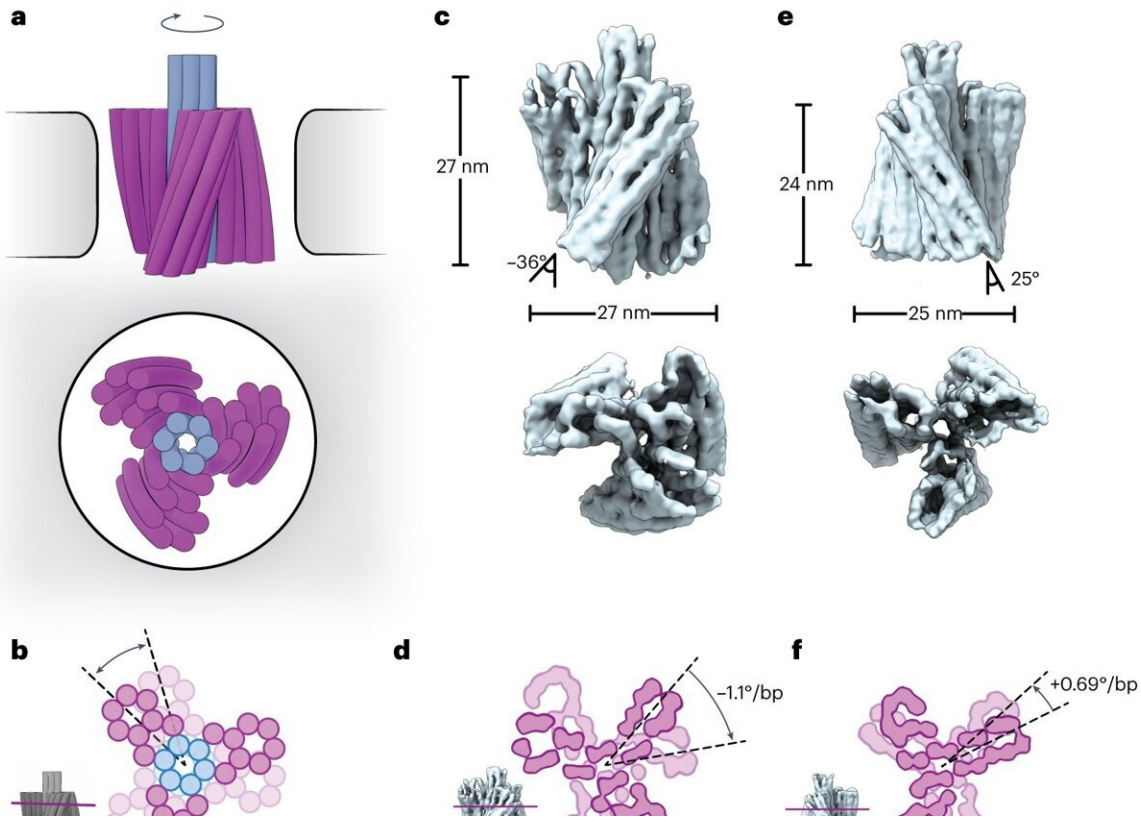
# DNA origami nanoturbine sets new horizon for nanomotors

October 27 2023




Design of a nanopore-powered DNA origami turbine. Credit: *Nature Nanotechnology* (2023). DOI: 10.1038/s41565-023-01527-8

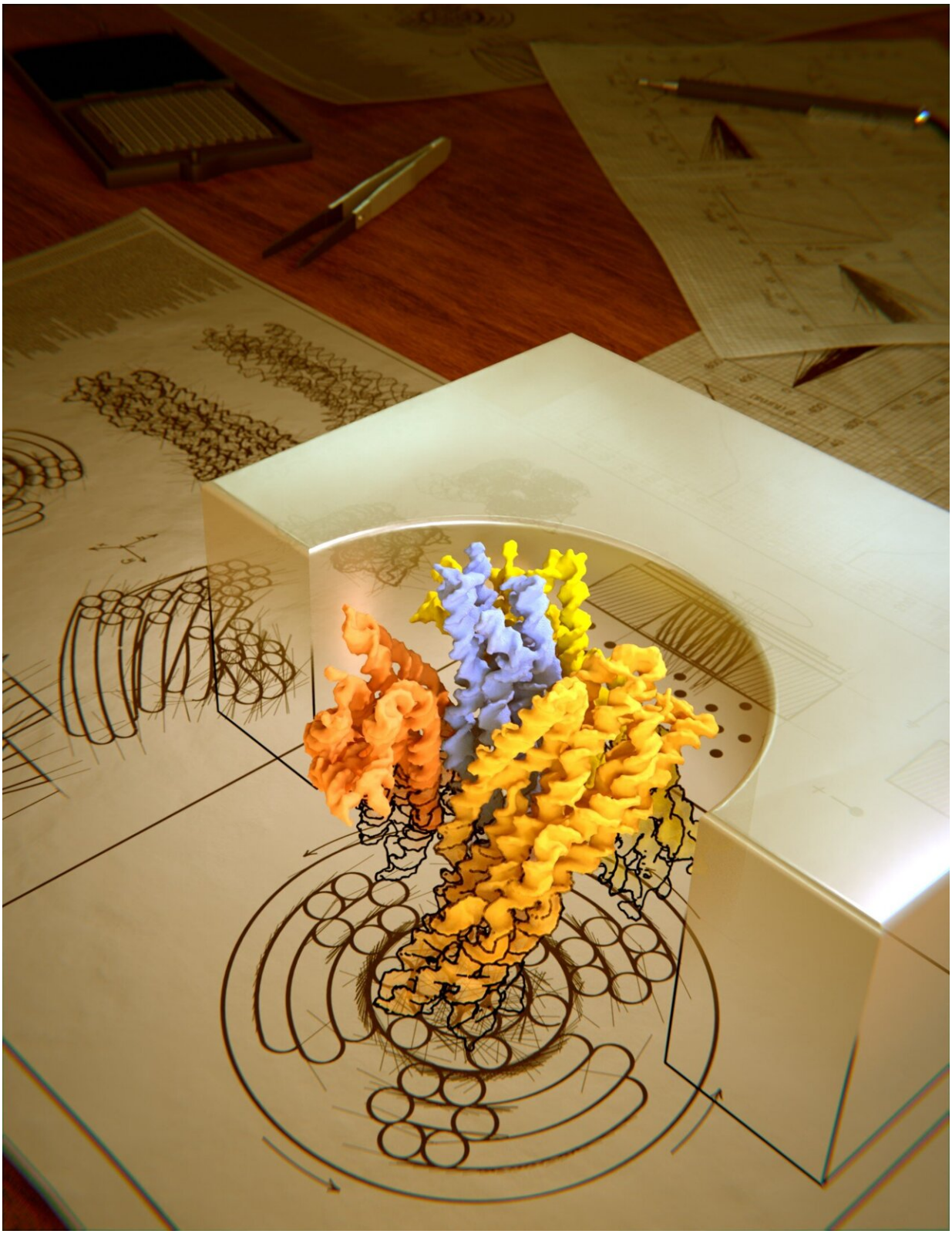
A collaborative team of researchers led by Prof. Cees Dekker at Delft University of Technology, in partnership with international colleagues,

have introduced a pioneering breakthrough in the world of nanomotors—the DNA origami nanoturbine. This nanoscale device could represent a paradigm shift, harnessing power from ion gradients or electrical potential across a solid-state nanopore to drive the turbine into mechanical rotations.

The core of this discovery is the design, construction, and driven motion of a "DNA origami" turbine, which features three chiral blades, all within a minuscule 25-nanometer frame, operating in a solid-state nanopore. By ingeniously designing two chiral turbines, researchers now have the capability to dictate the direction of rotation, clockwise or anticlockwise. Their findings have been published in *Nature Nanotechnology*.

## Nanoturbines: The heart of advancements

Flow-driven turbines lie at the heart of many revolutionary machines that have shaped our societies, from windmills to airplanes. Even life itself depends critically on turbines for fundamental processes, such as the FoF1-ATP synthase that produces fuels for biological cells and the bacterial flagella motor that propels bacteria.



DNA Origami nanoturbine sets new horizon for nanomotors. Credit: Cees

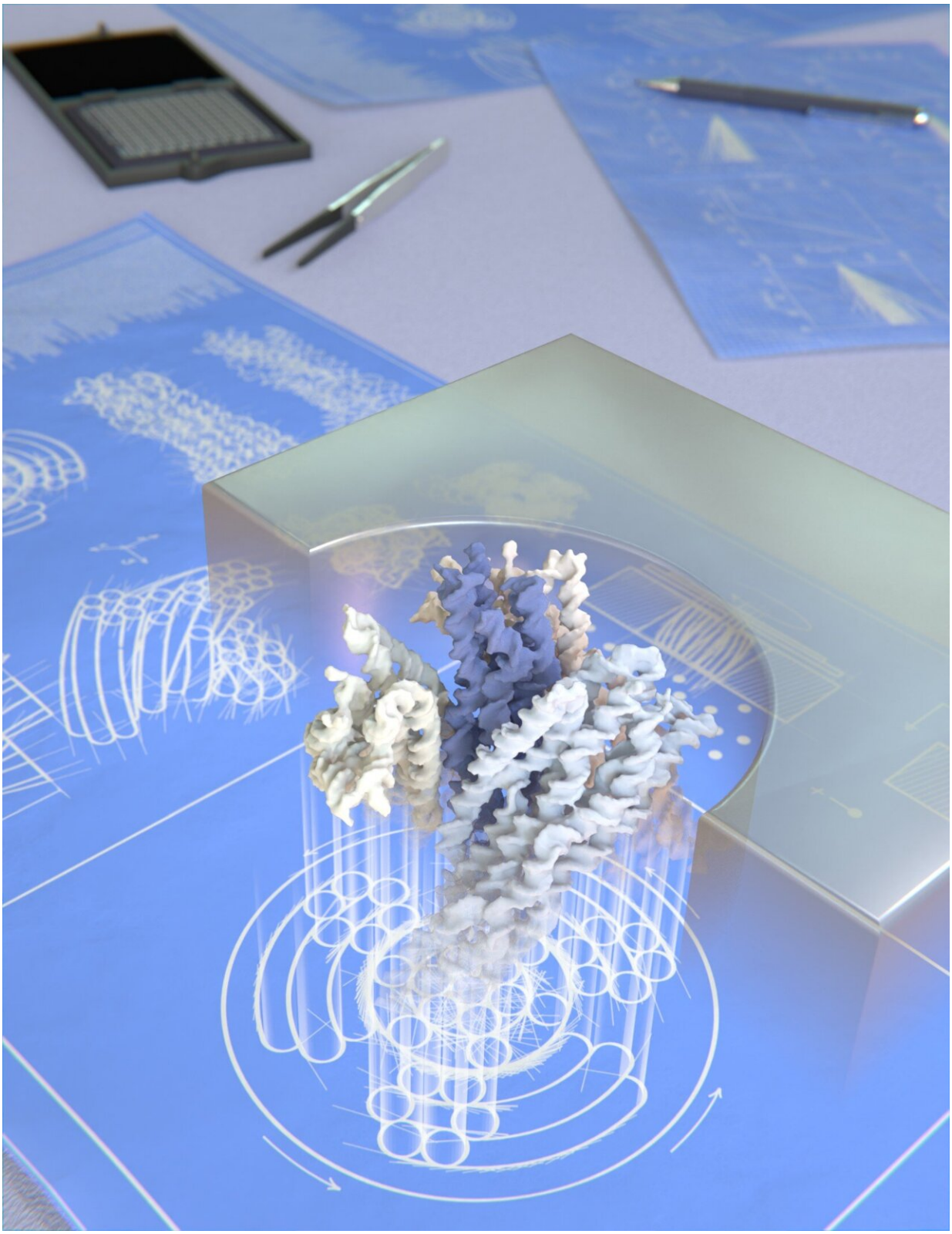
Dekker Lab / SciXel

"Our nanoturbine has a 25-nanometer diameter rotor made from DNA material with blades configured in a right-handed or left-handed sense to control the direction of rotation. To operate, this structure is docked in a strong water flow, controlled by an electric field or salt concentration difference, from a nanopore, a tiny opening, in a thin membrane. We used our turbine to drive a rigid rod up to 10 revolutions per second," says Xin Shi, lead author of the article.

## A fascinating revelation

One of the most intriguing discoveries of this research is the unique nature of the DNA origami nano-turbine's rotation. Its behavior is influenced by ion concentration, allowing the same turbine to spin either clockwise or anticlockwise, depending on the concentration of $Na^+$ ions in the solution.

This unique feature, exclusive to the nanoscale realm, results from the intricate interplay between ions, water, and DNA.



DNA Origami nanoturbine sets new horizon for nanomotors. Credit: Cees

These findings, rigorously supported by extensive molecular dynamics simulations by the group of Aleksei Aksimentiev at University of Illinois and theoretical modeling by Ramin Golestanian at MPI Göttingen, hold the promise of expanding the horizons of nanotechnology, and offer numerous applications. For example, in the future, we might be able to use DNA-origami to make nanomachines that can deliver drugs into the human body, to specific types of cells.

## DNA origami

Cees Dekker, who supervised the research, sheds light on their methodology saying, "Together with our collaborators at Hendrik Dietz's lab from the Technical University of Munich, we used insights from our previous work on DNA rotary motors to now create a turbine with full control over its design and operation."

The "DNA origami" technique uses the specific interactions between complementary DNA base pairs to build dynamic 3D nano-objects. This design allows the direction of rotation of the turbine in our nanopores to be controlled through the handedness of the blades and allows straightforward integration of the turbine to other nanomachines.

## A new step towards active transmembrane nanomachines

This research achievement follows last year's introduction of the DNA active nanorotor, a self-configuring device capable of transforming energy from electrical or salt gradients into practical mechanical work.

Reflecting on the work, Xin Shi said, "We've unveiled the fundamental principles behind propelling a nanoscale rotor using water and salt in nanopores. This year's breakthrough, driven by rational design, marks the next phase of our journey."

"The foundational principles from our previous paper, combined with the innovations in this one, set the stage for the future of biomimetic transmembrane machines, with the potential to harness energy from salt gradients, a vital energy source employed by biological motors."

**More information:** Xin Shi et al, A DNA turbine powered by a transmembrane potential across a nanopore, *Nature Nanotechnology* (2023). DOI: 10.1038/s41565-023-01527-8

Provided by Delft University of Technology