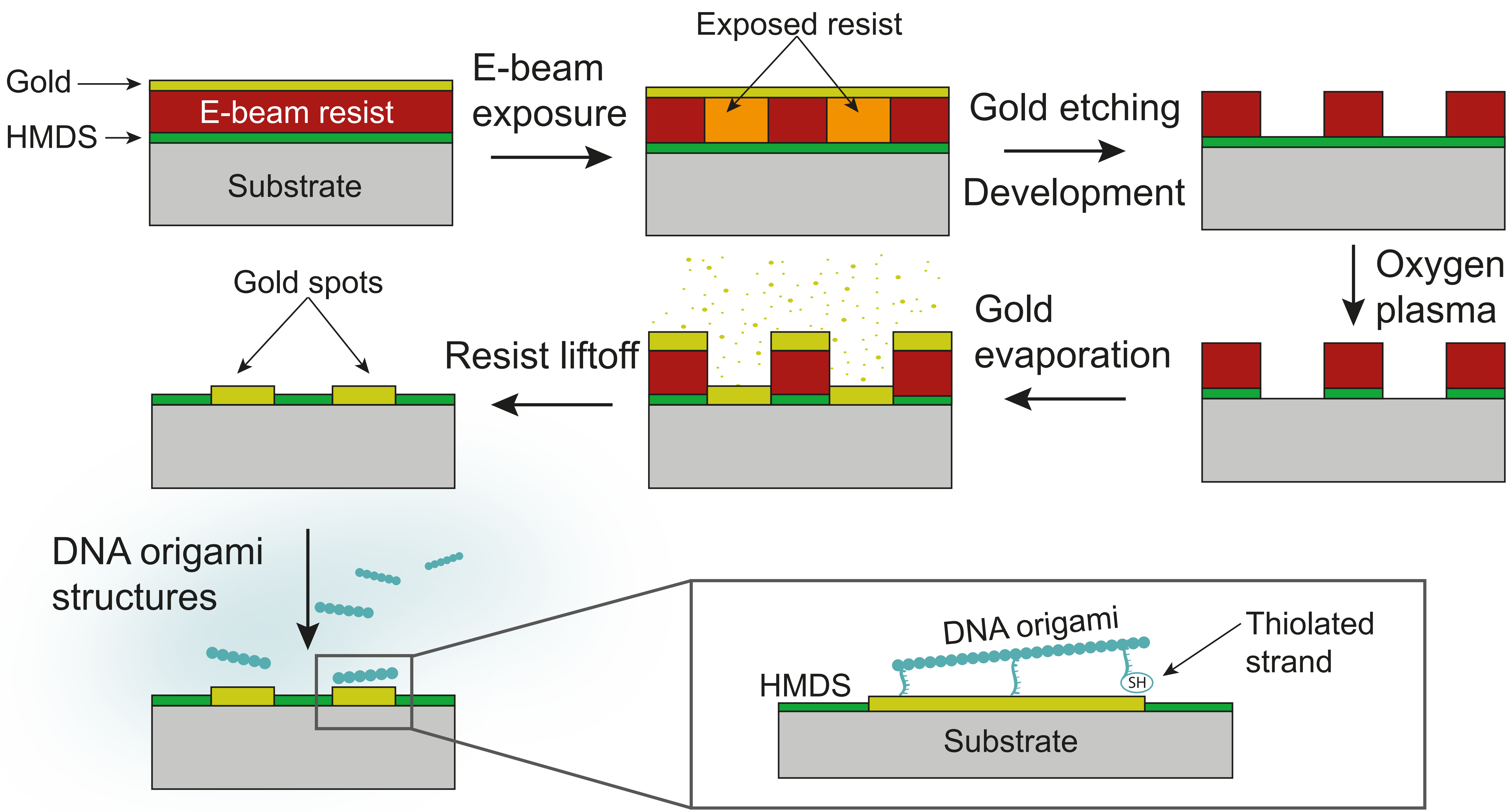
Placement and orientation of individual DNA shapes on lithographically patterned surfaces

Ryan J. Kershner[1†], Luisa D. Bozano[1], Christine M. Micheel[1†], Albert M. Hung[1†], Ann R. Fornof[1†], Jennifer N. Cha[1†], Charles T. Rettner[1], Marco Bersani[1†], Jane Frommer[1], Paul W. K. Rothemund[2*] and Gregory M. Wallraff[1*] Nature Nanotech 2009

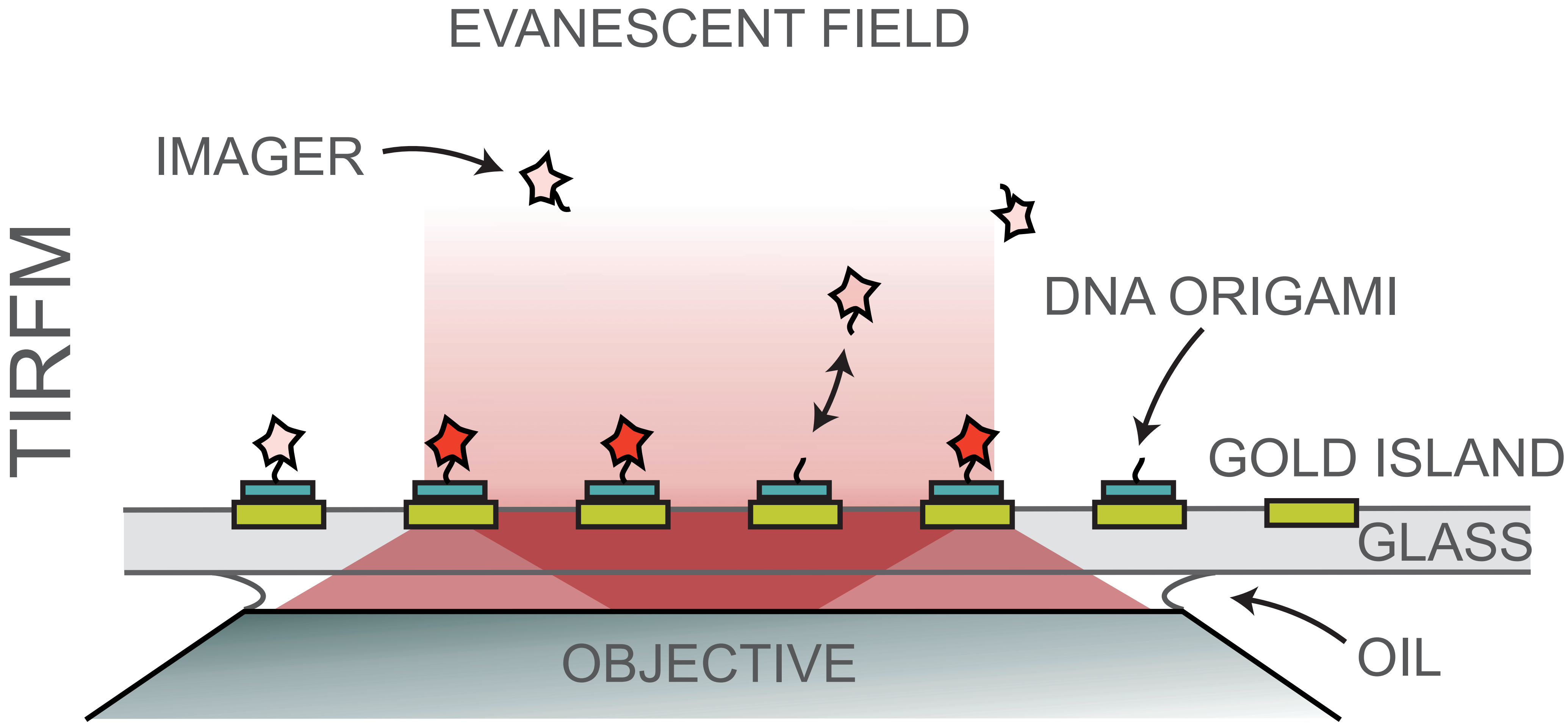




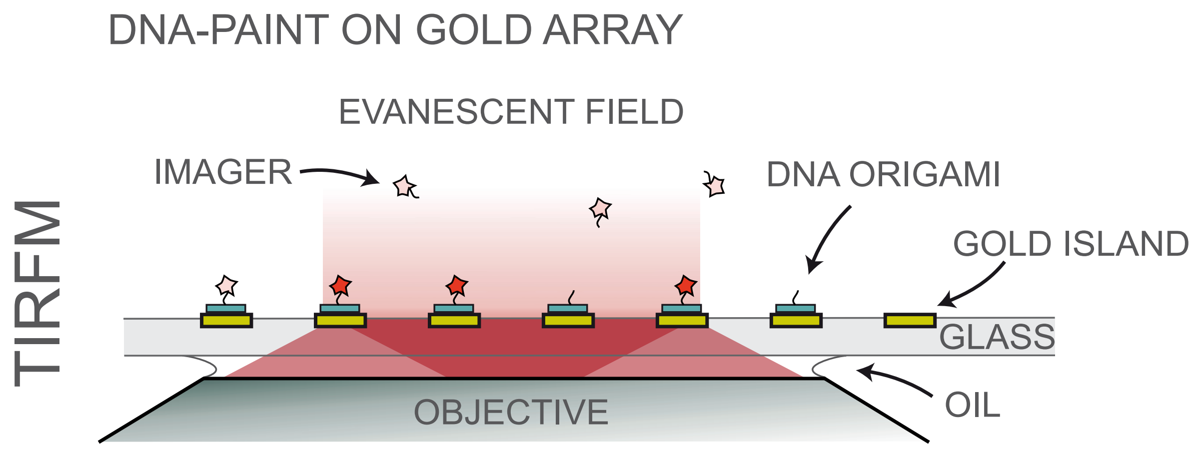
E-beam lithography on glass substrates



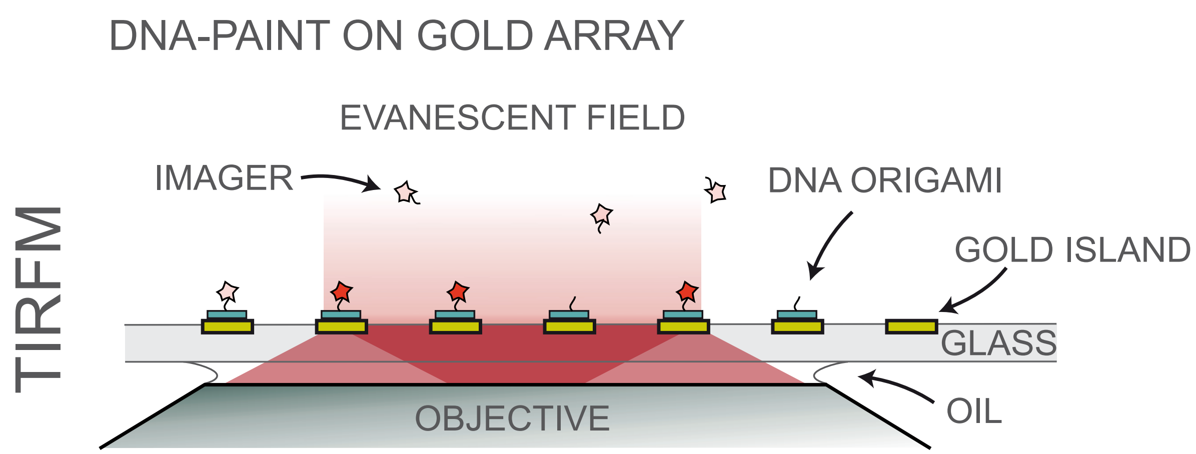
TIRF and DNA PAINT on lithographic origami arrays

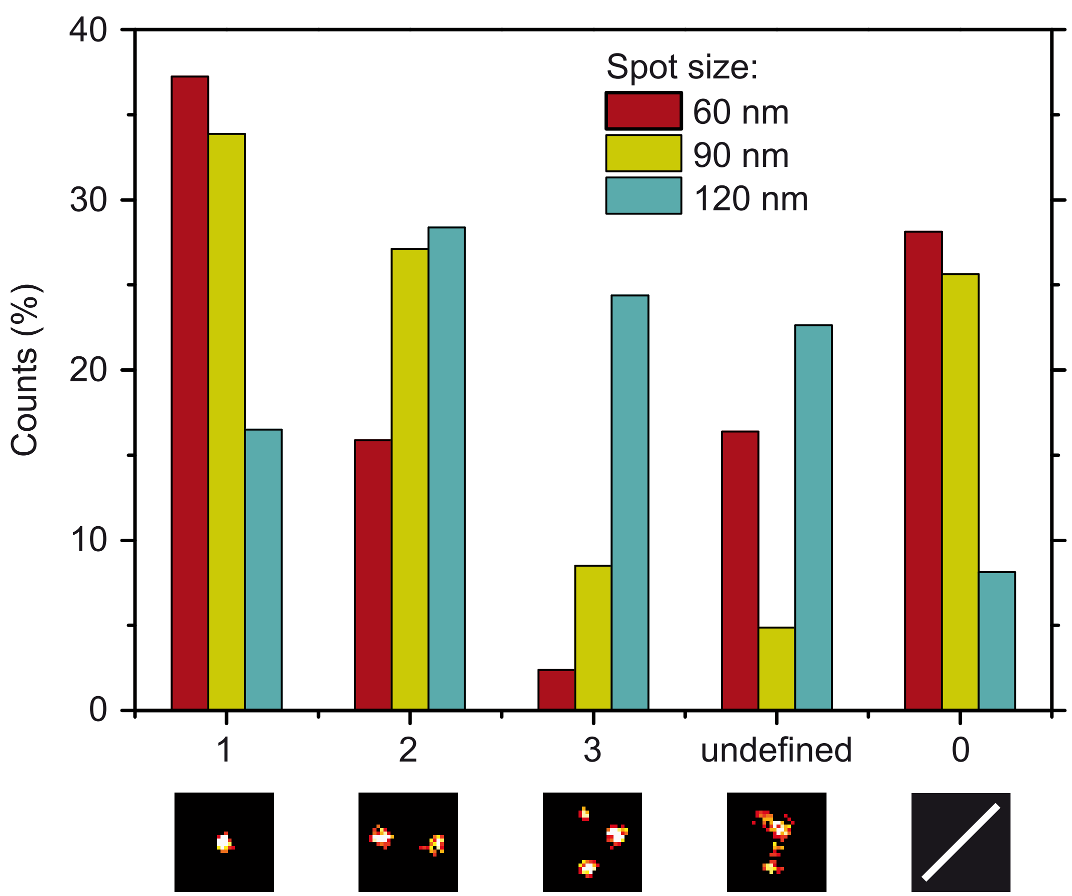


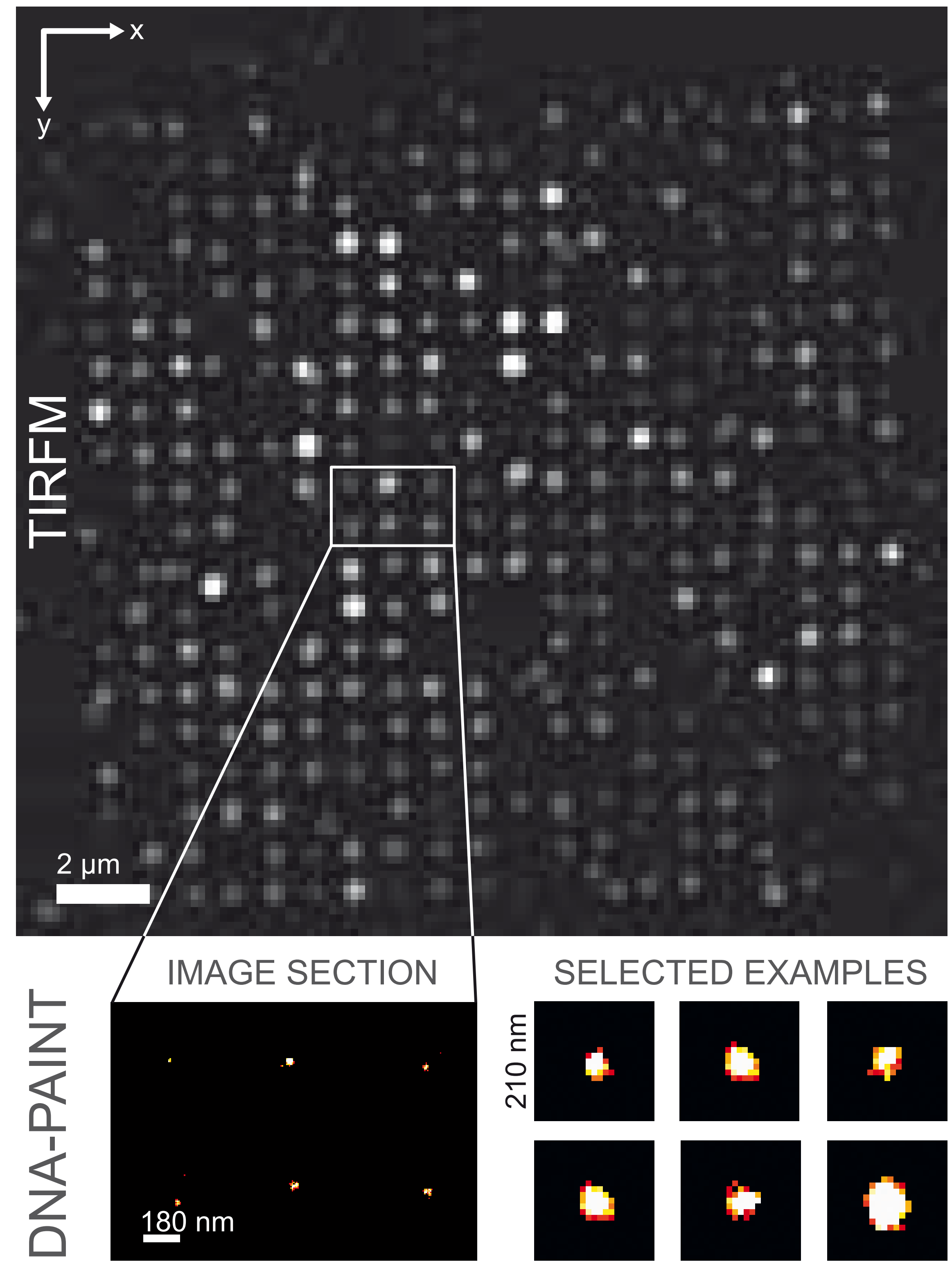
TIRF and DNA PAINT on lithographic origami arrays



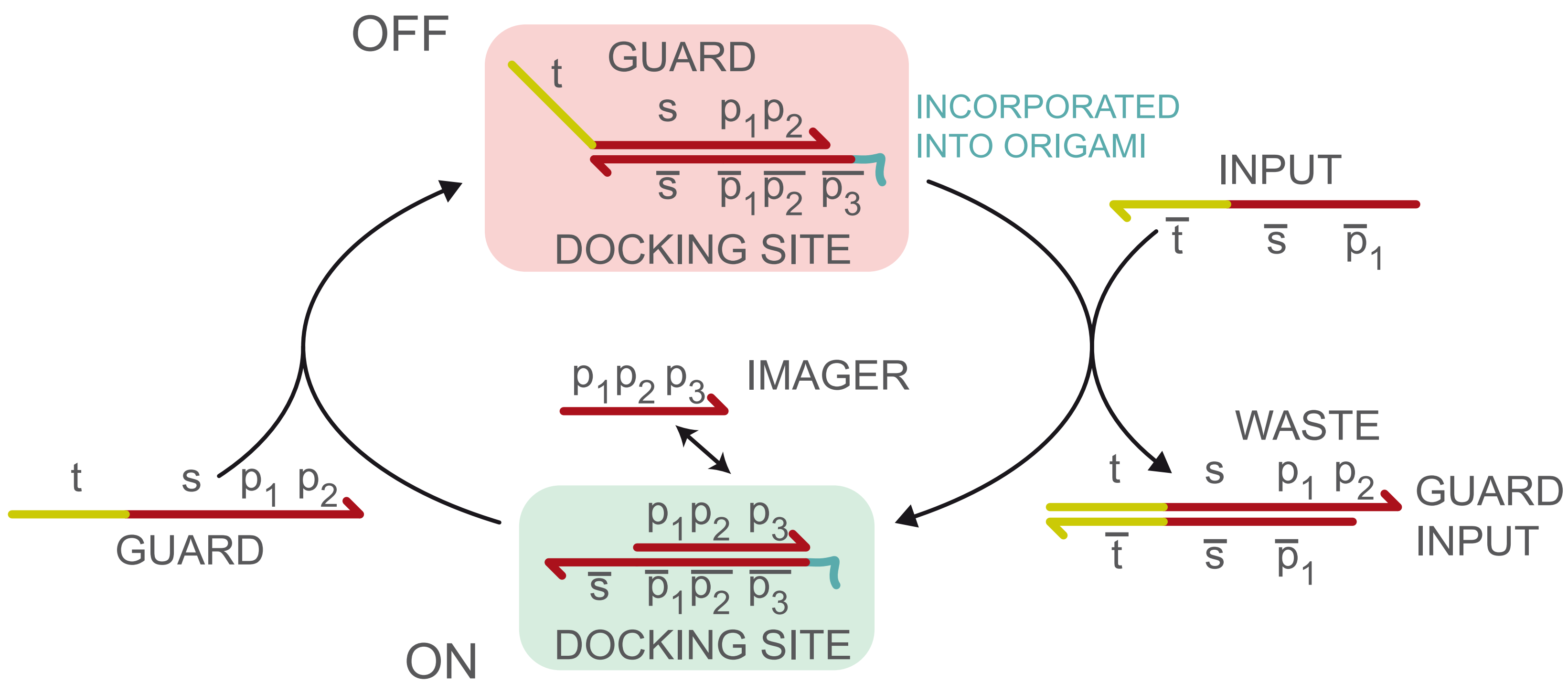
TIRF and DNA PAINT on lithographic origami arrays

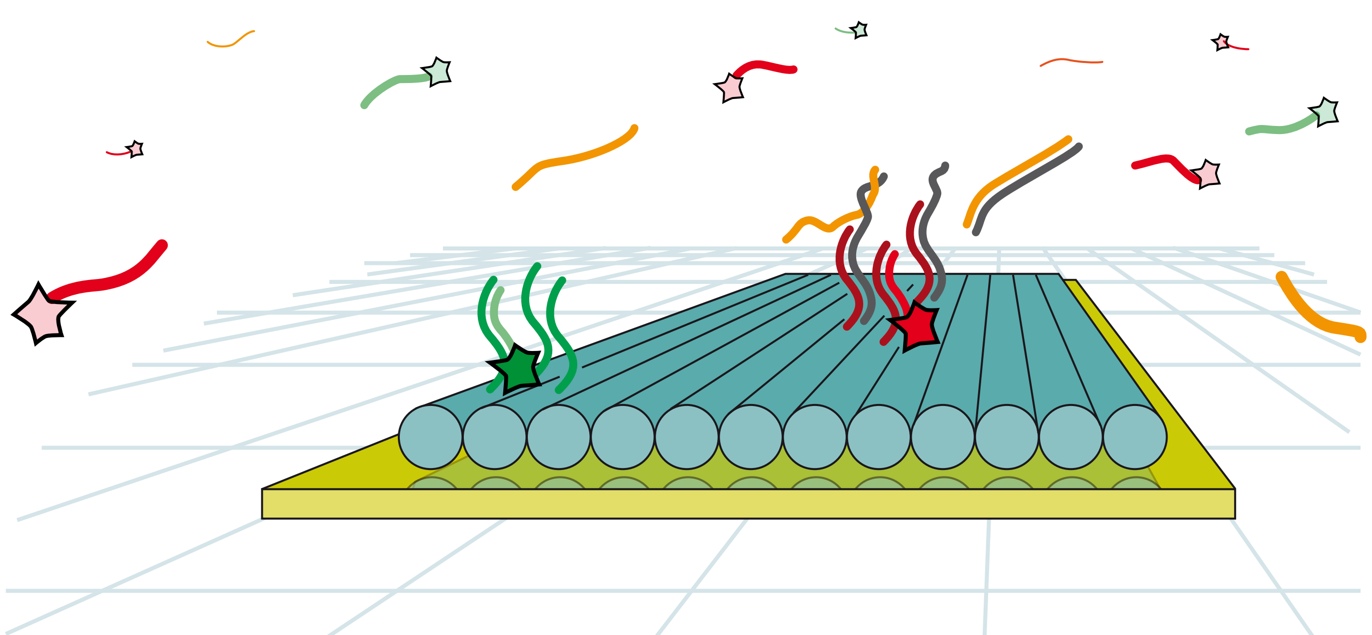


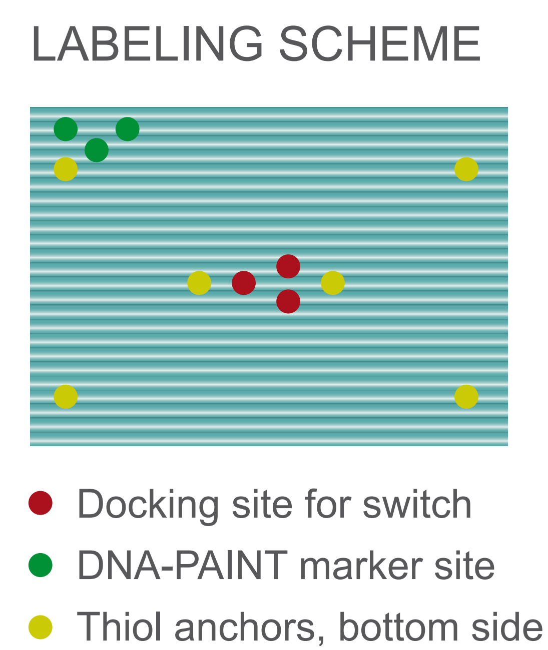




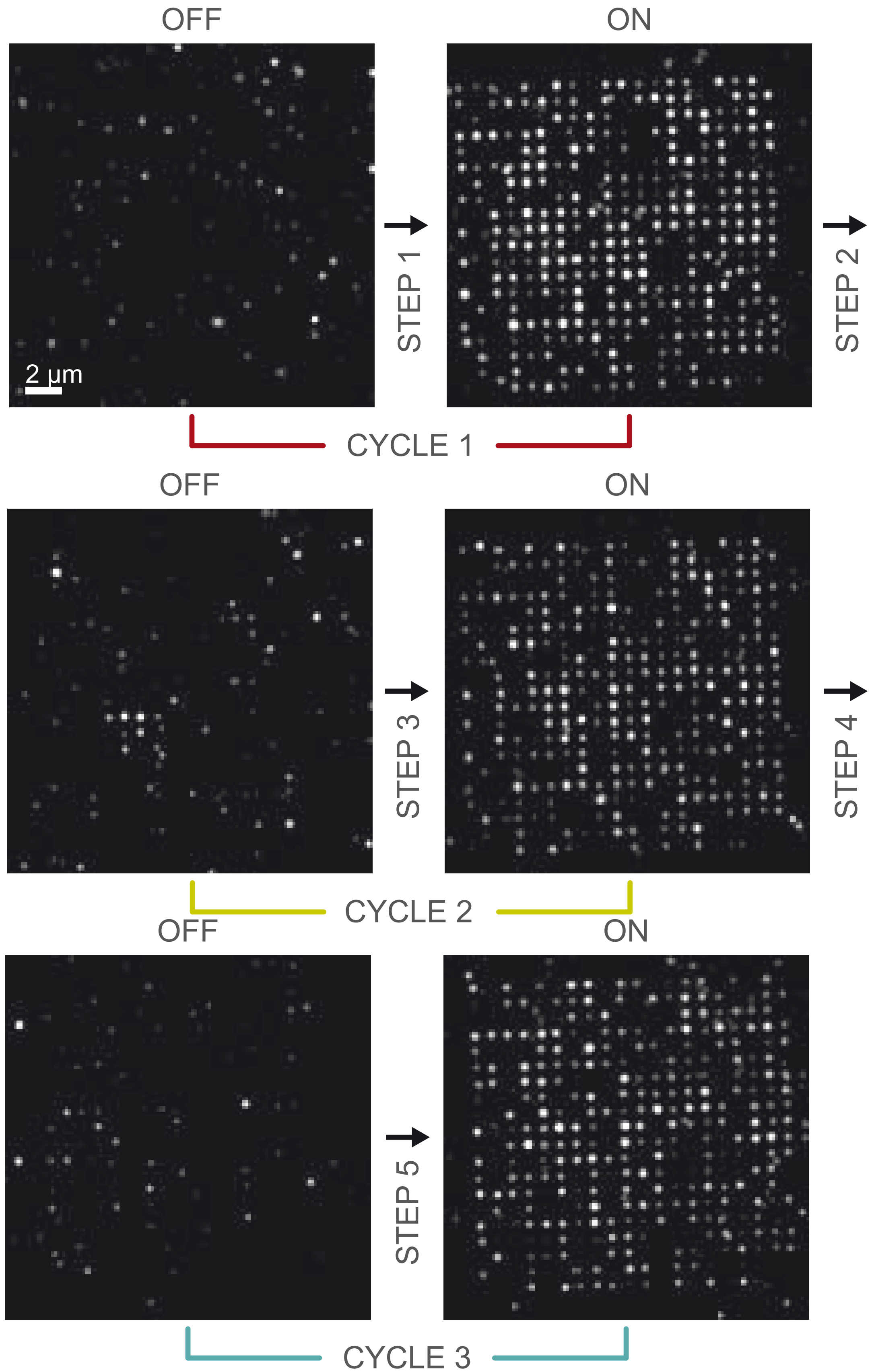
Strand displacement on origami arrays

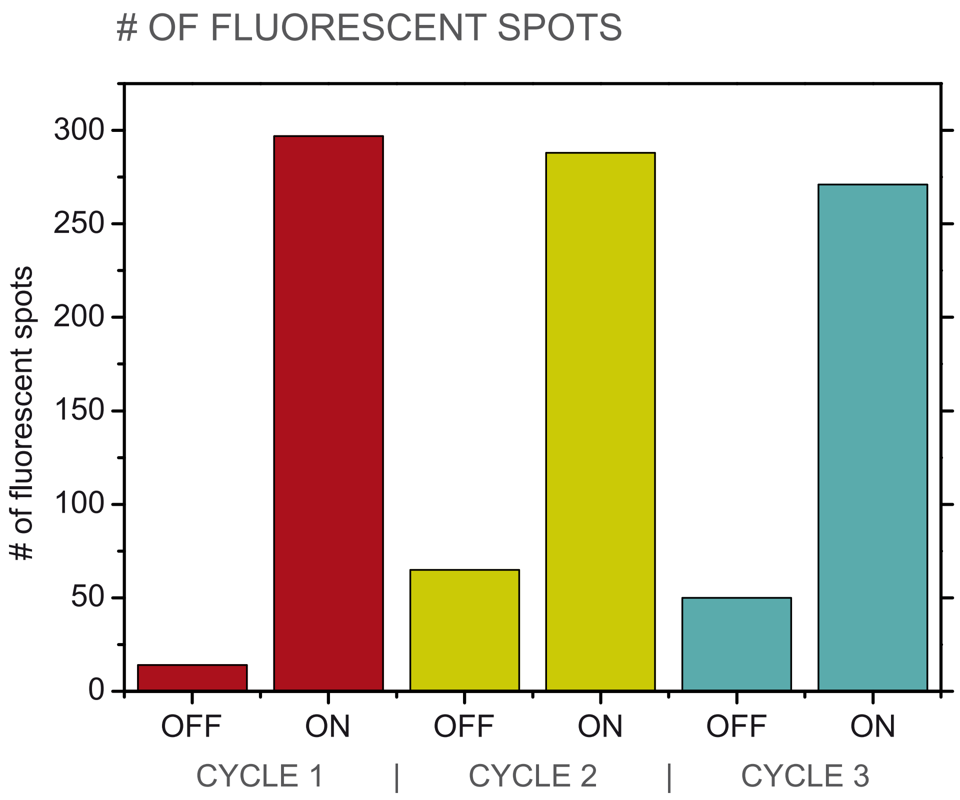


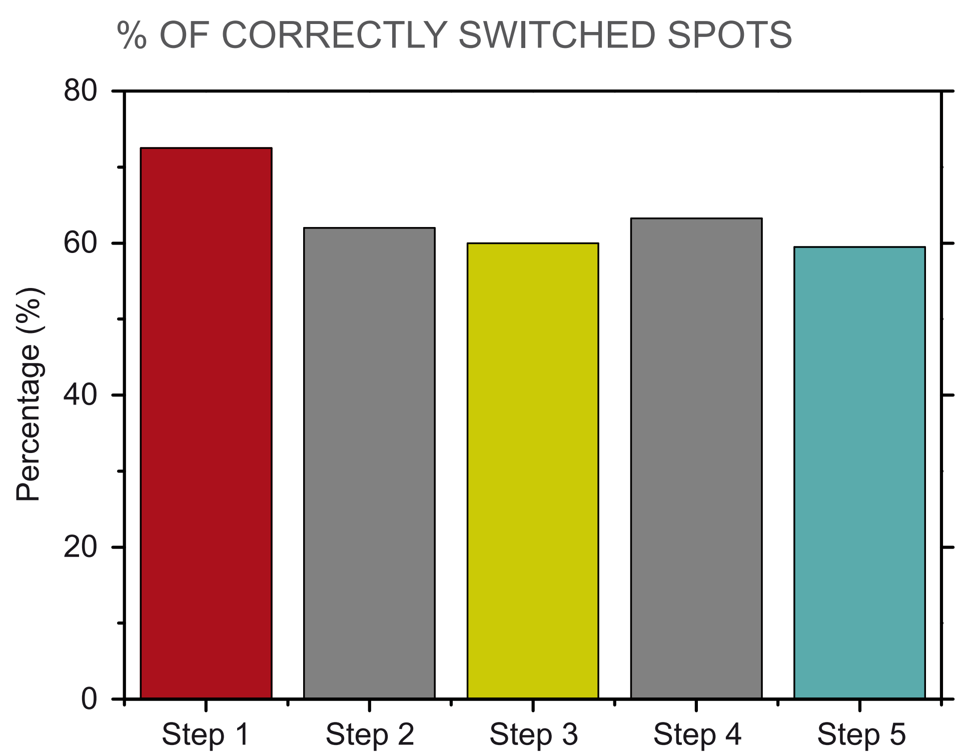




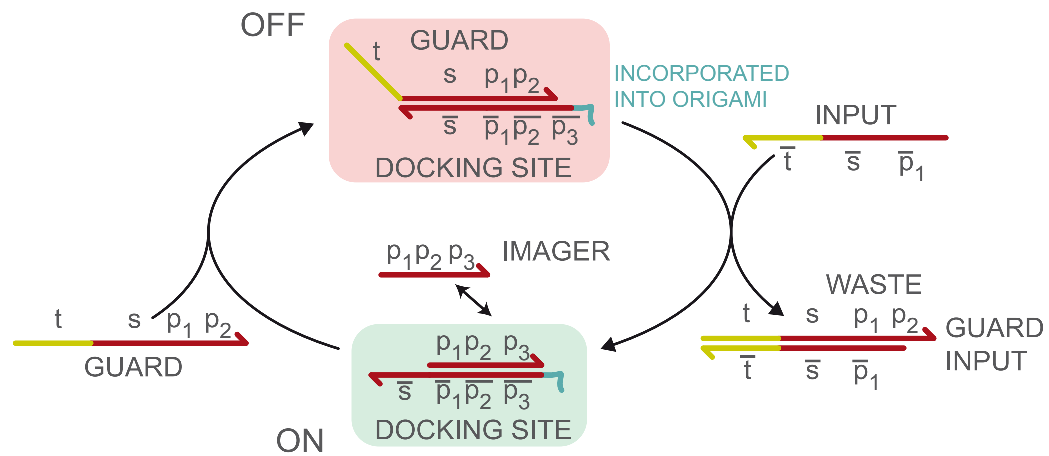
Strand displacement on origami arrays

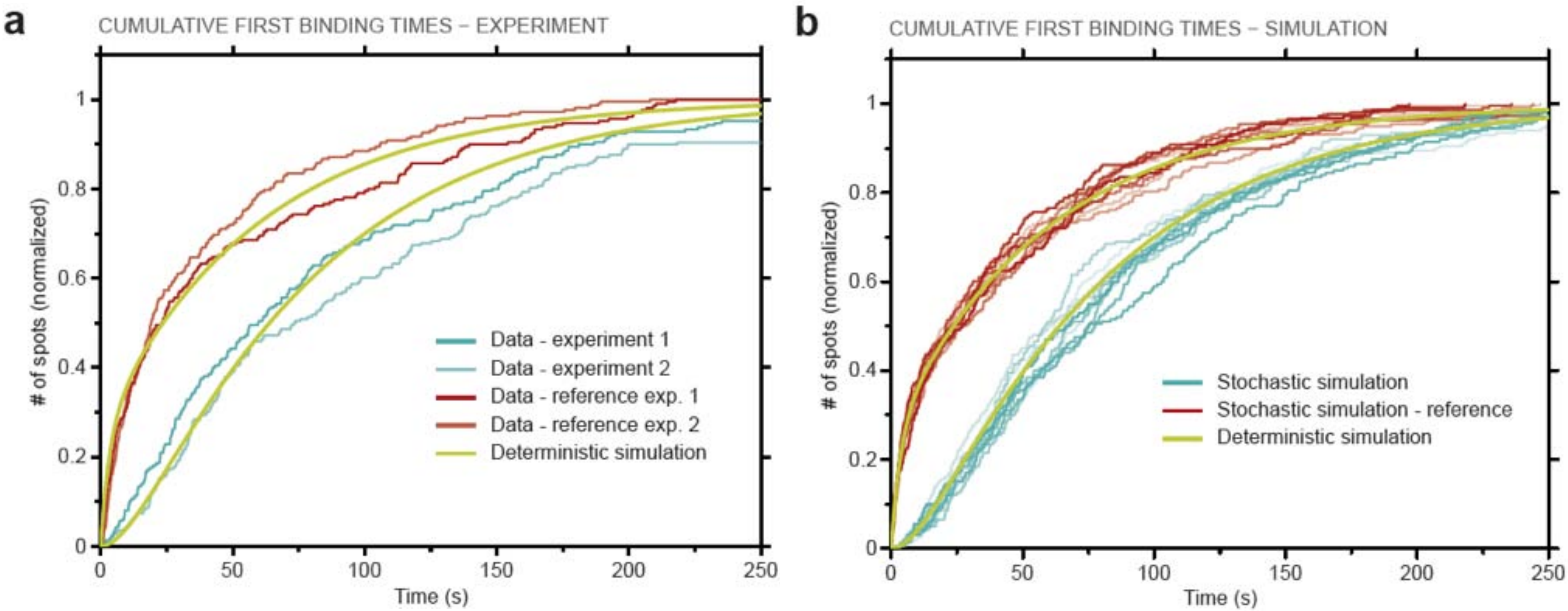






Kinetics of strand displacement on the array





(simulations with Visual DSD)

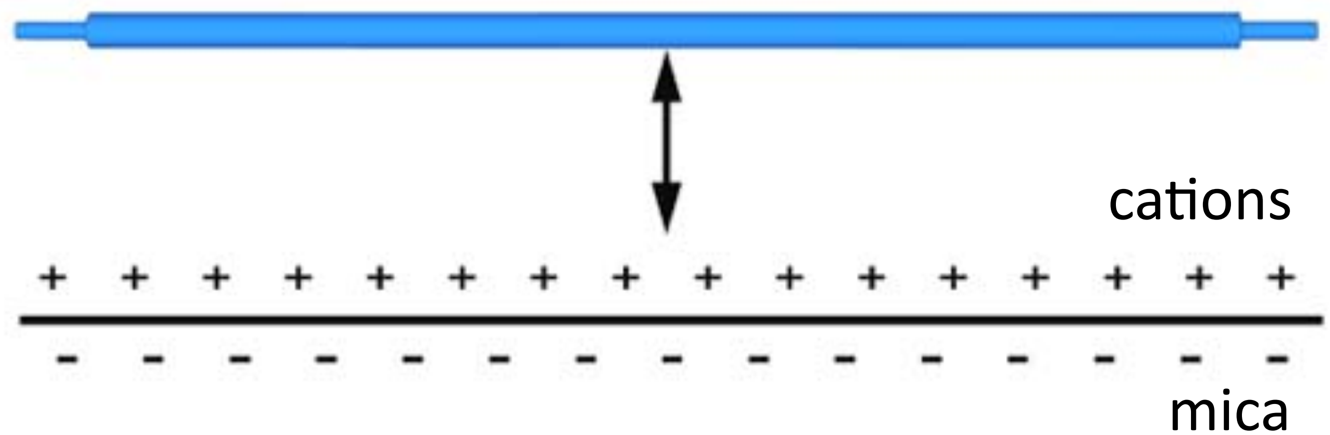
Phillips, A. & Cardelli, L. A programming language for composable DNA circuits. *Journal of The Royal Society Interface* **6**, S419-S436 (2009).

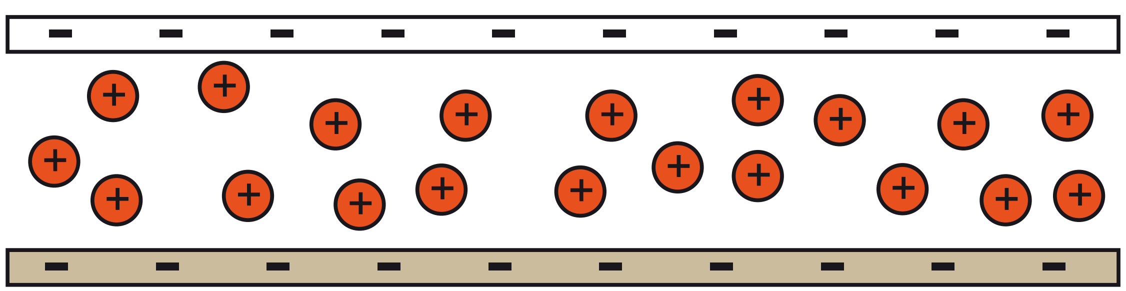
Large scale assembly of DNA origami tiles on surfaces

Ali Aghebat Rafat, Tobias Pirzer, Max Scheible, Anna Kostina

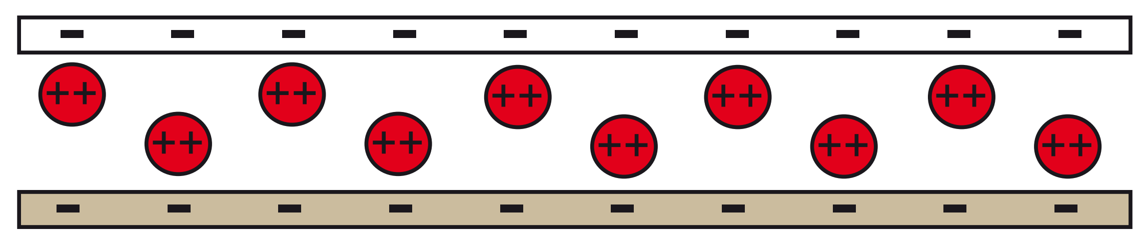
A. Aghebat Rafat, T. Pirzer, M.B. Scheible, A. Kostina, F.C. Simmel, Angewandte Chemie Int. Ed., **53** (29), 7665-7668 (2014)

DNA on mica surfaces



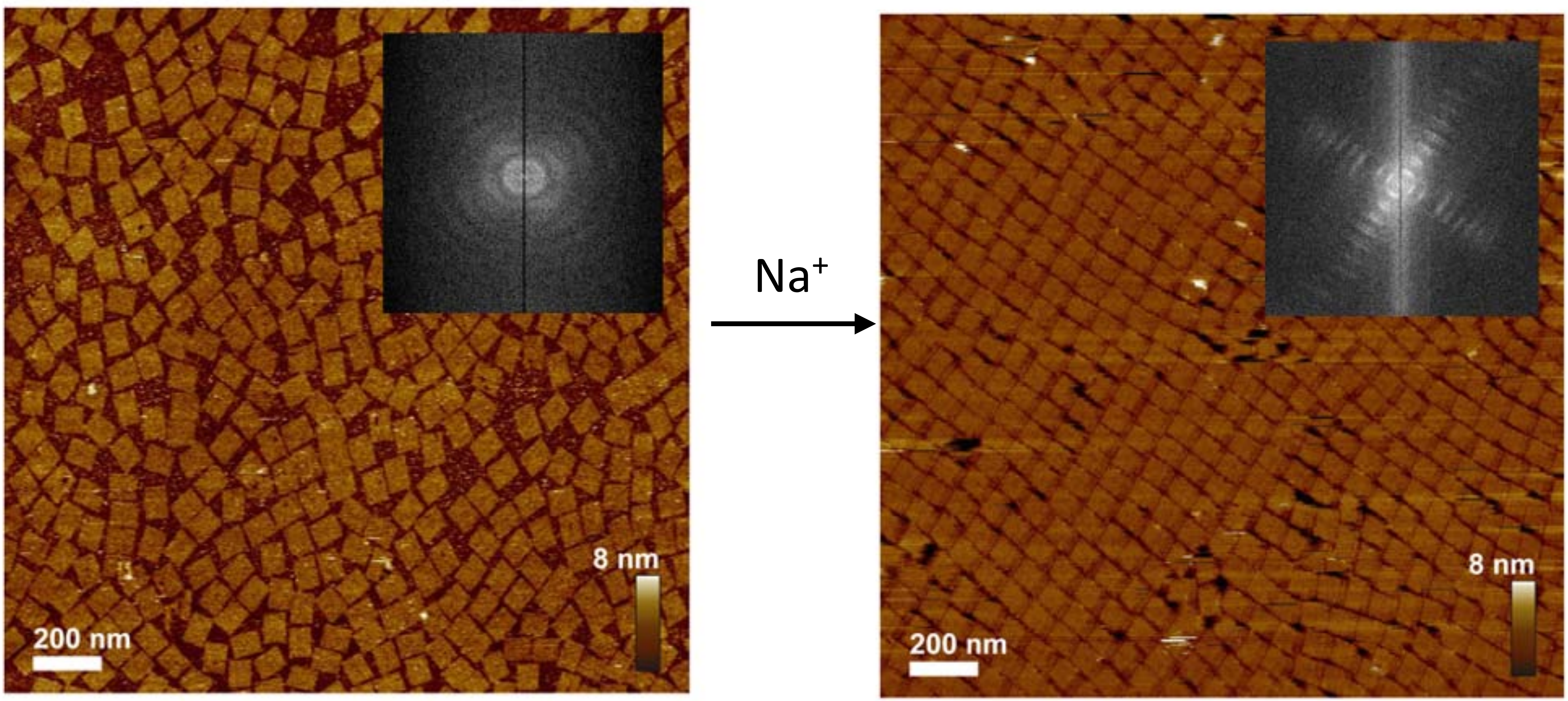


monovalent cations

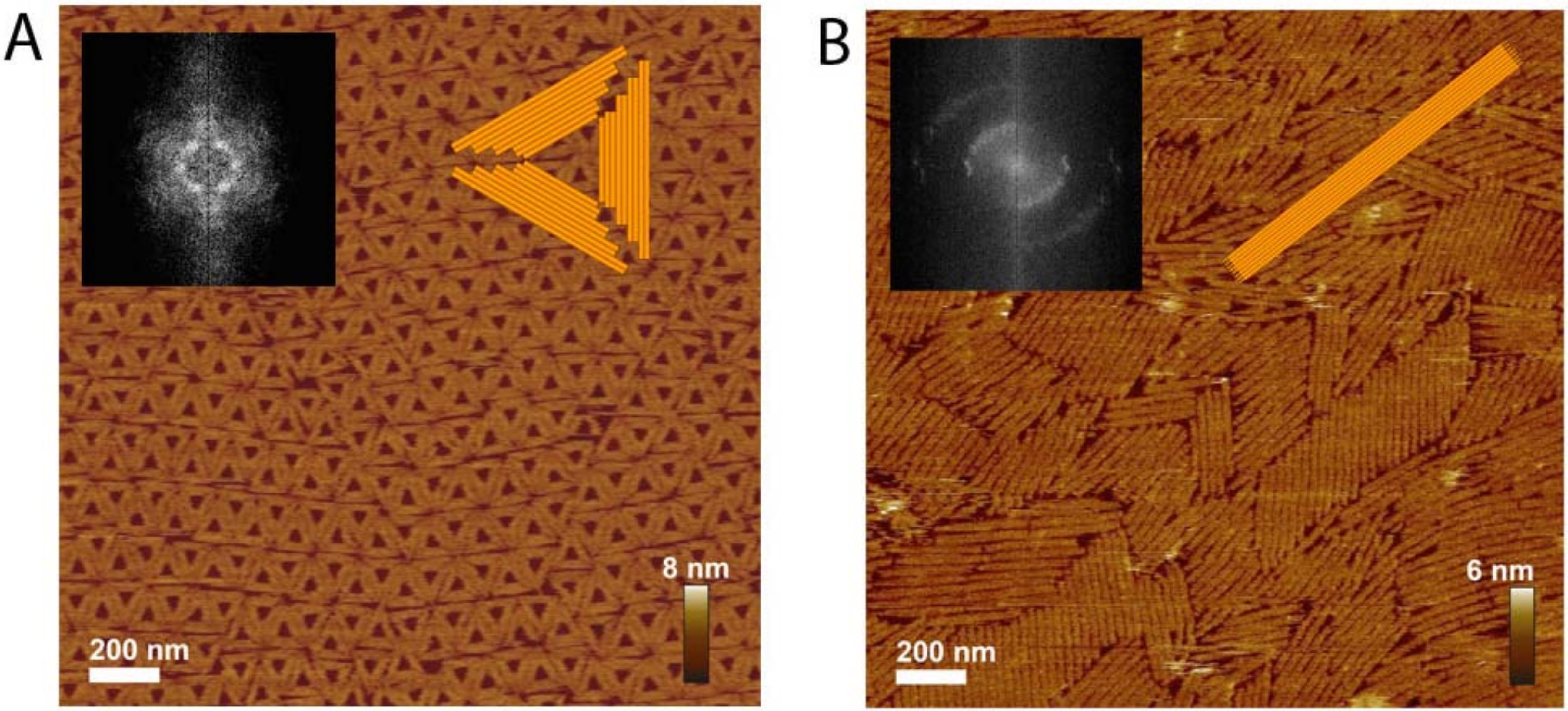


divalent cations

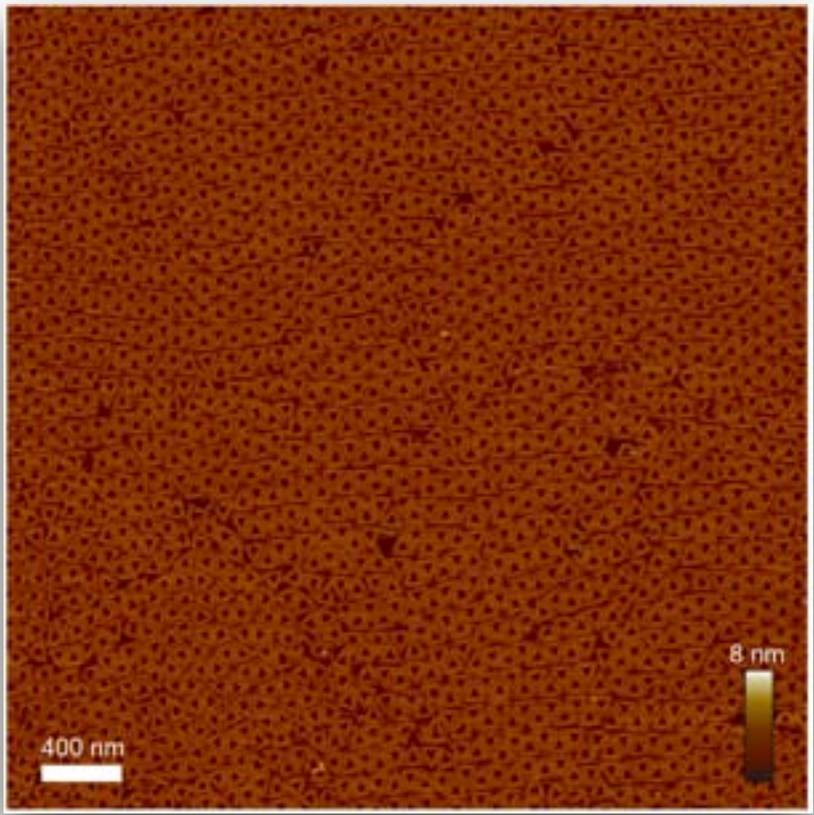
Surface-assisted arrangement of DNA origami tiles



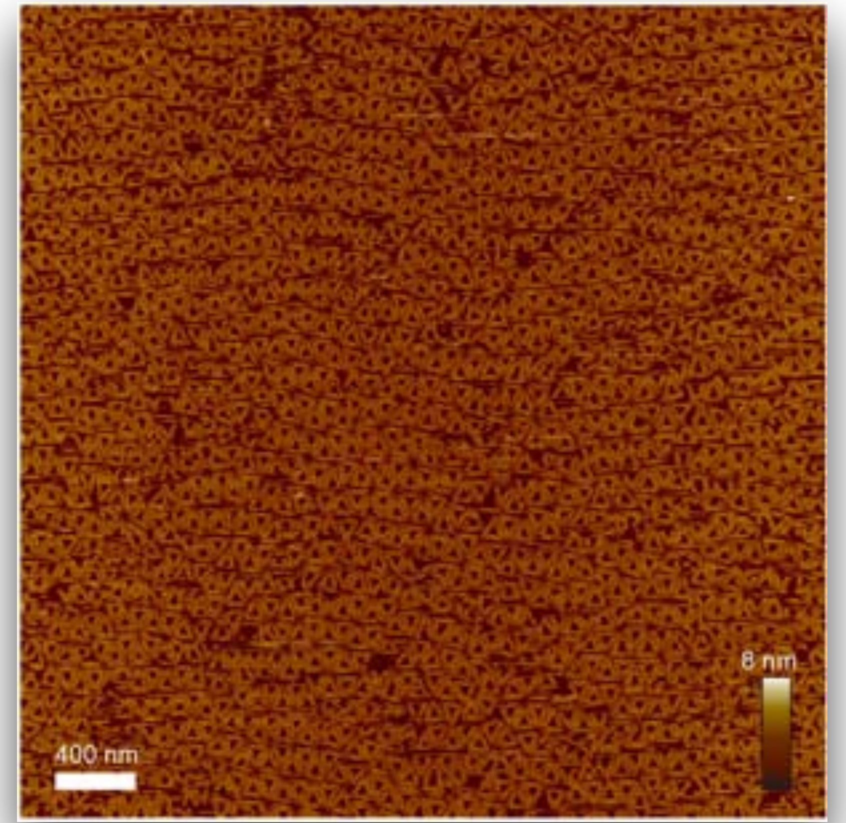
Surface-assisted arrangement of DNA origami tiles



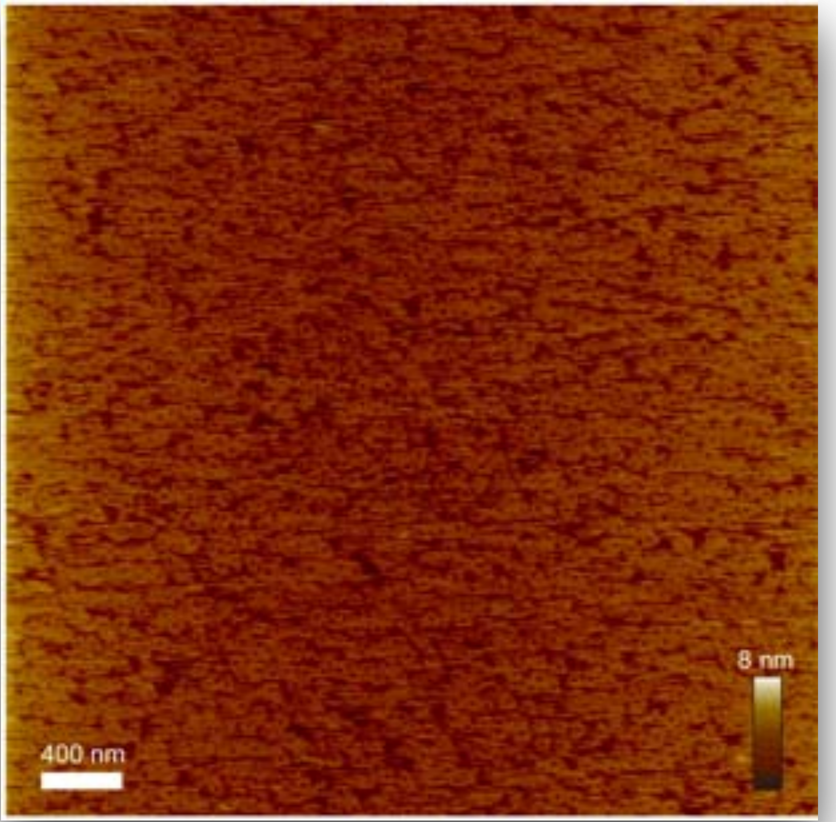
Surface-assisted arrangement of DNA origami tiles



[Na+]=100 mM



[Na+]=120 mM



[Na+]=200 mM

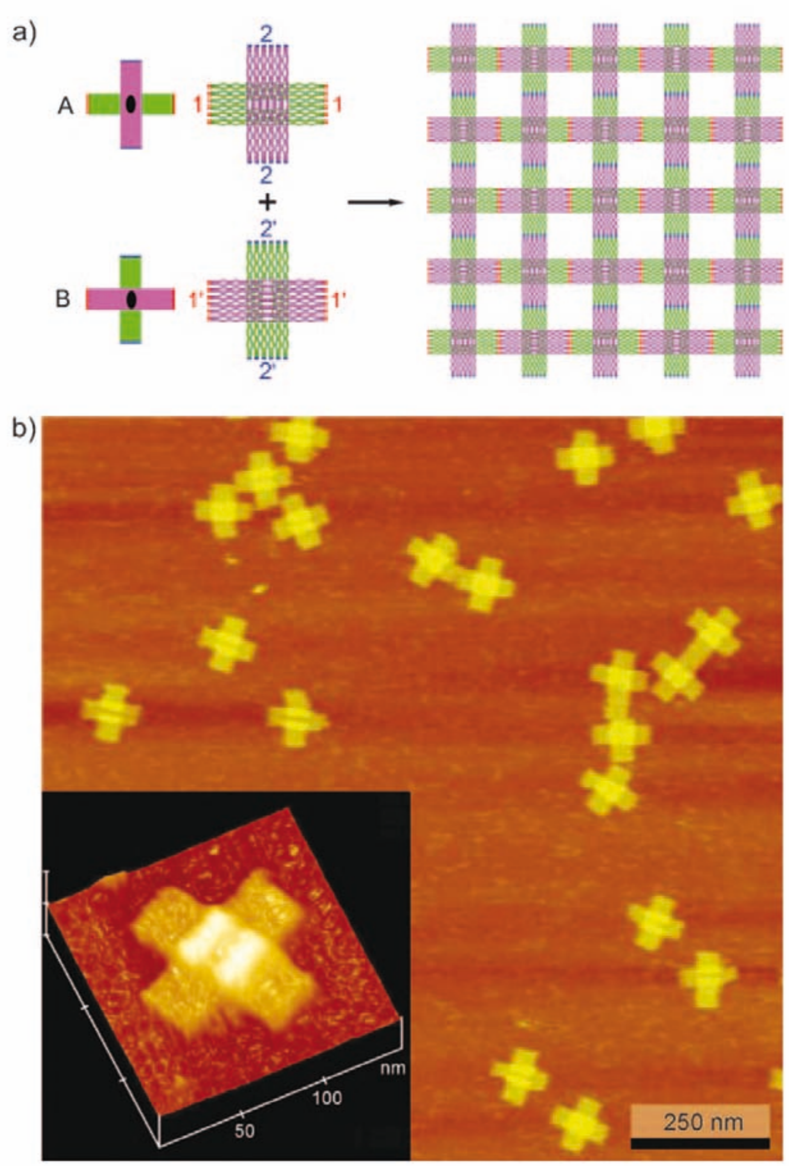
Cross-shaped DNA origami tiles

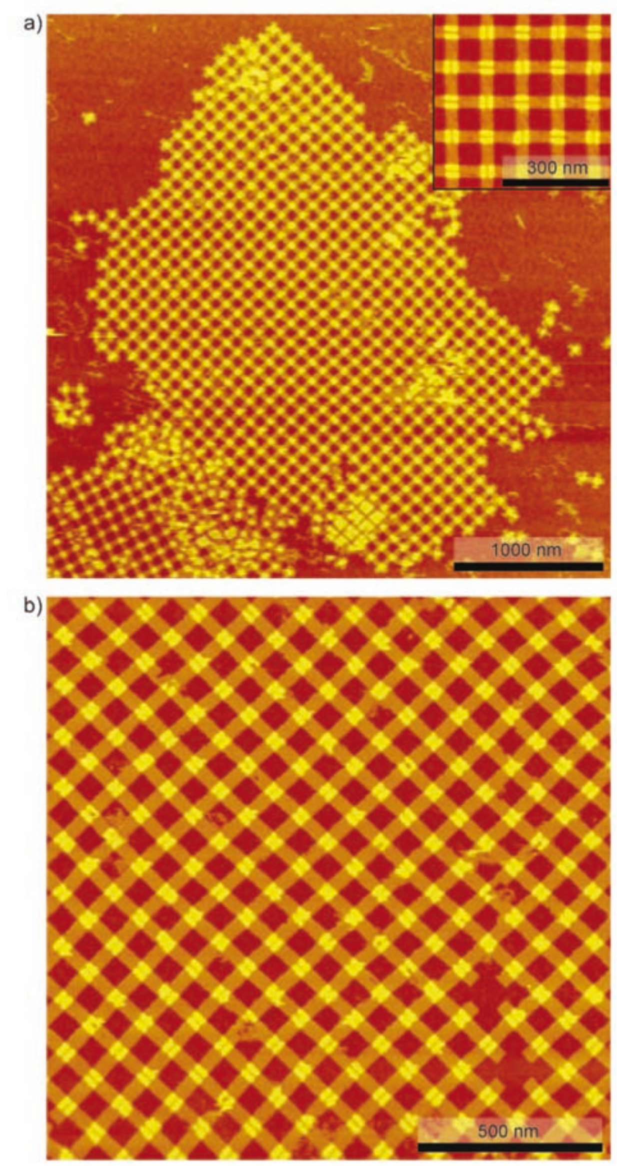
DNA Nanotechnology

DOI: 10.1002/anie.201005911

Crystalline Two-Dimensional DNA-Origami Arrays**

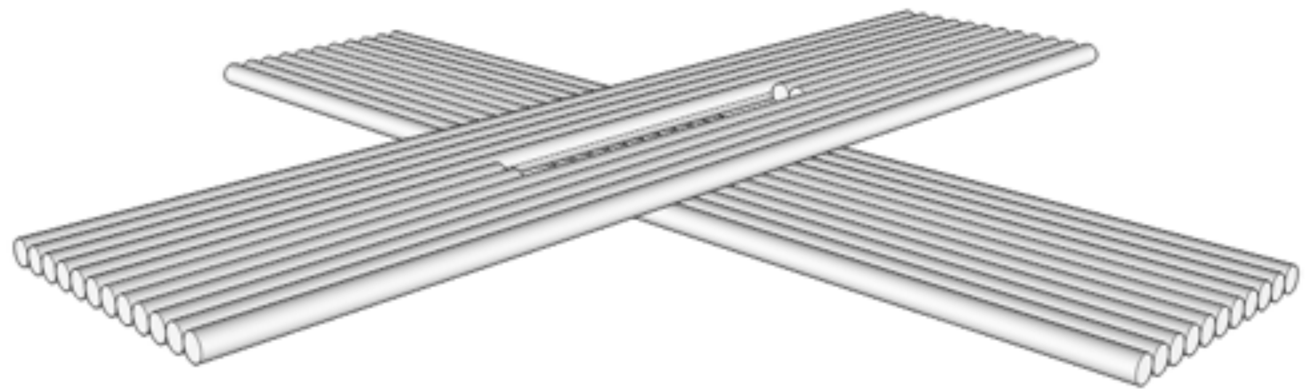
*Wenyan Liu, Hong Zhong, Risheng Wang, and Nadrian C. Seeman**



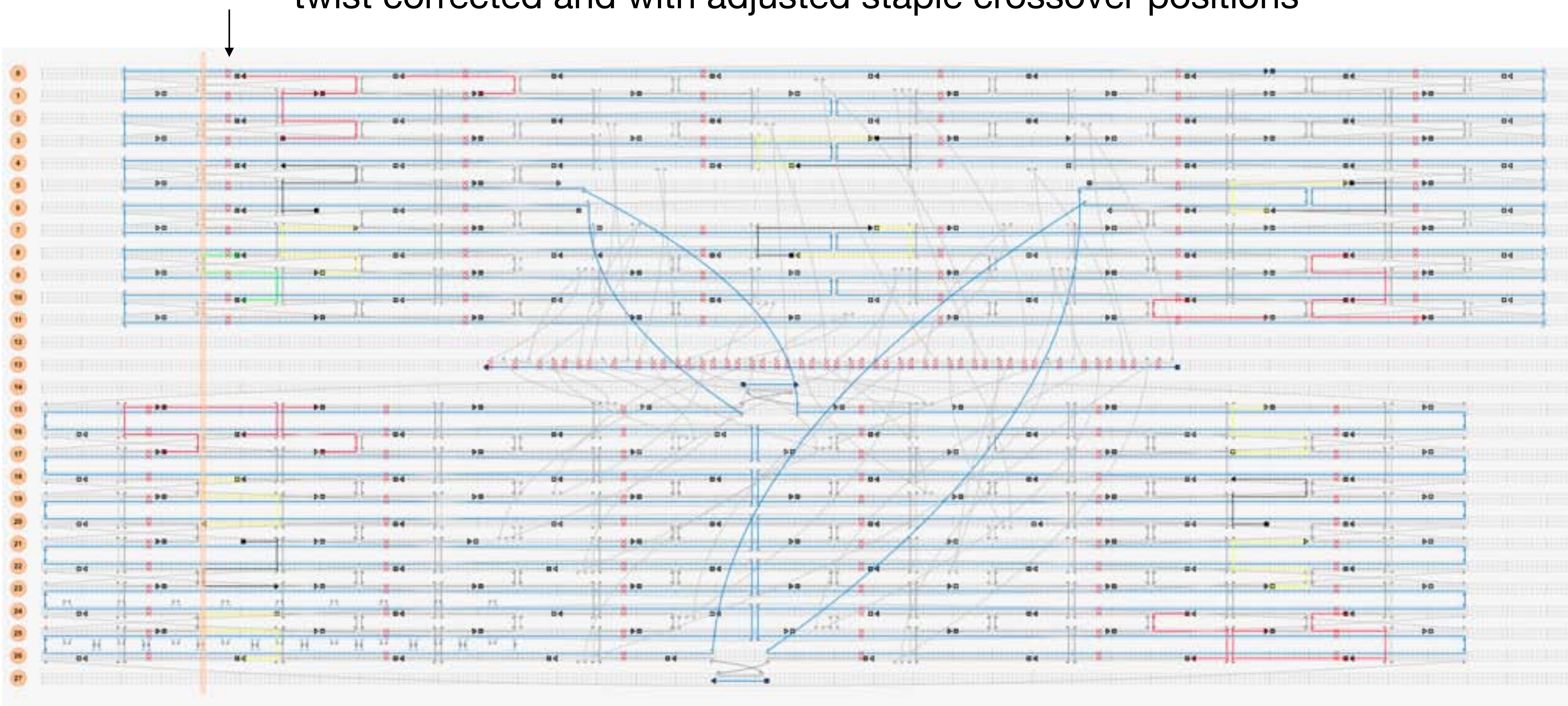


A DNA origami cross tile

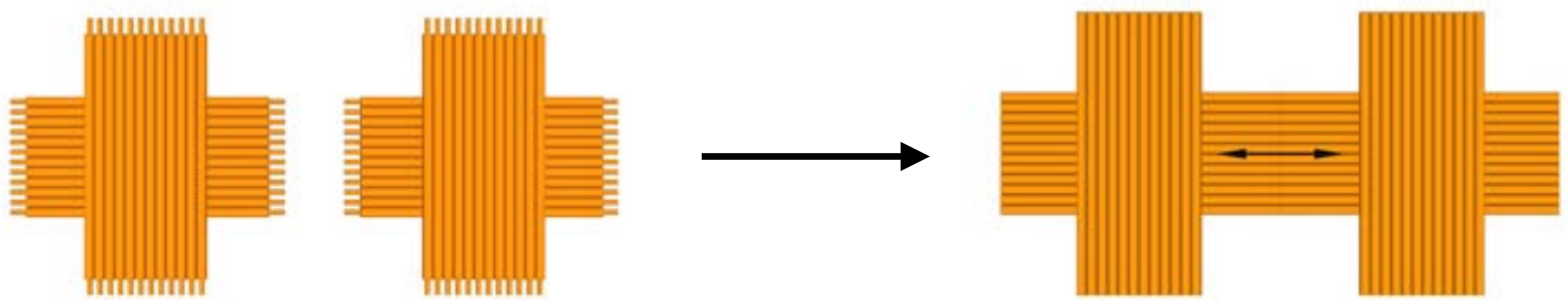
(cf. W. Liu, H. Zhong, R. Wang, N. C. Seeman, *Angewandte Chemie* 2011, *123*, 278-281)

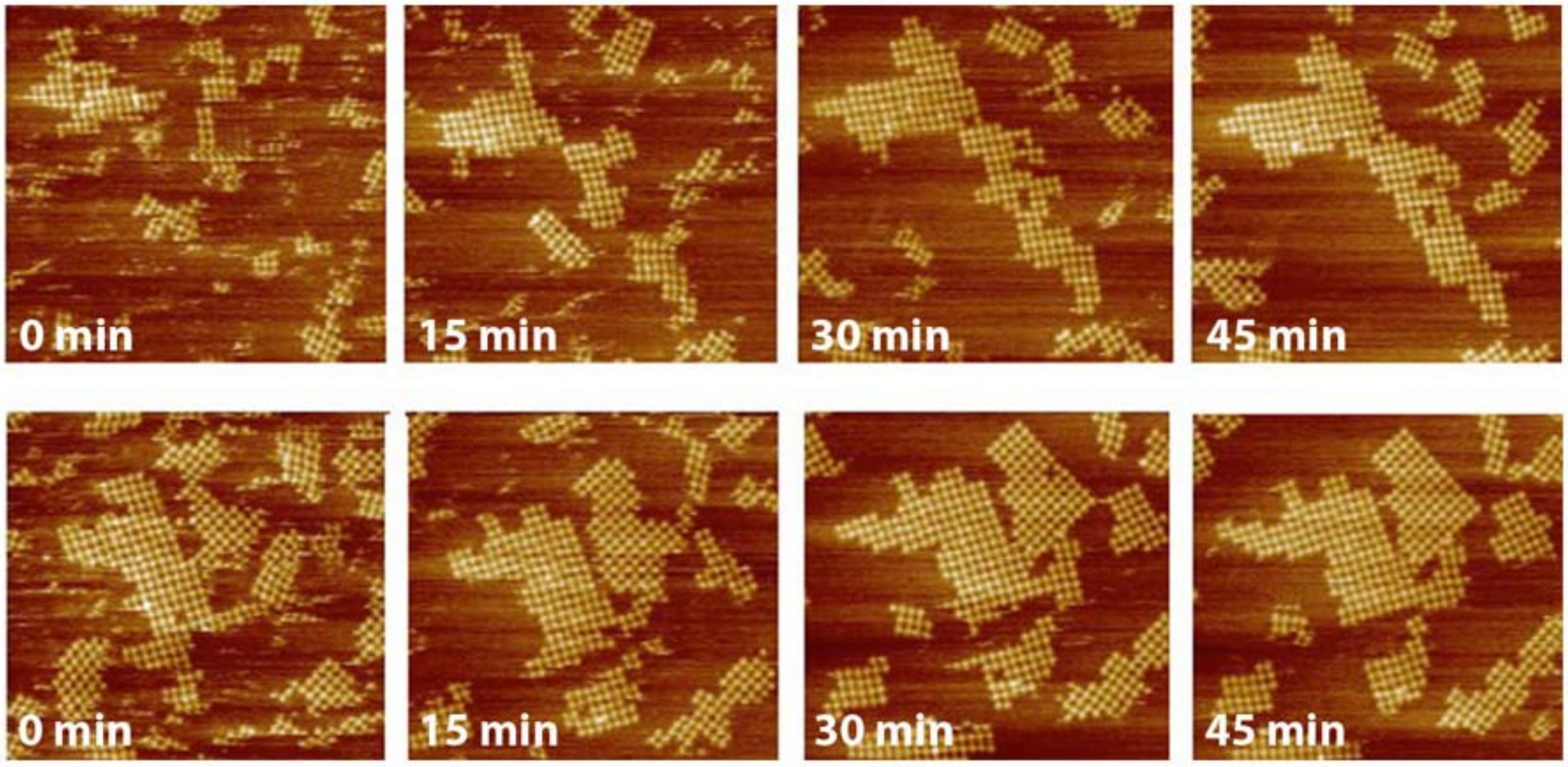


twist corrected and with adjusted staple crossover positions

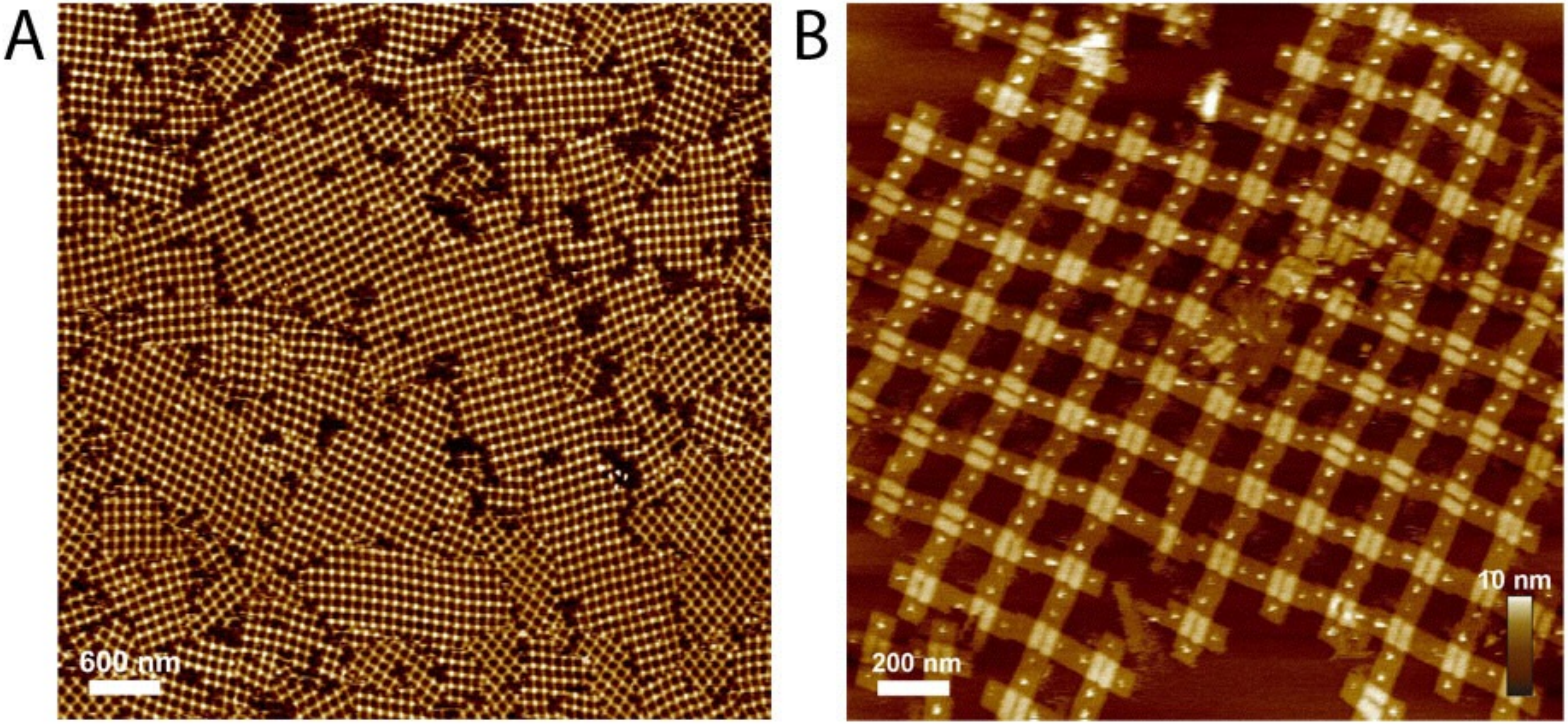


Utilizing stacking interactions

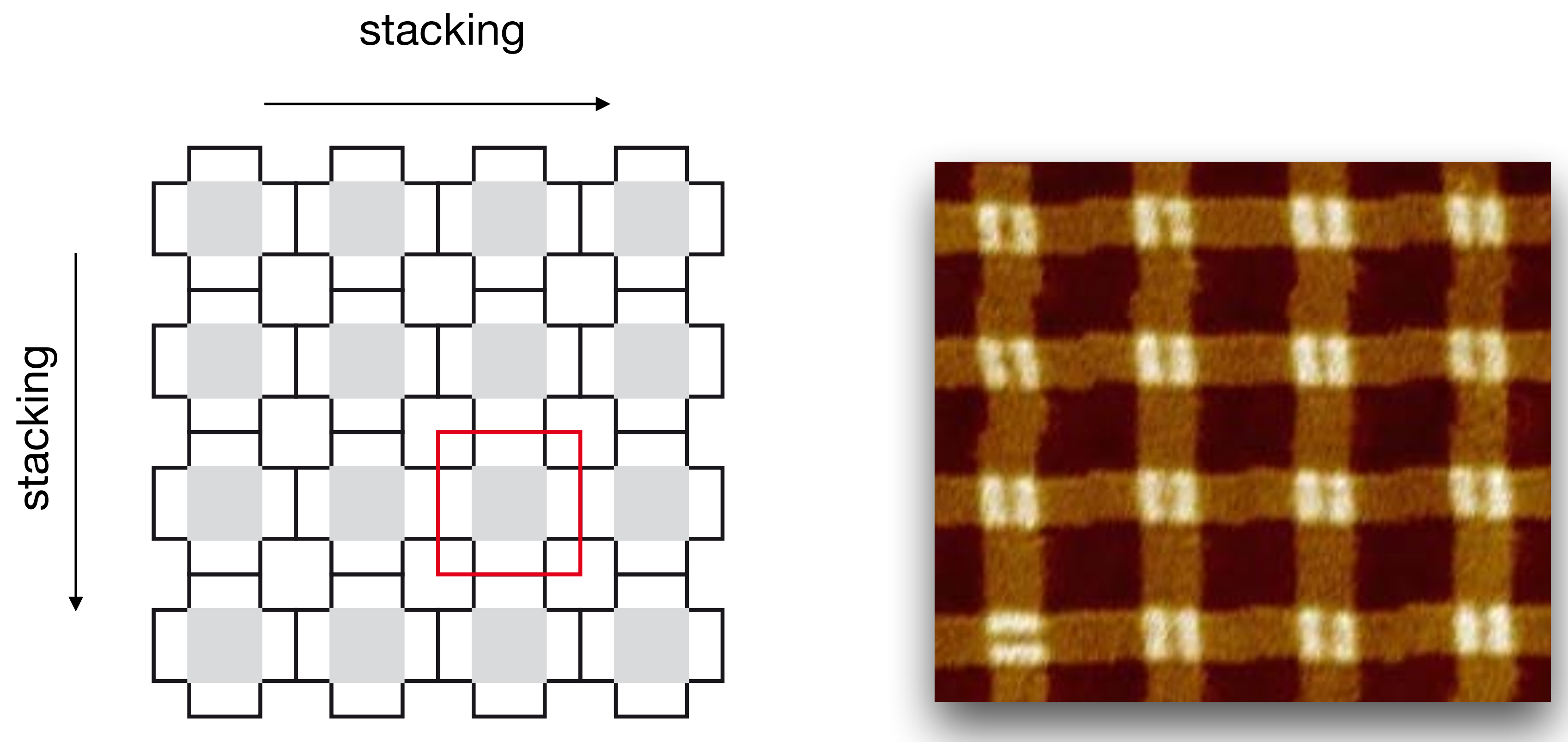


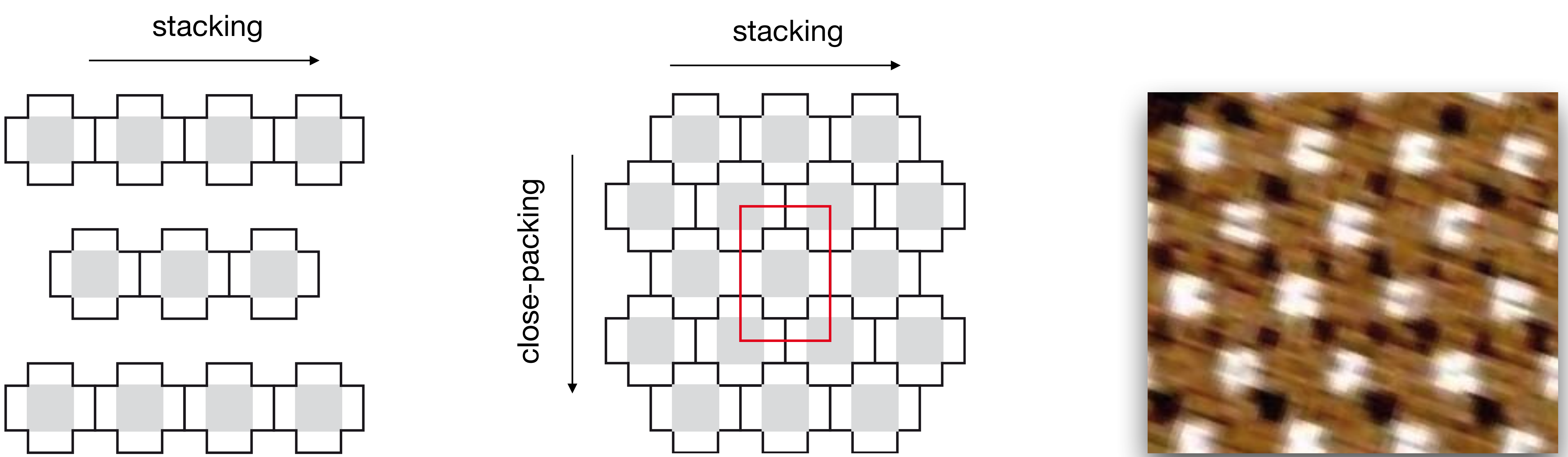


Utilizing stacking interactions

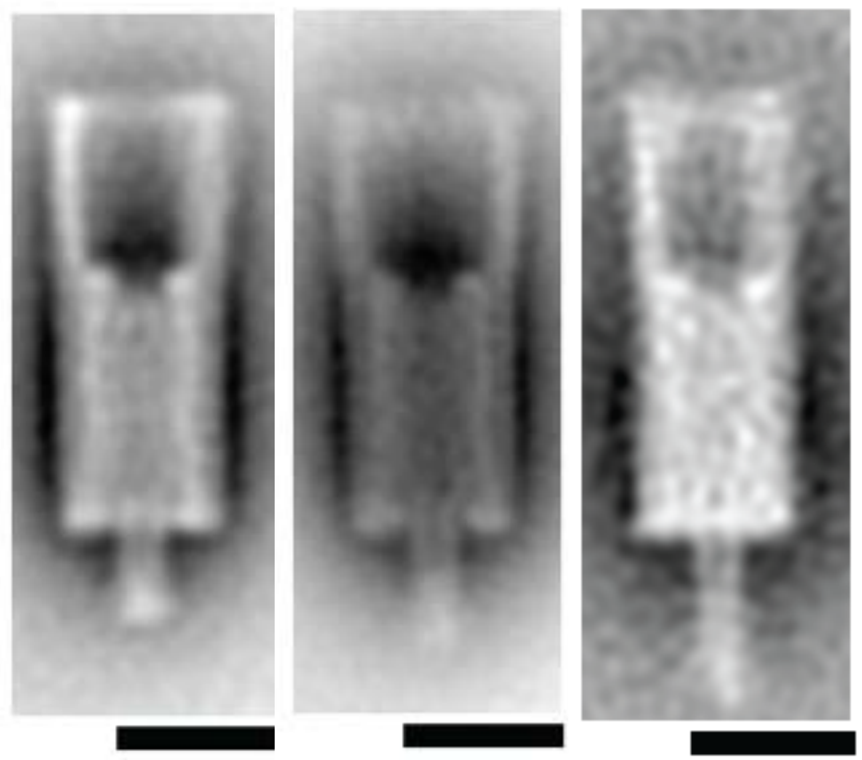


Surface-assisted arrangement of DNA origami tiles



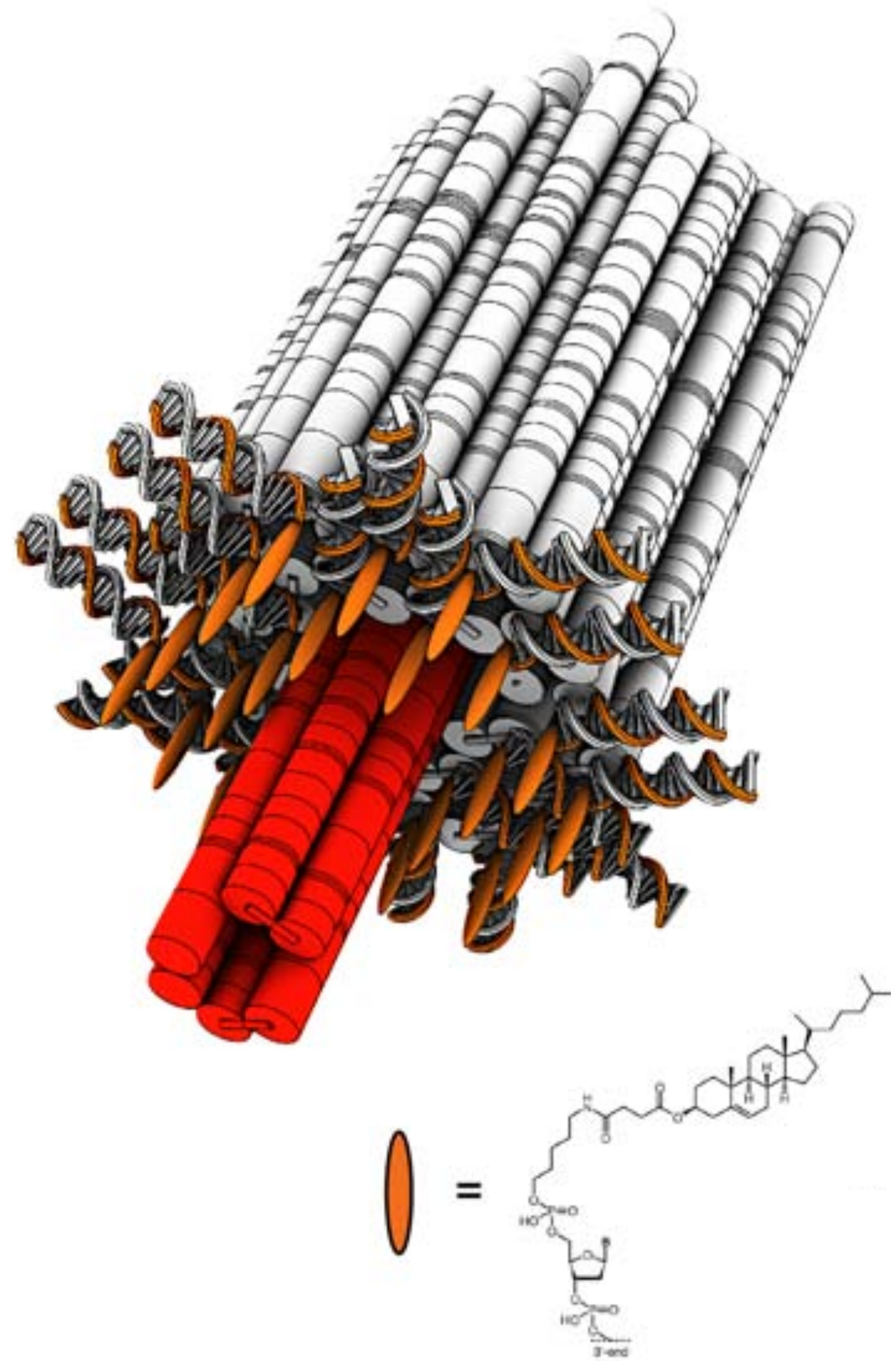


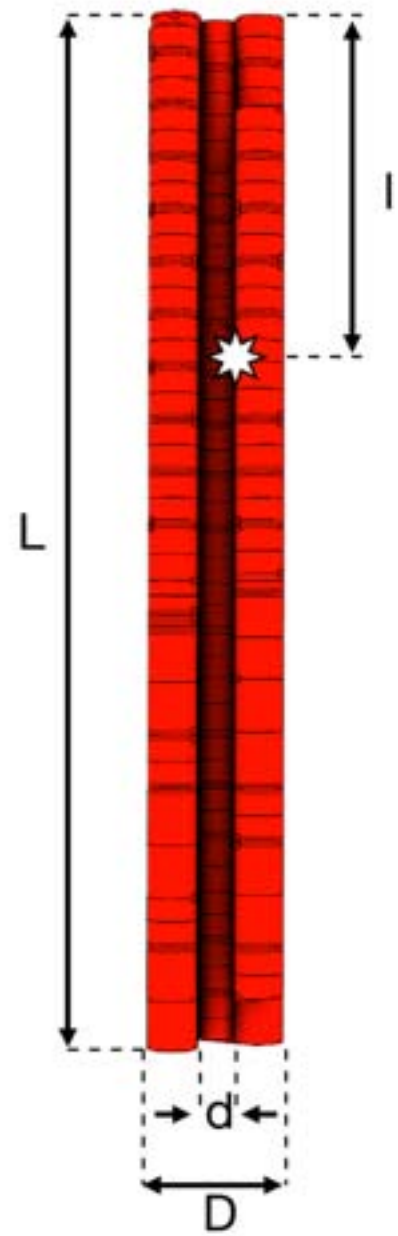
DNA-based membrane channels



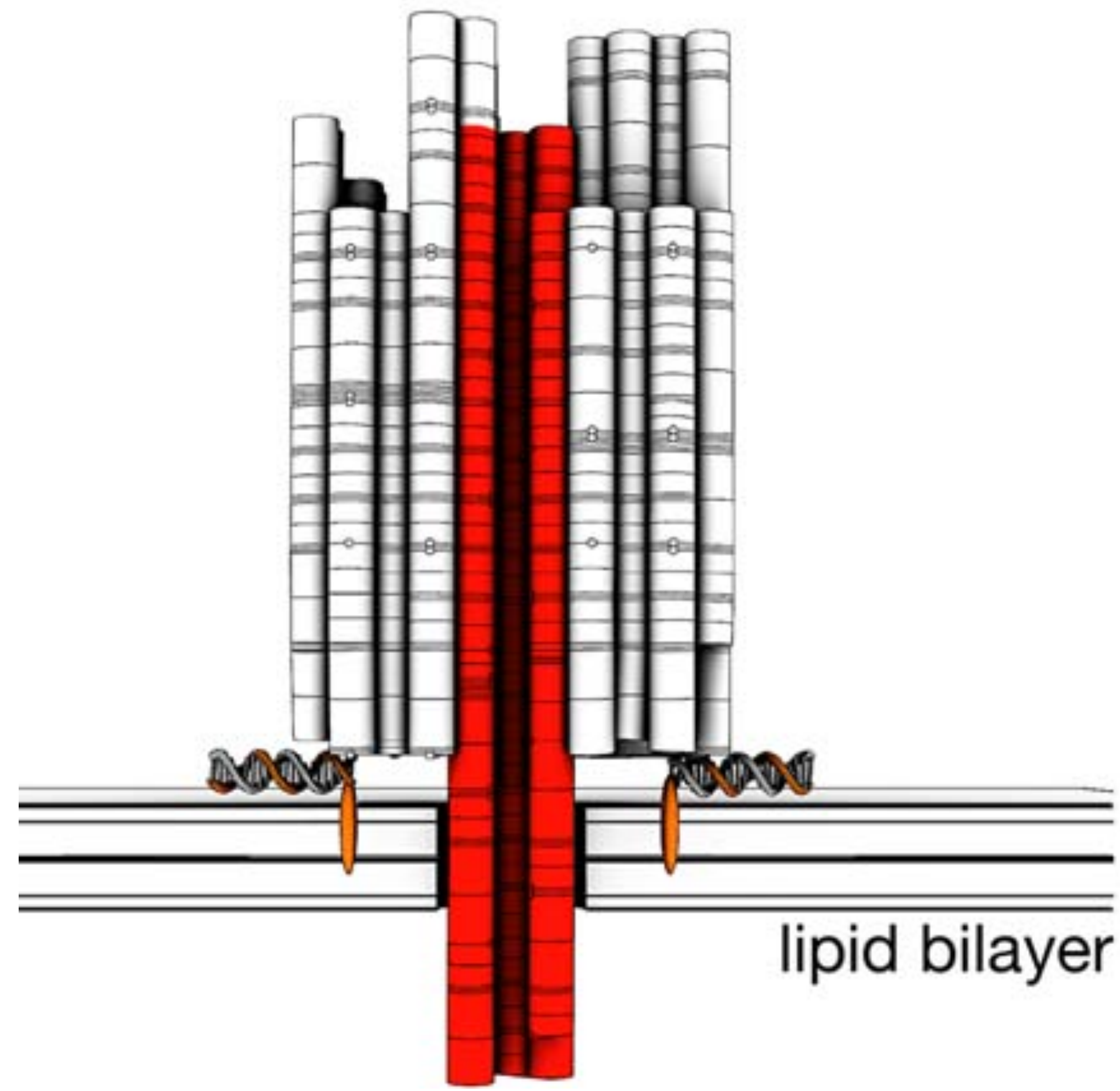
Langecker, M., Arnaut, V., Martin, T. G., List, J., Renner, S., Mayer, M., Dietz, H., Simmel, F. C.,
Synthetic Lipid Membrane Channels Formed by Designed DNA Nanostructures, *Science* **338**, 932-936 (2012).

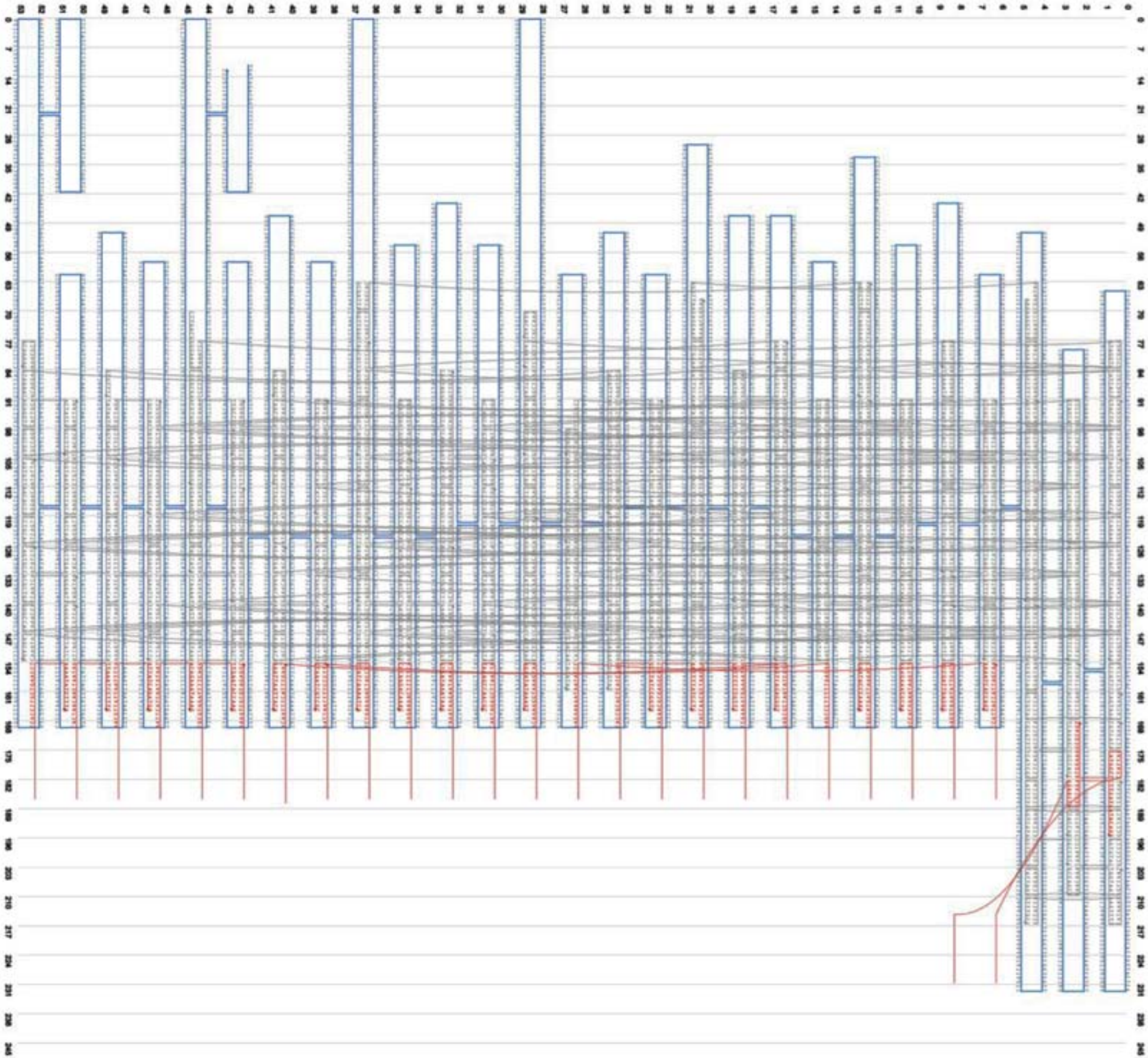
A synthetic membrane channel made from DNA



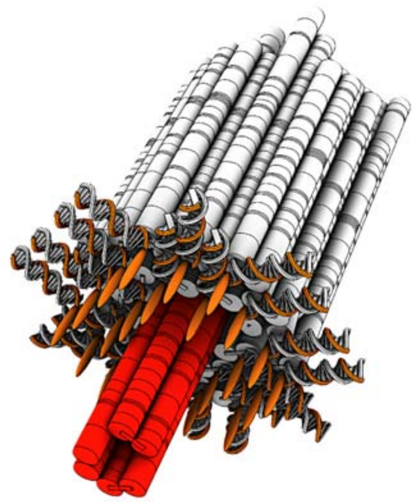


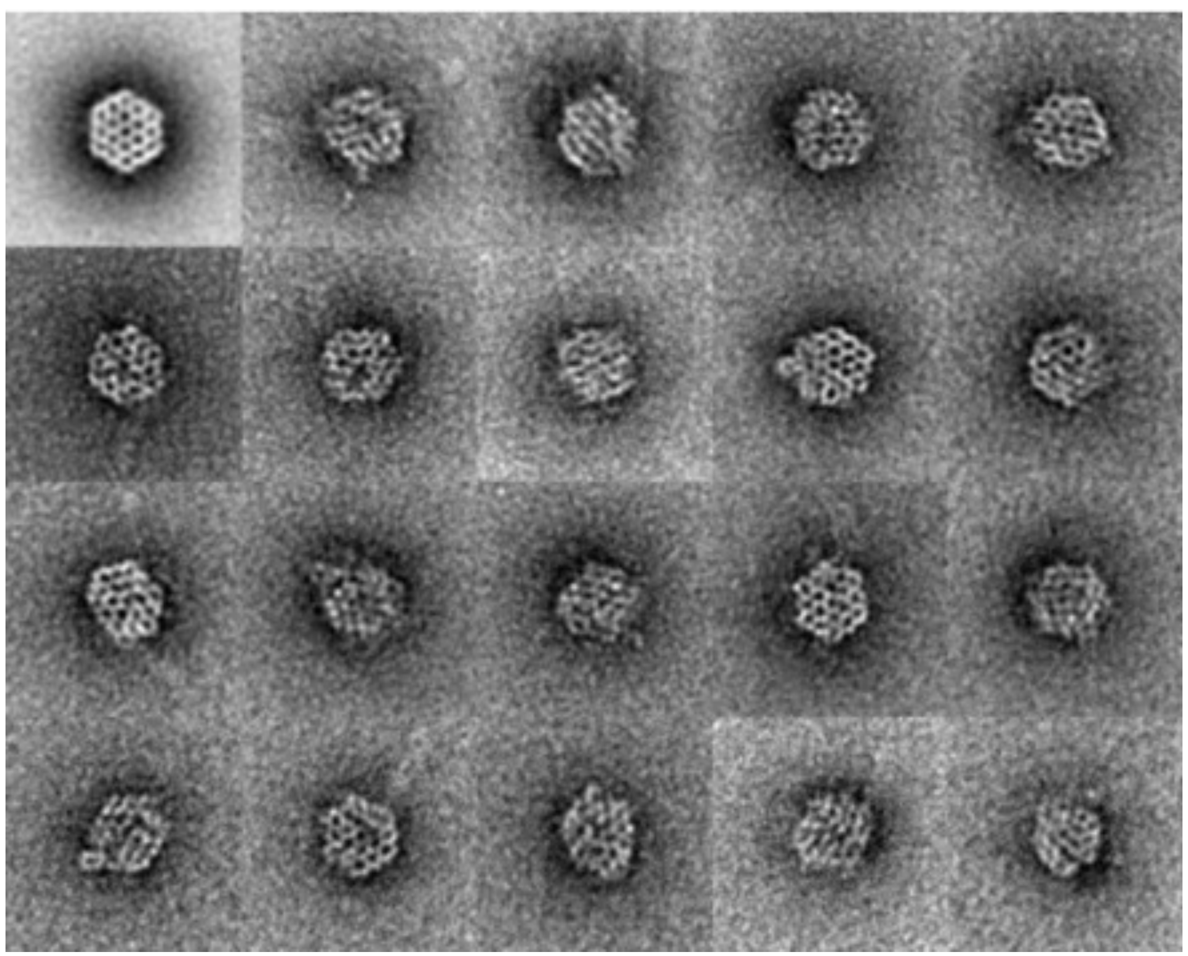
L=47 nm,D=6 nm,d=2 nm

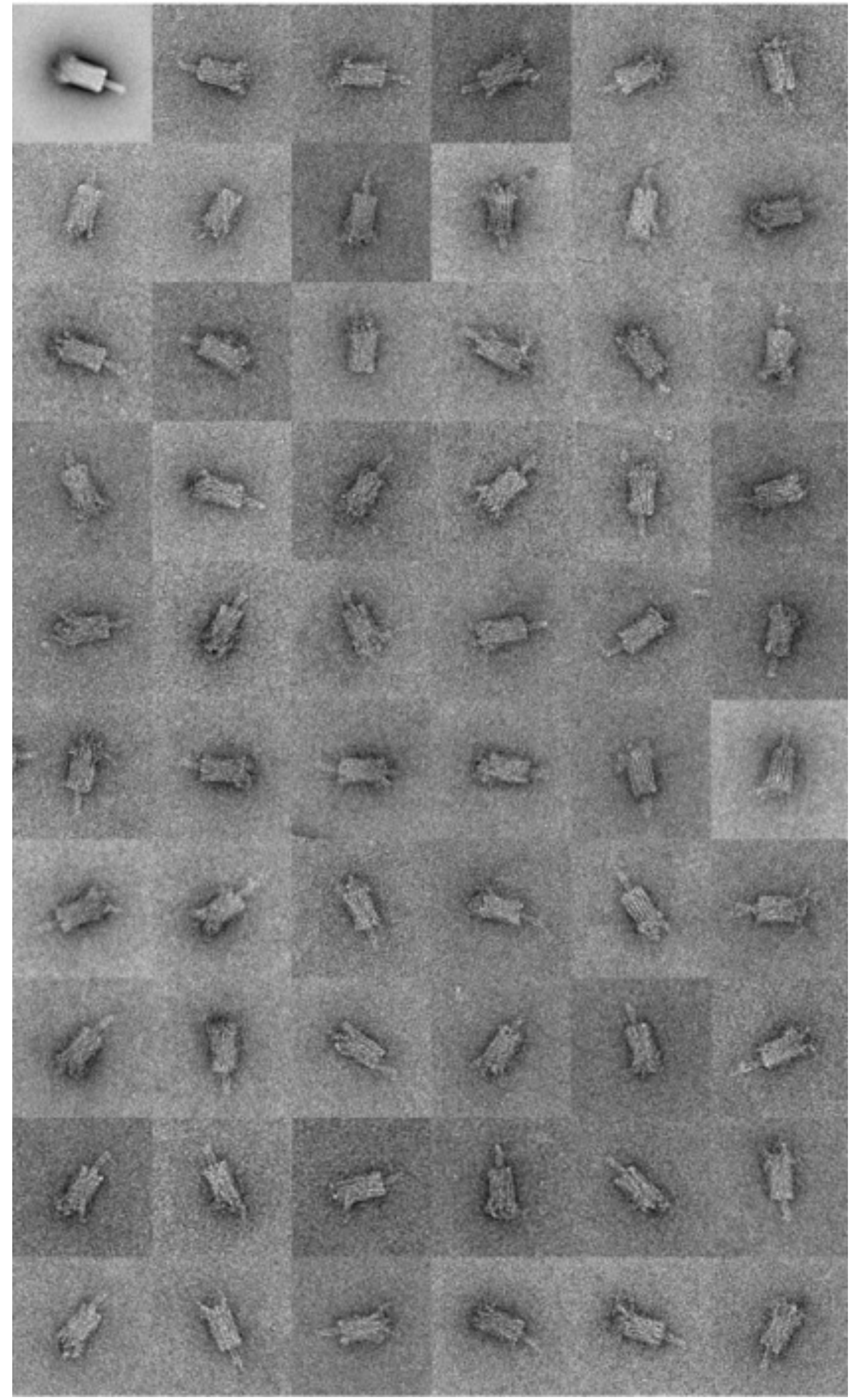




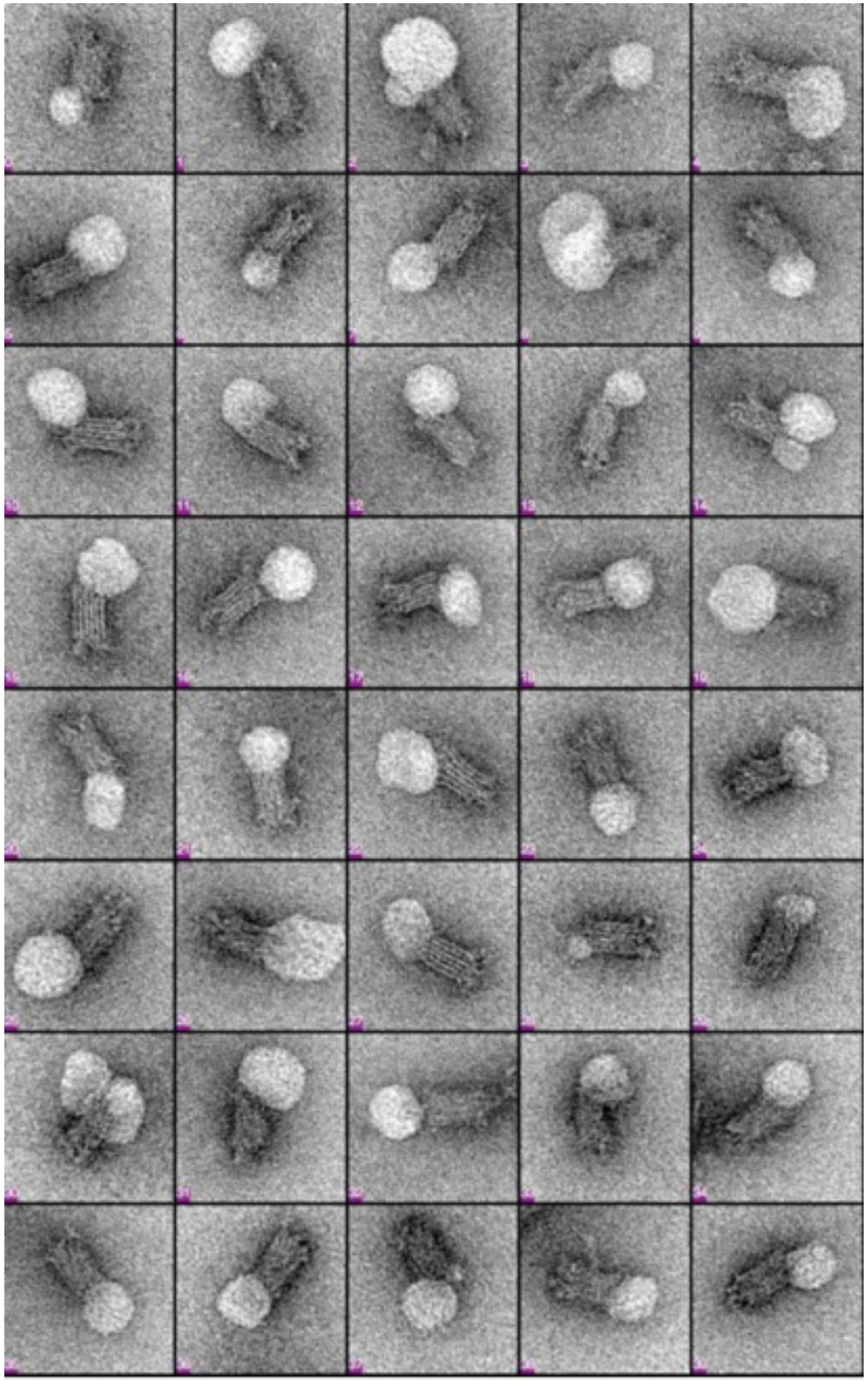
Quality control

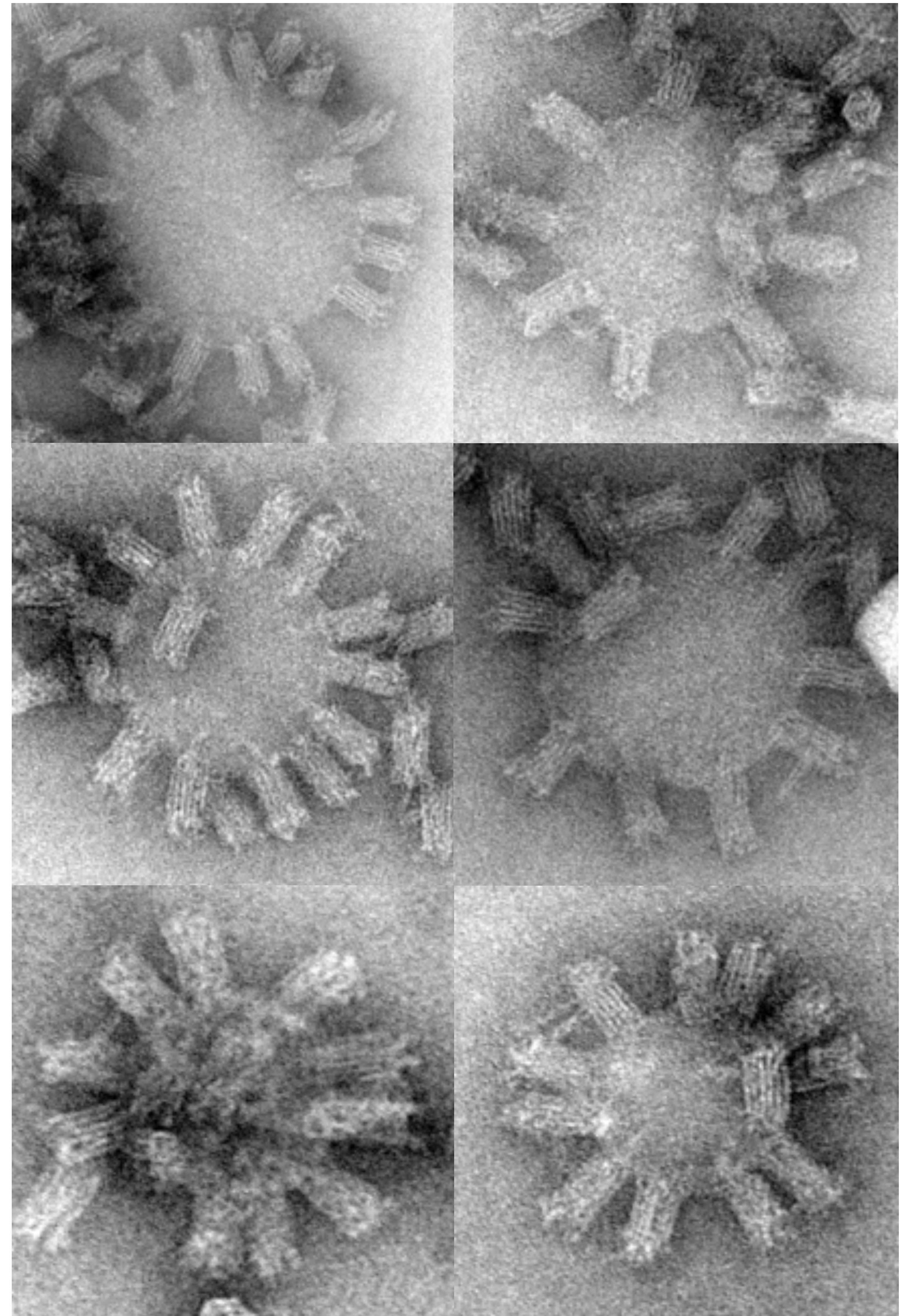






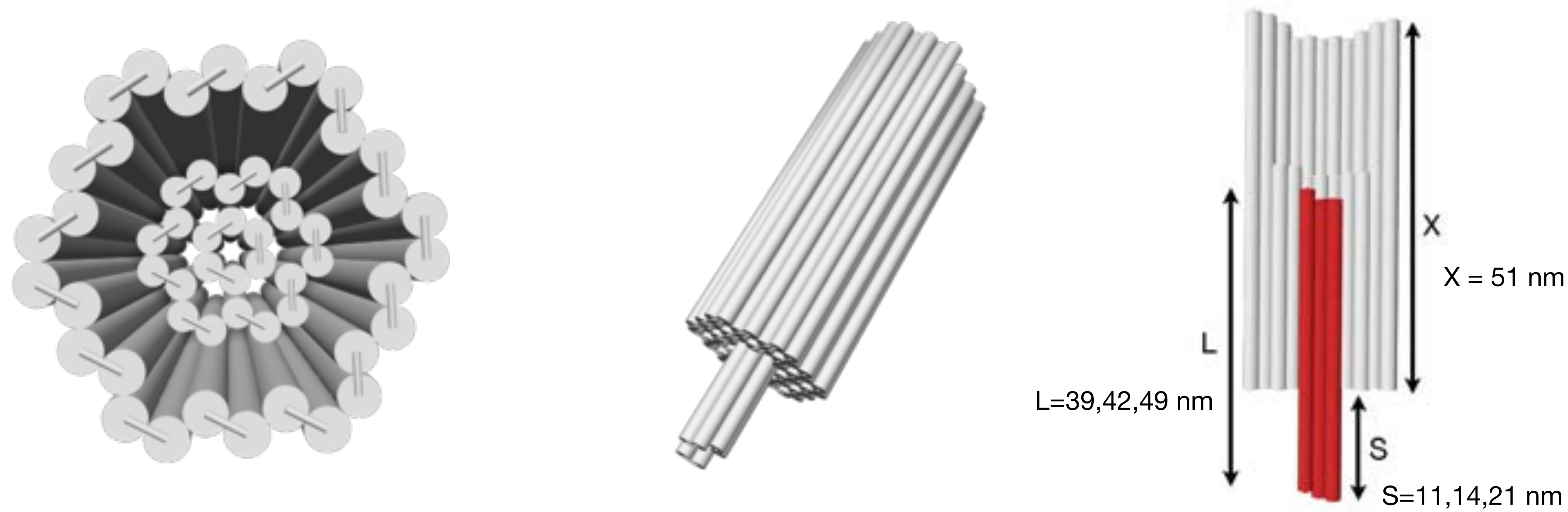
Binding of DNA channels to small vesicles (POPC)



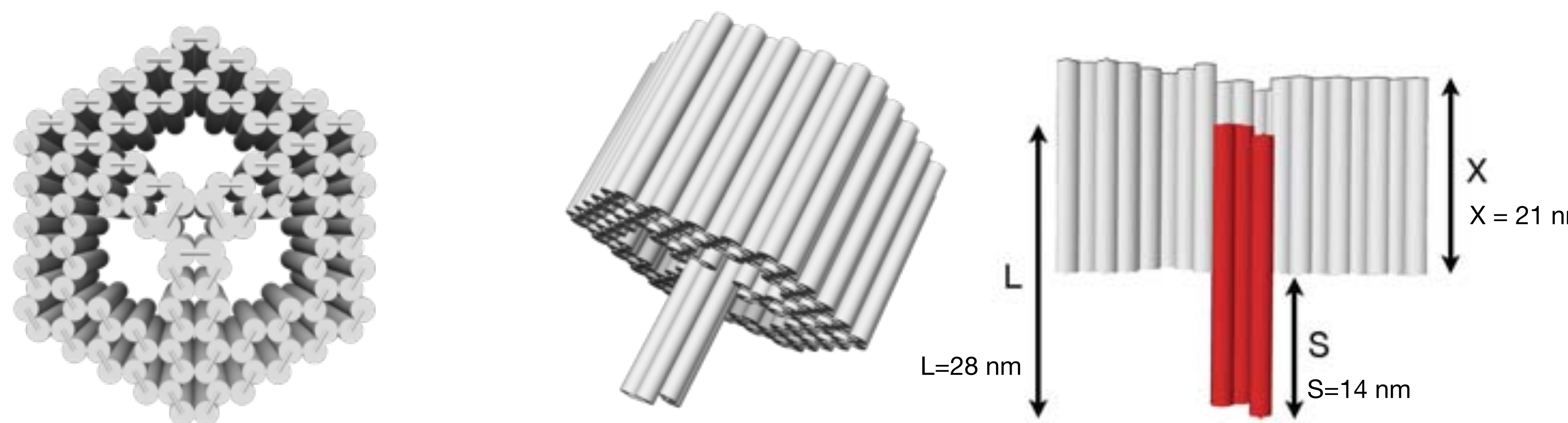


Various pore geometries

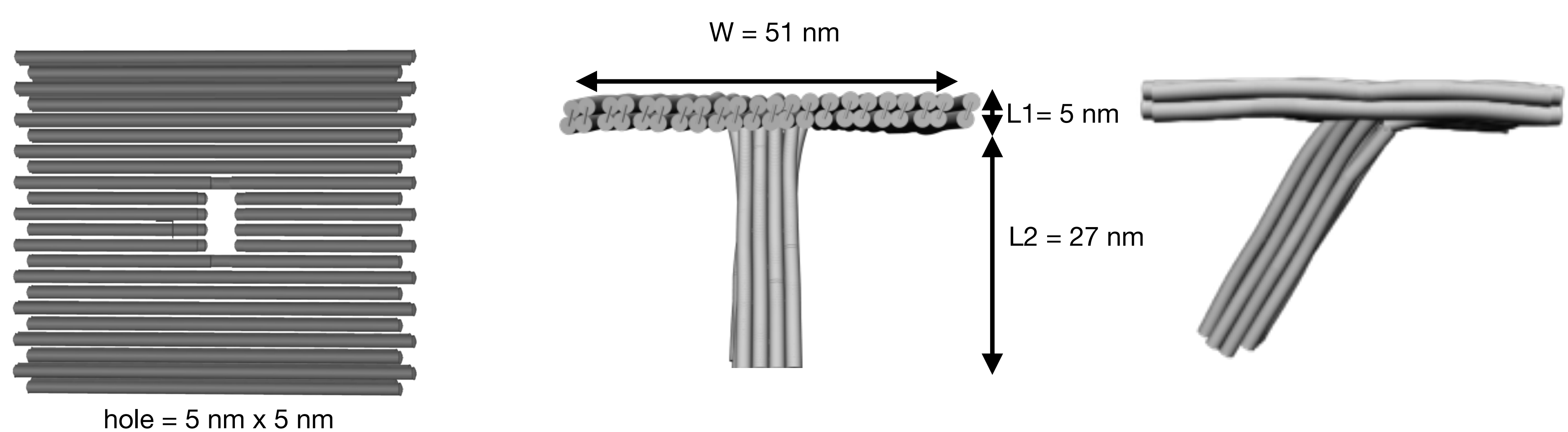
Pore with vestibule



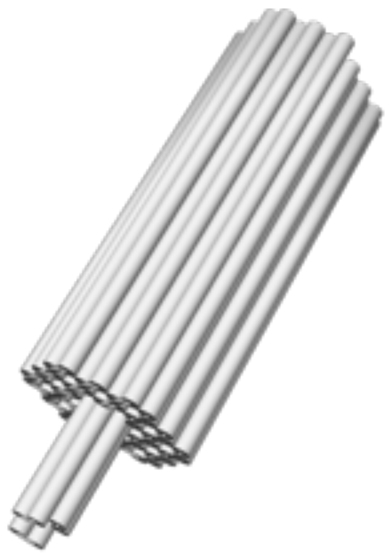
Flat & fat pore

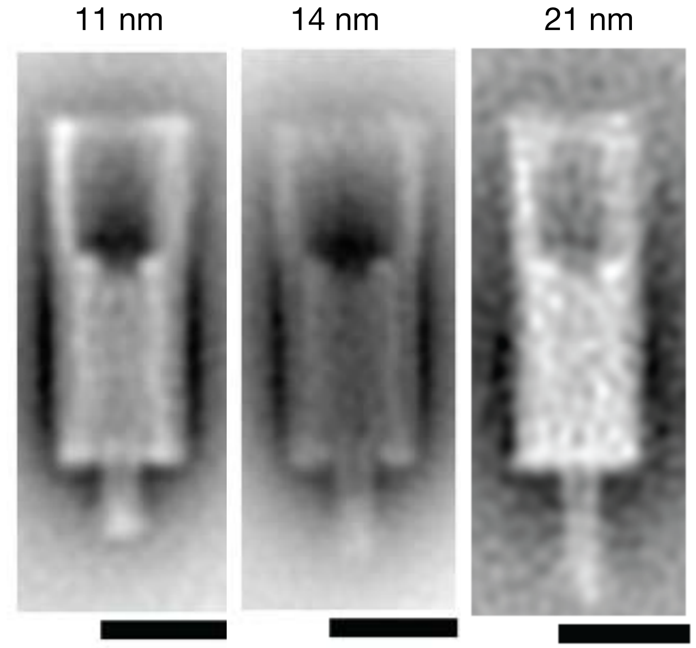


Square pore

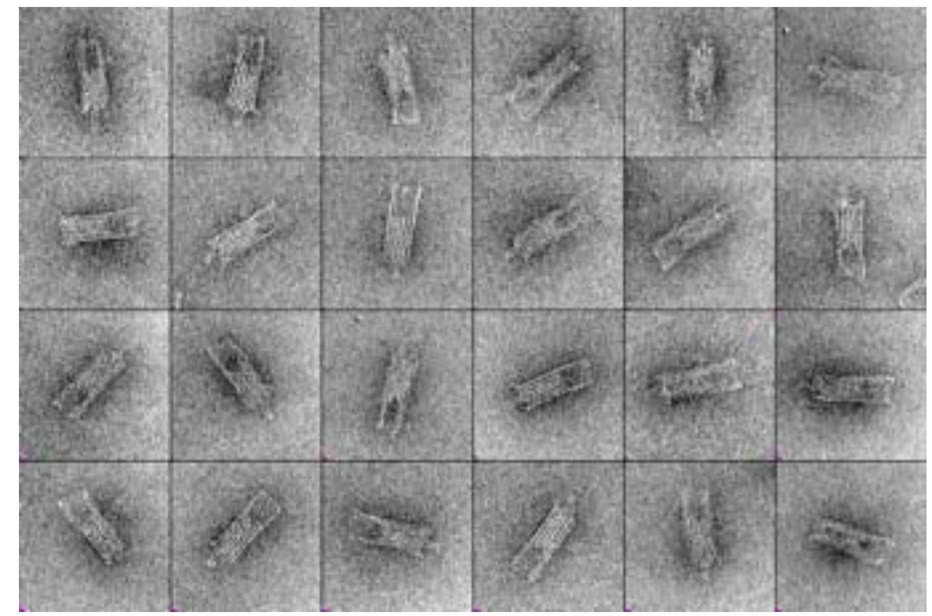


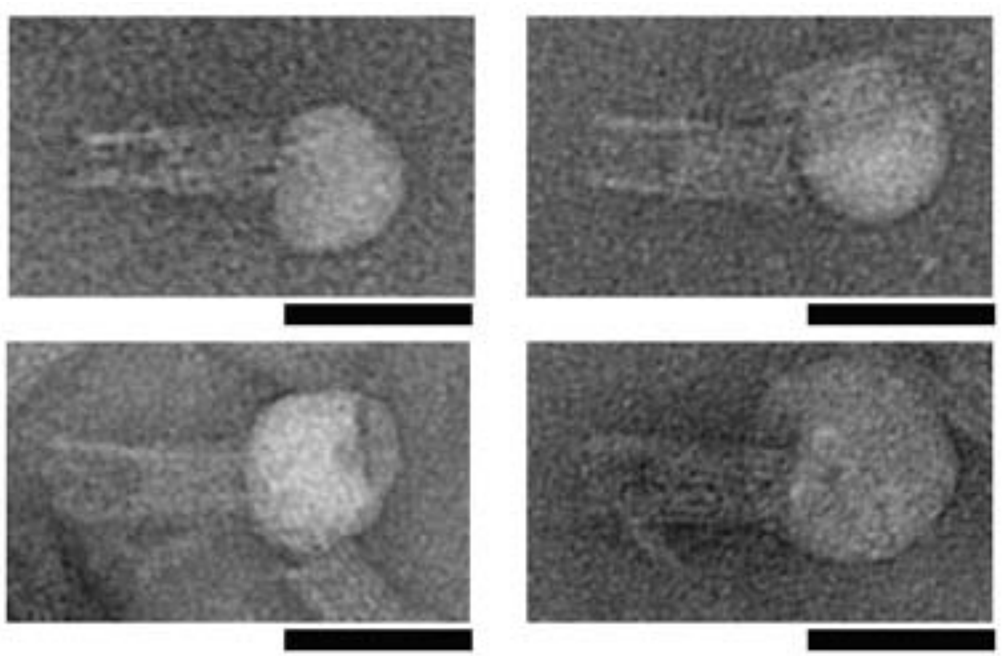
Pore with vestibule





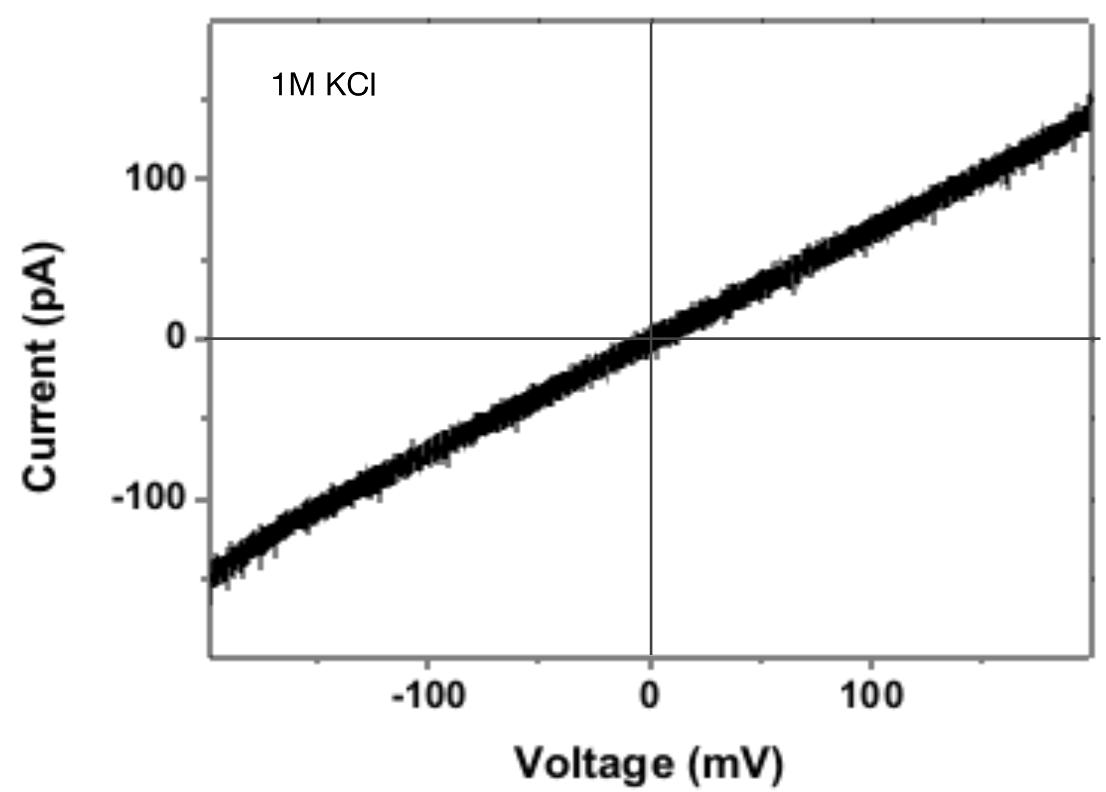
scale bars 20 nm



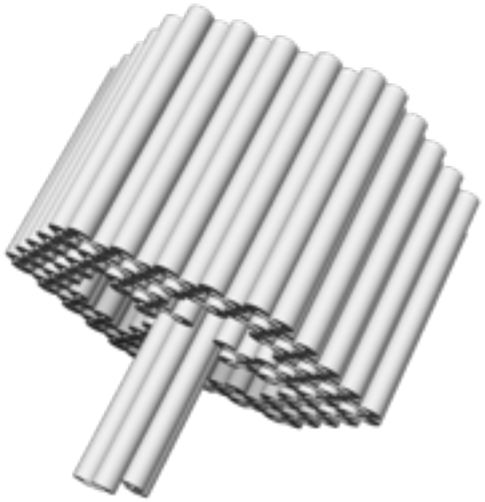


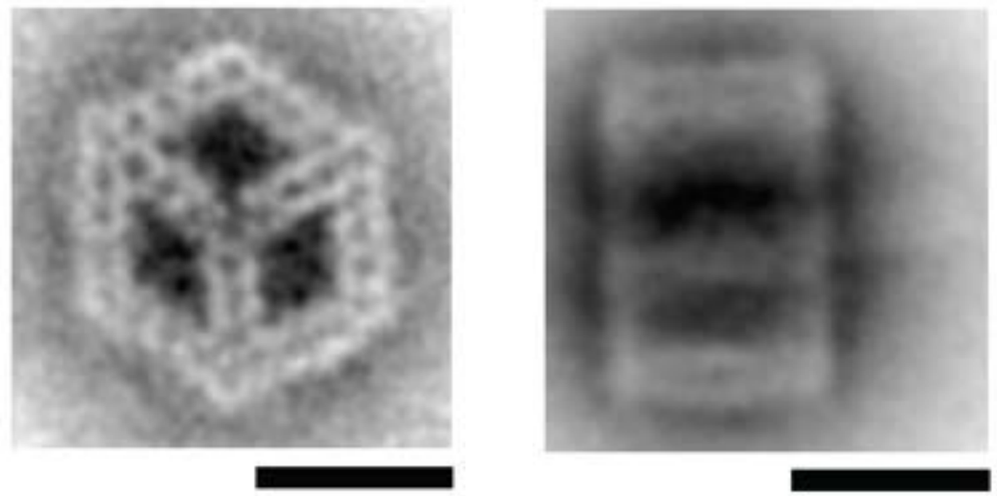
scale bars 50 nm

I-V characteristics

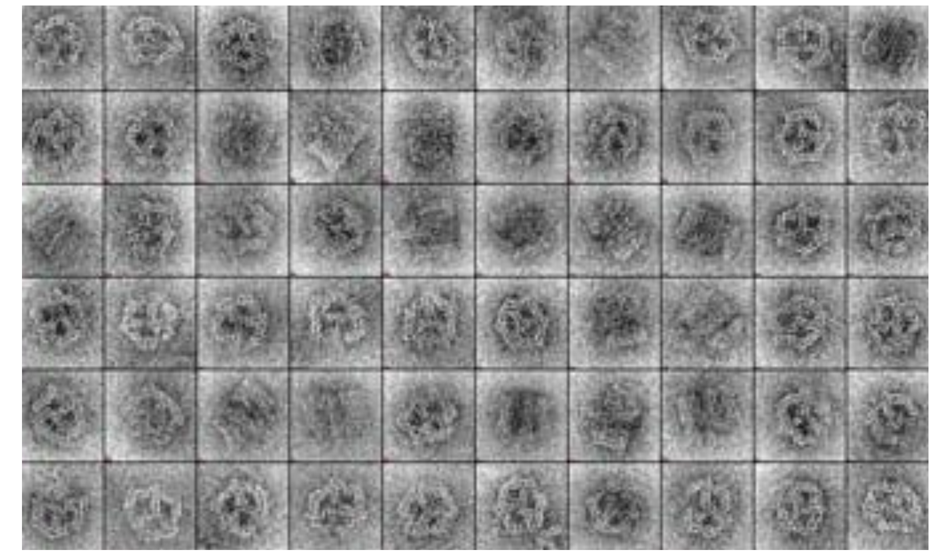


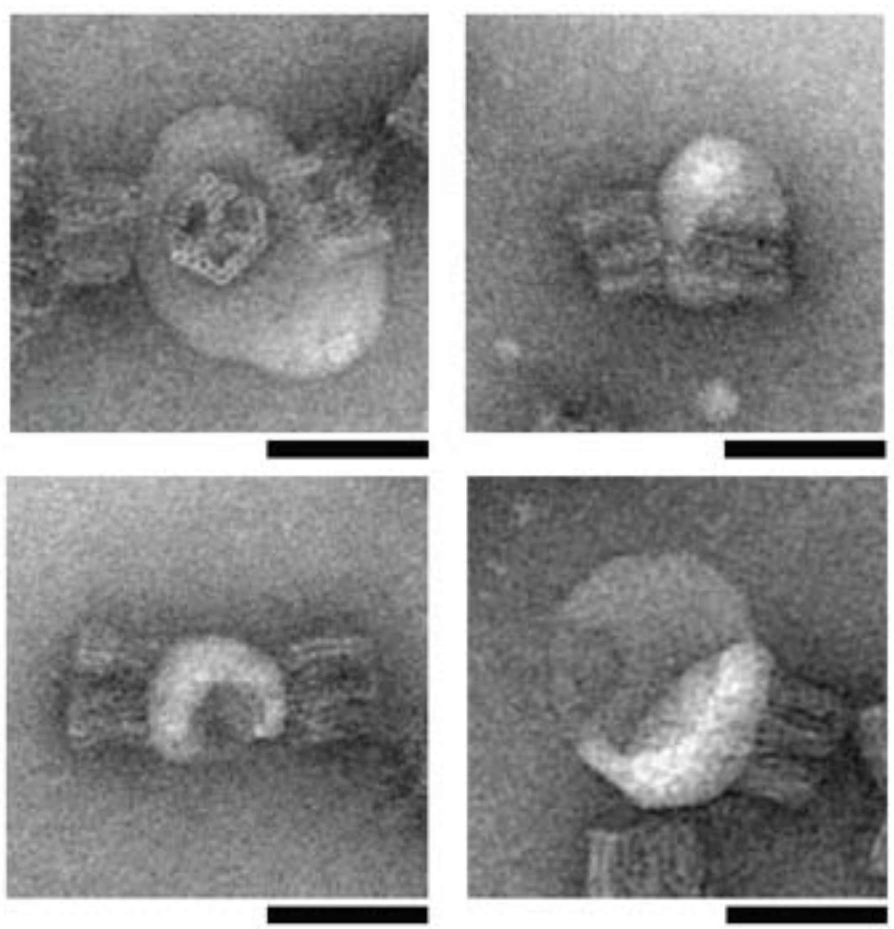
Flat & fat pore





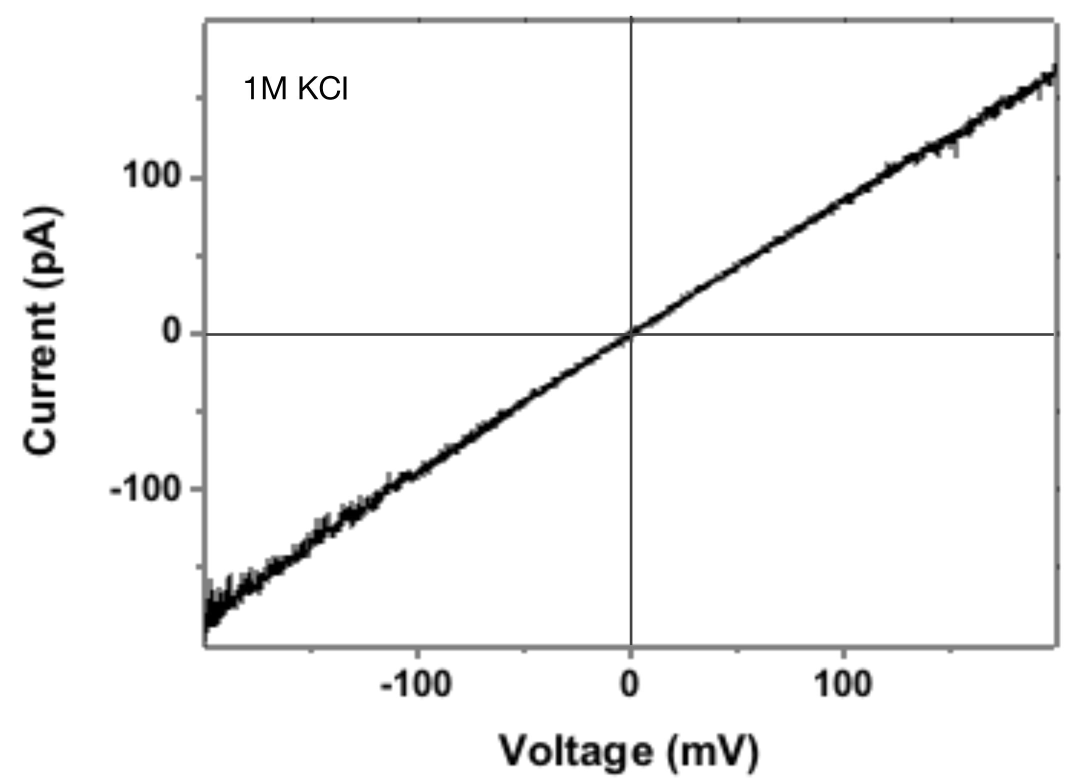
scale bars 20 nm



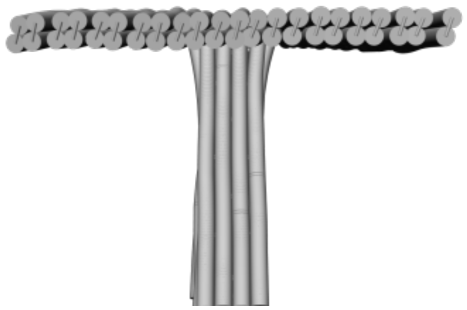


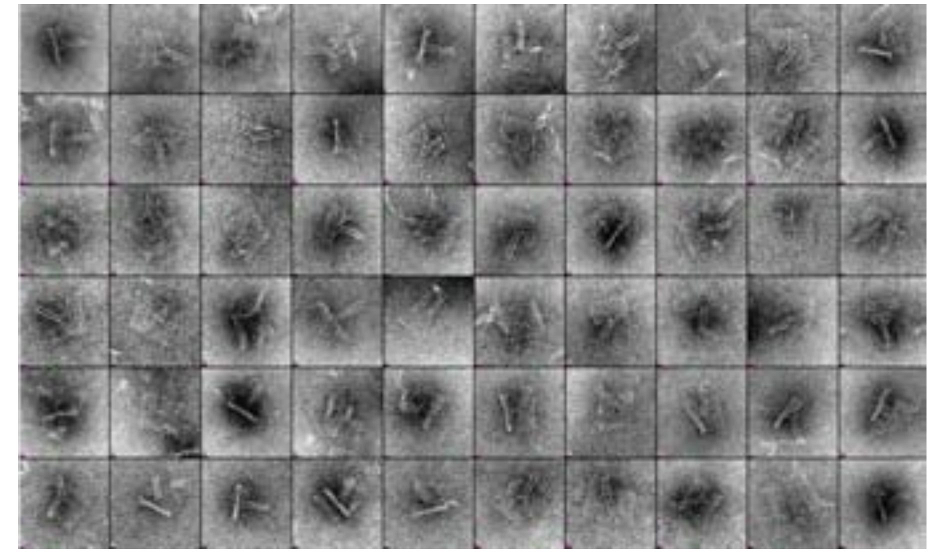
scale bars 50 nm

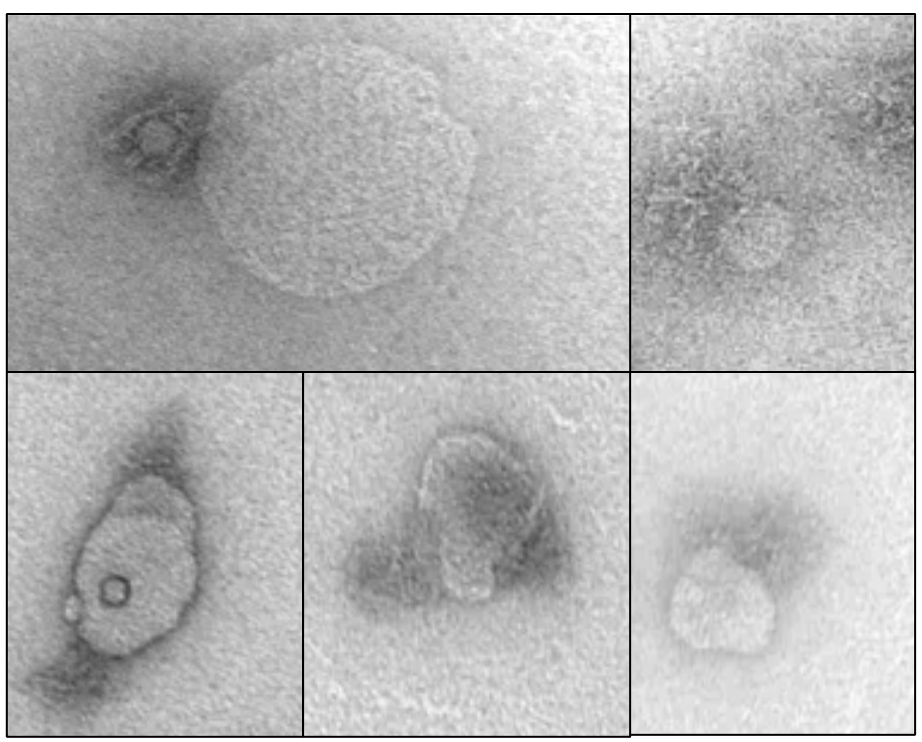
I-V characteristics



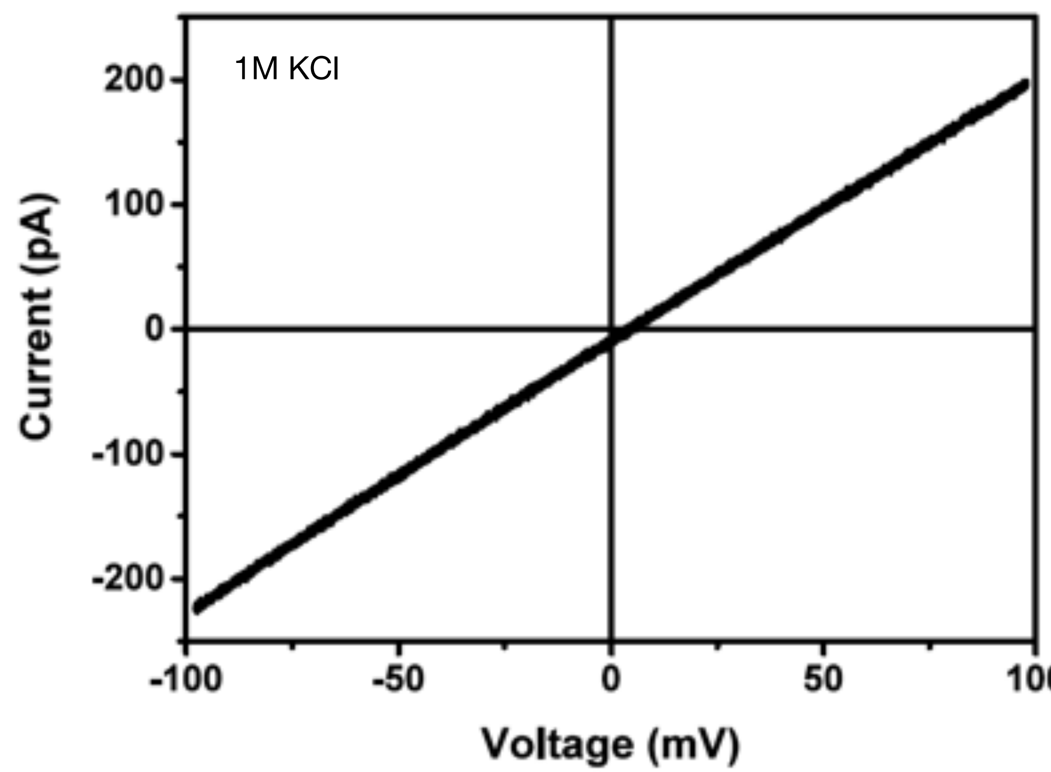
Square pore



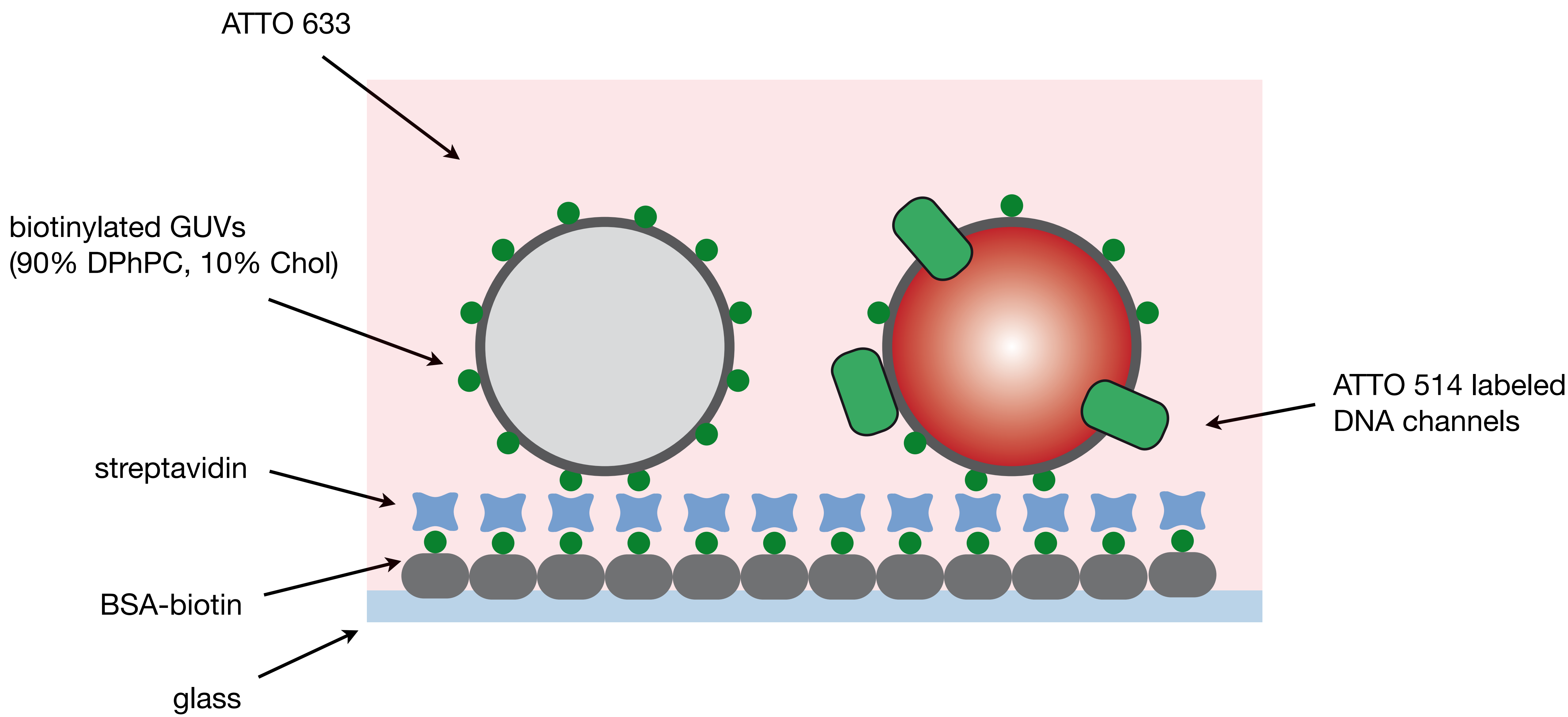




I-V characteristics

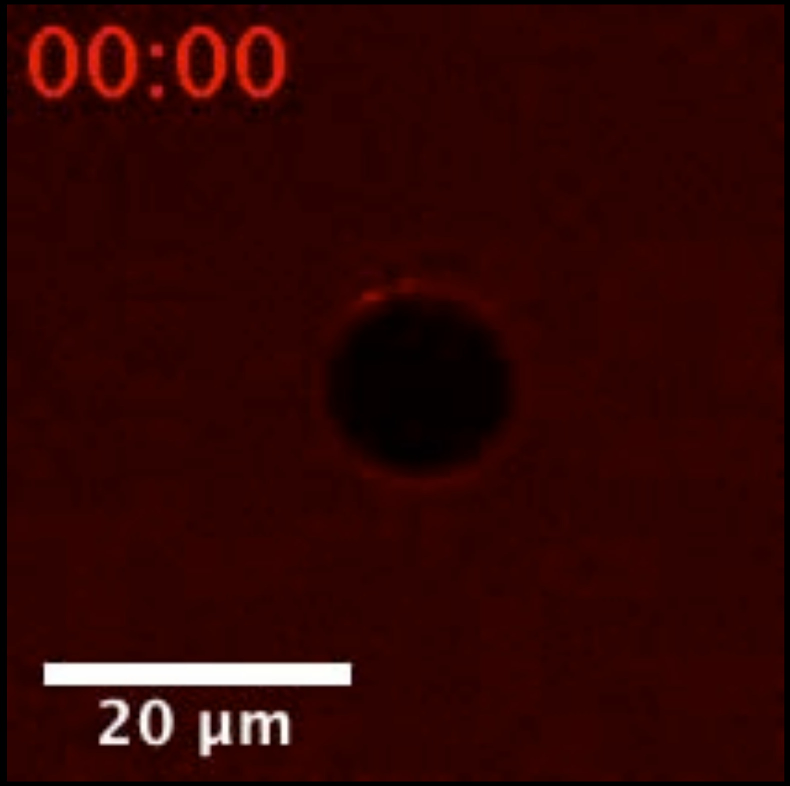


Dye influx experiments with immobilized vesicles

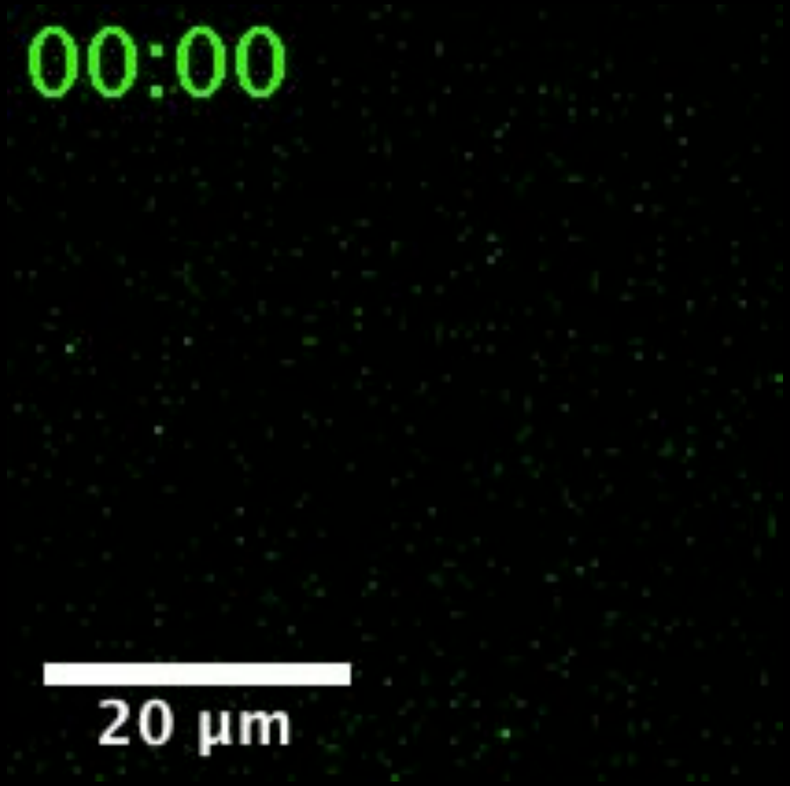


Dye influx experiments with immobilized vesicles

ATTO 633

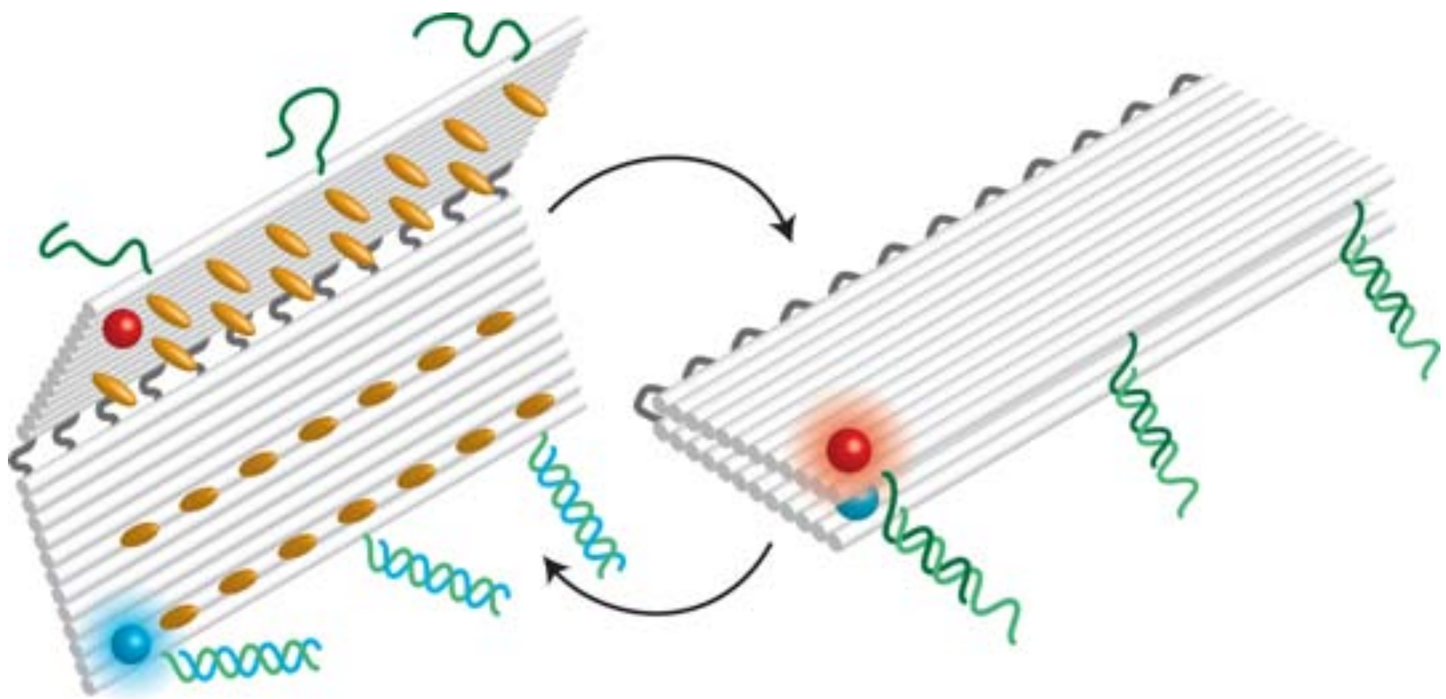


ATTO 514 labeled DNA channels



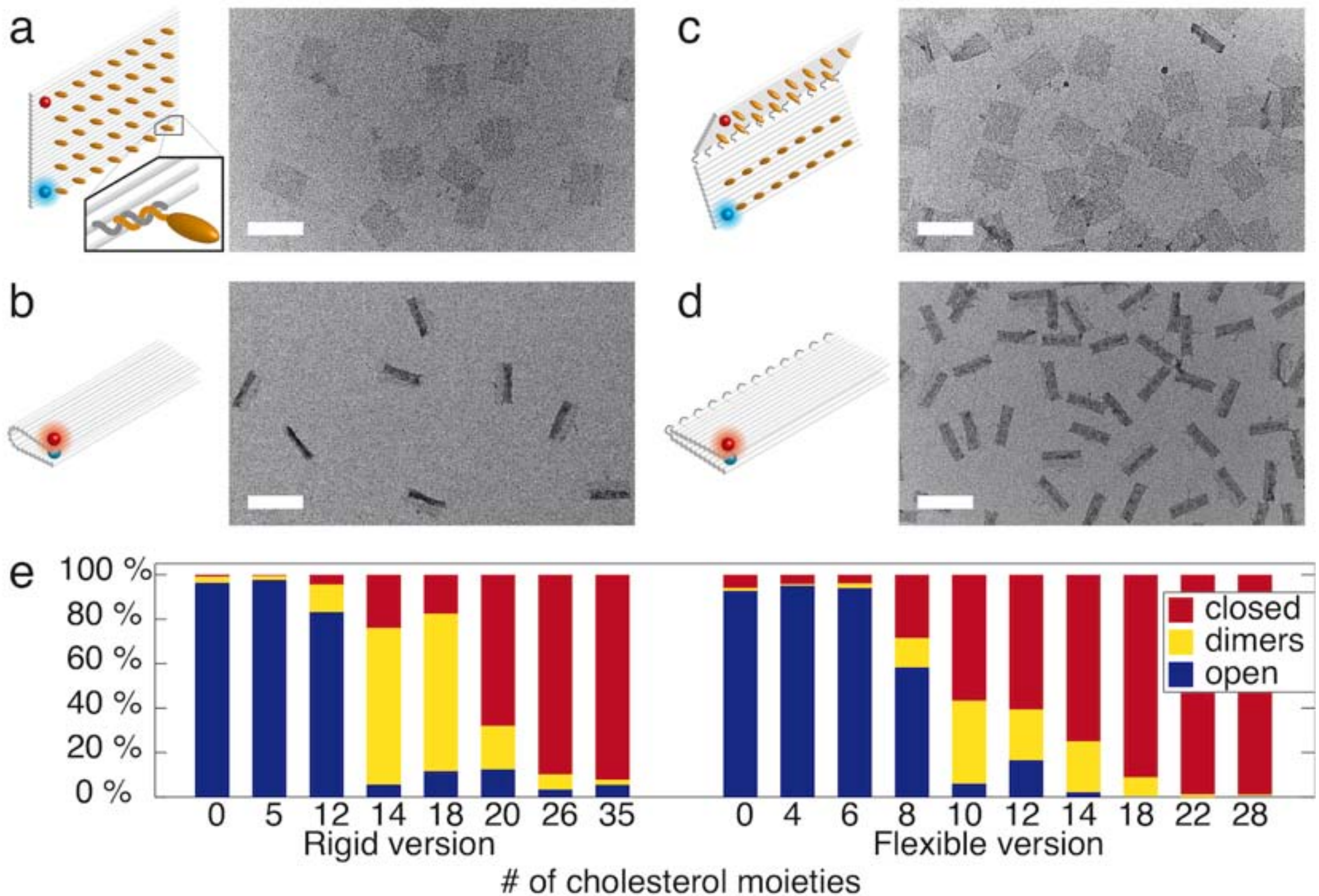
300 mM KCl, 10mM Tris, 1mM EDTA

A switchable DNA bilayer structure

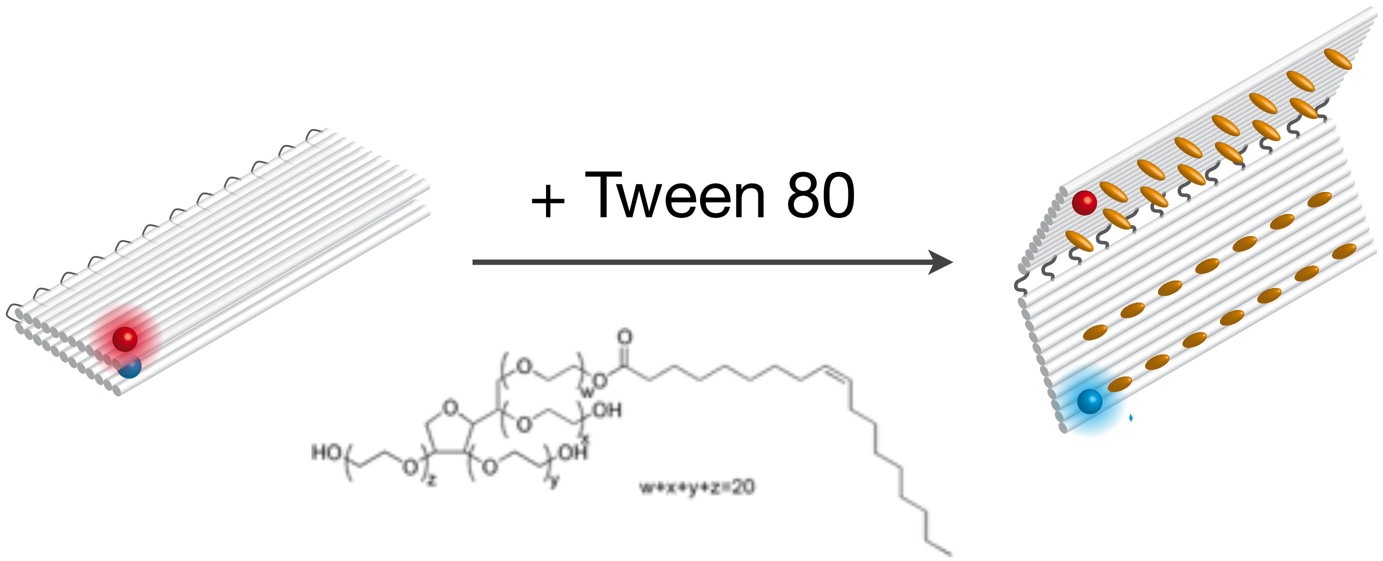


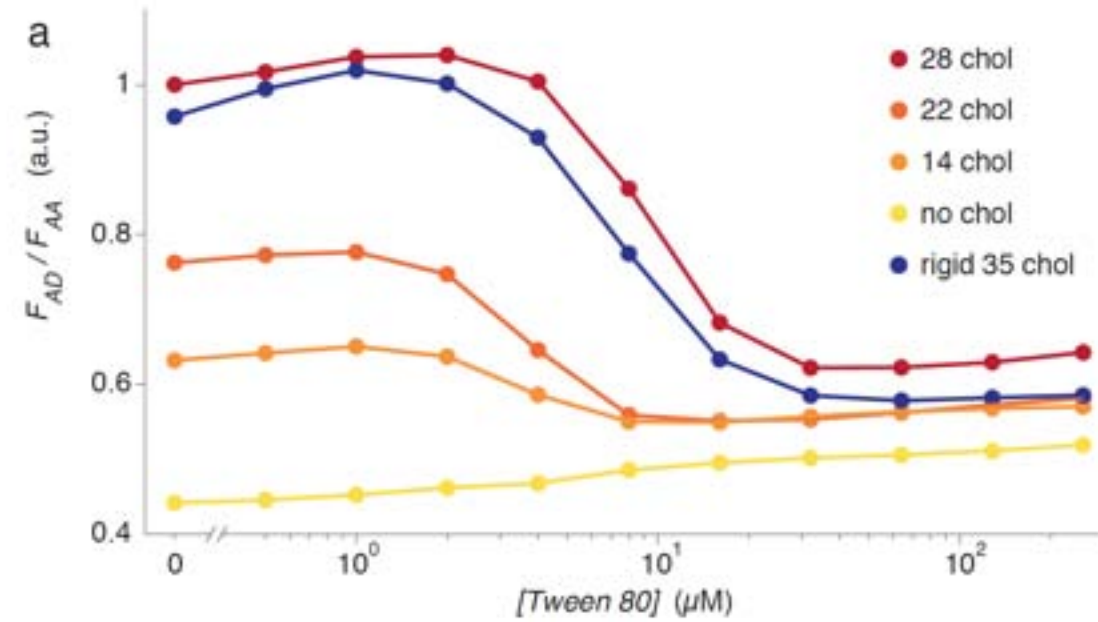
List, J., Weber, M. & Simmel, F. C. Hydrophobic Actuation of a DNA Origami Bilayer Structure. *Angew. Chem. Int. Ed.* **53**, 4236-4239 (2014).

Hydrophobic interactions bend DNA origami sheets

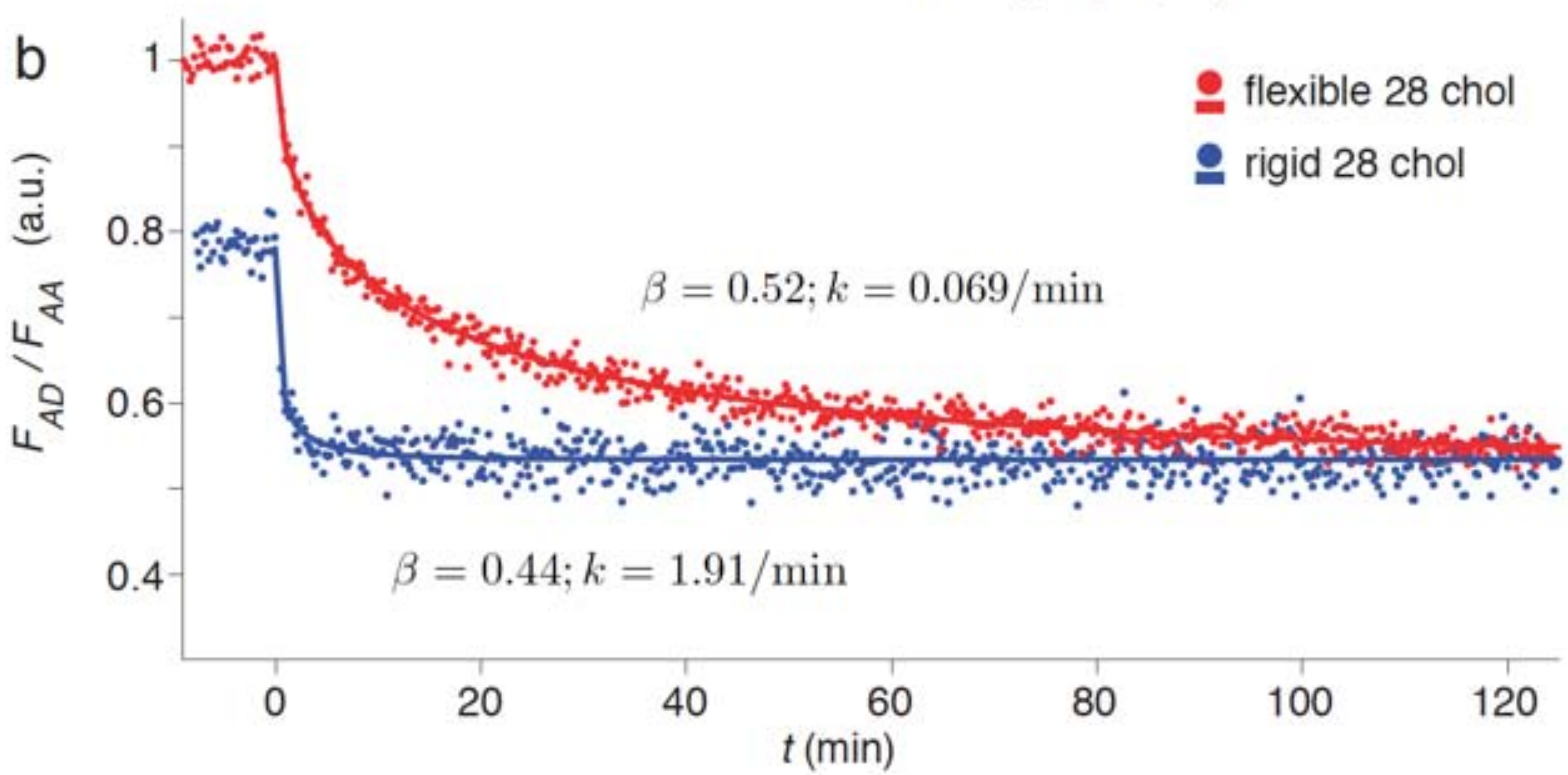


Opening the DNA bilayers with a surfactant

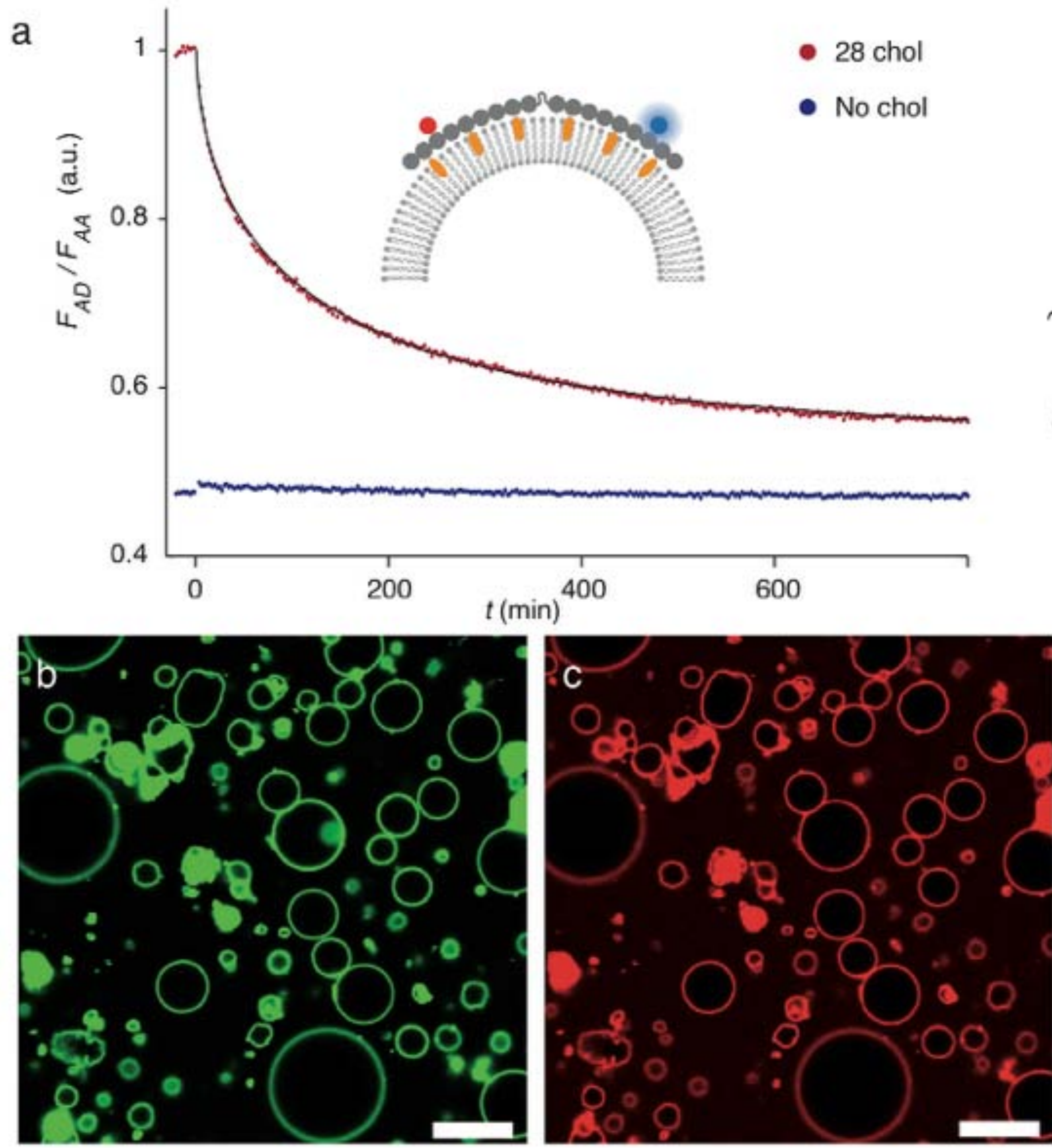




opening kinetics $\sim \exp\left(-(kt)^{\beta}\right)$



Opening in the presence of SUVs and GUVs



$$\sim \exp\left(-(kt)^{\beta}\right)$$

$$\beta = 0.4; k = 0.025/\mathrm{min}$$

A conditional hydrophobic switch ...