DNA as building material for tiny machines and artificial cells

Humboldt Research Award winner Prof. Hao Yan has been conducting research at the 2nd Institute of Physics at the University of Stuttgart since May. He is regarded as one of the world's leading experts in the field of DNA nanotechnology. "My work has many points of commonality with the topics that my colleagues in Stuttgart are focusing on," says Yan. "I have therefore been cooperating with Professor Laura Na Liu's working group for some time.

The Humboldt Research Award gives me the opportunity to strengthen this collaboration." The US scientist will be a regular guest in Stuttgart over the next twelve months. During this time, he will focus on the question of how specially designed DNA molecules can be used to mimic important cell functions.

Making tiny machines with DNA origami

DNA is a long molecule in which different building blocks are strung together, similar to letters in a sentence. Like a book in a library, DNA therefore is primarily an information store for organisms. However, biodesigners exploit another property of the molecular filament: As it can be folded in almost any way, it can be used for creating complicated three-dimensional structures. This "DNA origami" can even be used for producing tiny nanomachines - containers with movable lids and motors, or even entire robots just a few millionths of a millimeter in size.

Molecular machines that assemble themselves

There is another aspect, which is particularly interesting: If the building blocks in the DNA strands are arranged appropriately, these molecular machines assemble themselves as if by magic. Because DNA molecules are a bit like the pieces of a jigsaw puzzle: They can be joined together with other strands, but only with those that match them exactly. Hao Yan uses this self-organization to produce complicated nanostructures for physical, chemical, and biological applications. His research and inventions focus on techniques with which tiny DNA strands can be manipulated as desired. For example, he has succeeded in advancing the development of nanorobots for the diagnosis and treatment of cancer. "In future, for example, these could take medications directly to where they are needed," he explains.

Synthetic molecules mimic photosynthesis

Another focus of his work is the design of DNA molecules that mimic the functions of certain cell components. These include structures in which light-sensitive molecules can be brought together in a strictly organized form, as in a kind of cage. "In this way, it is possible, for example, to capture light energy and pass it on to be used for chemical reactions," he says. "Light antennas" like this can also be found in the chloroplasts of plants, which provide energy for photosynthesis - i.e. the production of sugar from water and CO_2.

"This mimicking of cell functions using synthetically produced molecules is considered a promising field of research," explains Prof. Laura Na Liu, Director of the Institute of Physics (2) at the University of Stuttgart. "We are also working on using DNA to recreate certain structural elements of cells. One example is the cytoskeleton, which mechanically stabilizes cells and allows them to move. Normally, it consists of protein fibers, but we are recreating it from DNA, so to speak." Such structural elements could one day be used in very simple artificial cells that are used for researching certain cell processes.

Working groups complement each other

Na Liu hopes that the cooperation with her renowned guest will lead to further progress in this field: "In Stuttgart, we have many years of experience in building nanomachines and analyzing self-assembling structures," she points out. "For example, we are developing special microscopy and spectroscopy methods that can be used, among other things, for visualizing the movement of DNA motors. Together with Professor Yan's sophisticated molecular engineering tools, these are good

prerequisites for making great progress in the development of DNA molecules that mimic cell functions."

About Prof. Hao Yan

Hao Yan received his doctorate in chemistry from New York University, USA, in 2001. He worked as an assistant research professor at Duke University before transferring to Arizona State University (ASU) in 2004. There, he has been Director of the Biodesign Center for Molecular Design and Biomimetics since 2015 as well as Milton D. Glick Distinguished Professor at the School of Molecular Sciences. During his career, he published more than 230 papers in top-tier journals, most of them on DNA nanotechnology and bioinspired molecular designs. Professor Yan has received numerous awards, including the Rozenberg Tulip Award in DNA Computing (2013) and the Foresight Institute Feynman Prize in Nanotechnology (2020). The Fast Company business magazine selected him as one of the "100 Most Creative People in Business" in 2019. He is currently President of the International Society for Nanoscale Science, Computation and Engineering (ISNSCE).

About the Humboldt Research Award

The Alexander von Humboldt Foundation awards up to 100 Humboldt Research Awards each year to internationally renowned researchers from abroad, in recognition of their overall contribution to science. The award winners are also invited to carry out a research project of their choice in Germany working closely with local researchers. These projects may run for between six months and a year. The award is open to nominees whose fundamental discoveries, new theories, or findings have had a significant impact both within their own field and beyond, and who can be expected to continue to achieve scientific excellence going forward.

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