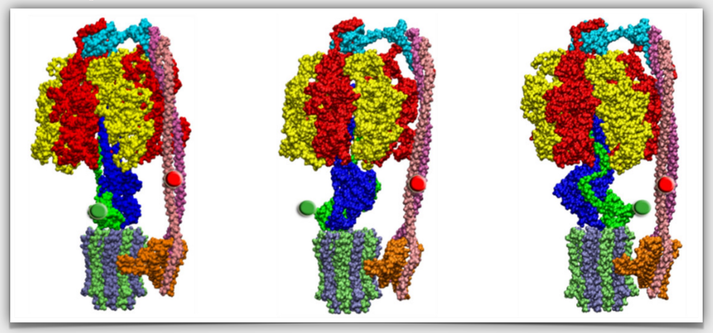
A DNA rotary mechanism with coordinated mobility control

E. Bertosin*§, C.M. Maffeo°, T. Drexler*, M.N. Honemann*, A. Aksimentiev°, H. Dietz*

* Lehrstuhl für Biomolekulare Nanotechnologie, Physik Department, and Munich Institute of Biomedical Engineering, Technische Universität München, Garching near Munich, Germany; ° Department of Physics and Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana Champaign, Urbana, IL 61801, USA.
§ Currently at Kavli Institute of Nanoscience, Department of Bionanoscience, TU Delft, the Netherlands

Biological inspiration

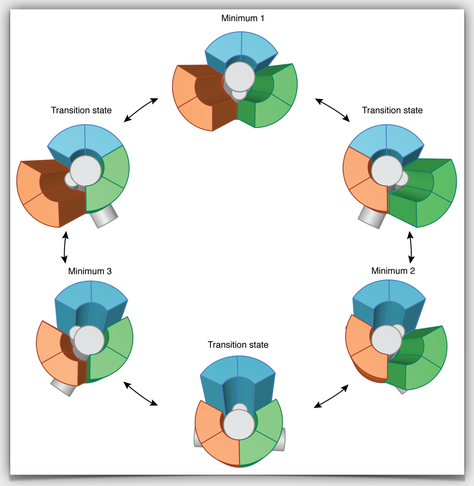
ATP synthase



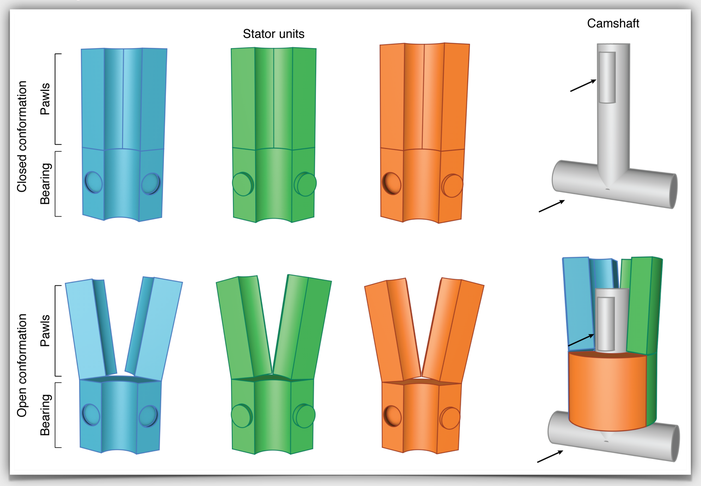
The ATP synthase[1] is an efficient rotary molecular machine that converts electrochemical gradients to chemical energy (ATP) through coupled conformational changes.

Design of the DNA origami rotary mechanism

Principle of the mechanism



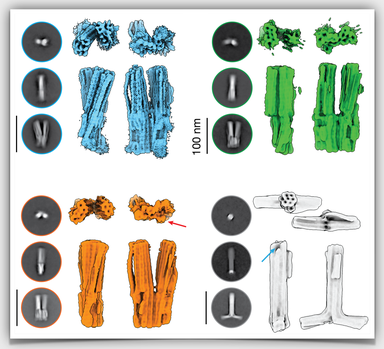
Components



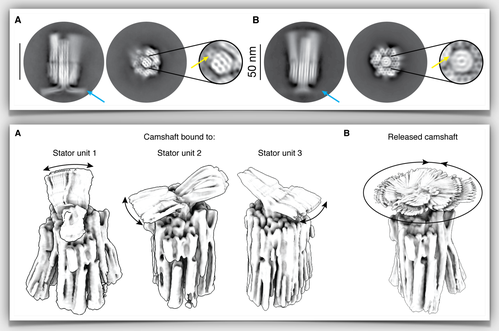
Inspired by the ATP synthase, we designed a DNA origami rotating mechanism[2] composed of a trimeric stator and a central asymmetric unit. The rotation of the central unit is coupled to conformational changes of the surrounding stator units.

Cryo EM characterisation

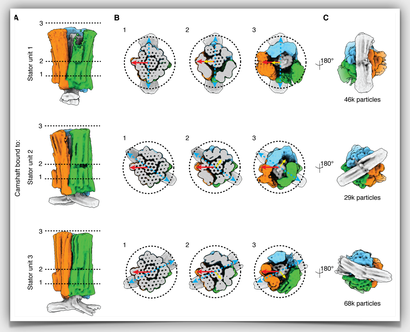
3D maps of the subunits



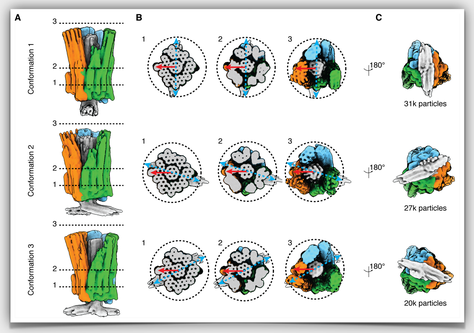
Central unit bound to stator vs released



Central unit bound to stator



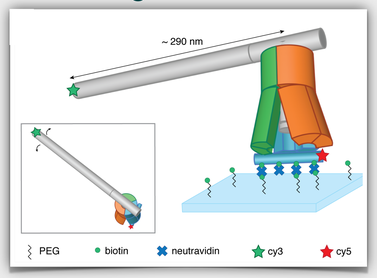
Central unit released from stator



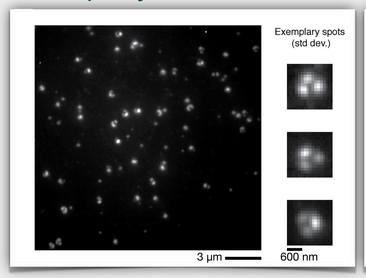
When the central unit is bound to different stator subunits, we see less variability in the dataset, indicating that the central unit is firmly anchored. When the central unit is released from the stator, we find 3 preferred conformations, indicating that the central unit is free to change position inside the stator and rotate due to brownian motion.

The central unit performs brownian motion and has 3 dwelling positions

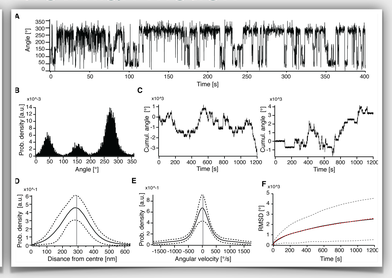
Anchoring scheme



Exemplary motion



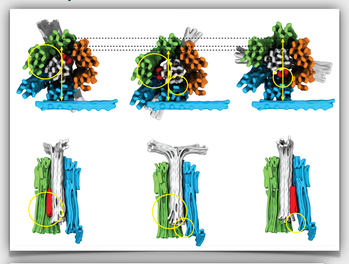
Brownian motion

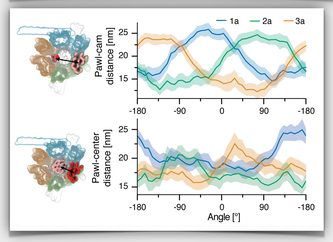


Anchoring the complex to a TIRFM slide, we monitored the central unit movements over time. We confirmed that it performs brownian motion and shows 3 preferred dwelling positions.

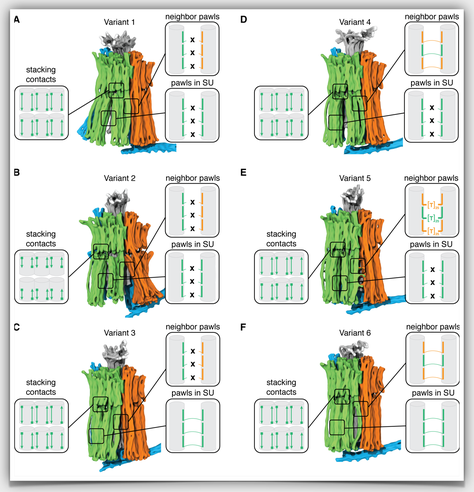
The central unit rotation is coupled to the stator units conformational changes

Coupled mechanism

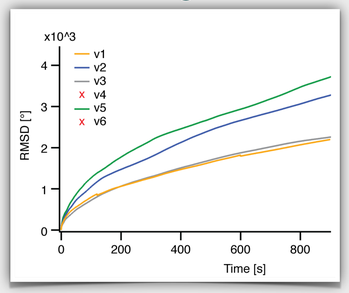




Stator modifications



Motion changes



MD simulations showed that the central unit rotation and the stator movements are coupled. By changing the flexibility of the stator units, we could experimentally tune the central unit rotation, demonstrating a coupled mechanism.

[1] Sielaff et al., *Molecules* 2019, 24(3), 504

[2] Bertosin et al., *Nat. Comm.* 2021, 12, 7138

Funding: ERC; DFG; SFB; National Science Foundation; National Institute of Health; Leadership Resource Allocation