Robot operations in the circulatory system—in reality, medical nanomachines are still a long way from being as sophisticated as in this computer animation

A SMALL INTERVENTION

Making motors from an atom? Tiny particles that carry out transportation tasks? Nanorobotics will make tremendous technical progress possible in medicine and other fields

TEXT **BJÖRN THEIS**

The Czech scientist Dr. Jan Beneš defects to the West in 1965. After his flight is discovered, his pursuers lie in wait and attack him, causing severe injuries. Beneš manages to escape, but a blood clot in his brain threatens to gradually kill him. His rescuers quickly decide to run a risky experiment: They miniaturize a submarine manned by a crew of physicians and CIA agents and inject it into the scientist's body, with the mission of dissolving the blood clot.

The science fiction film *Fantastic Voyage* made in 1966 has inspired generations of researchers. One of them was Eric Drexler, who wrote *Engines of Creation*, a visionary basic work on nanotechnology, in 1986. In this book he describes numerous possible designs and applications of machines on a nanometer scale. By way of comparison, a sheet of paper is about 100,000 nanometers thick. According to Drexler, in the future we will be able to use molecular technologies to, among other things, diagnose illnesses, transport medications directly to diseased cells in the body, and carry out surgical operations as needed.

MOLECULAR MACHINES

Today we have already come much closer to making this vision a reality. In 2016 Jean-Pierre Sauvage, James Fraser Stoddart, and Bernard Lucas Feringa received the Nobel Prize in Chemistry for their design and synthesis of molecular machines. These three researchers were able to successfully combine molecules into units such as nanocars, muscles, and molecular motors that can execute controllable movements and perform certain tasks. "The 2016 Nobel Laureates in Chemistry have miniaturized machines and taken chemistry to a new dimension," wrote the Nobel Committee for Chemistry. In the same year, a research group from the Universities of Mainz, Kassel, and Erlangen-Nuremberg unveiled the world's smallest motor. This heat engine, which consists of a calcium atom, could be used as a driver of nanoobjects in the future.

A TRANSPORT VEHICLE INSIDE THE BODY

In the years since then, this development has accelerated. In 2018 the research group Micro, Nano, and Molecular Systems at the Max Planck Institute for Intelligent Systems presented a nanomachine that can move through an eye. This propeller-shaped minirobot is only 500 nanometers in size. A test using a pig's eye demonstrated that a swarm of thousands of these robots can move through the meshes of the collagen network in the vitreous body of the eye without causing any damage. The team is now aiming to get this nanopropeller ready to transport active ingredients. Their visionary goal is to use it as a tool for minimally invasive treatments of all illnesses in which the problem area is surrounded by dense tissue that makes it hard to reach.

Even though we probably won't be navigating through the human body in nanosubmarines in the future, nanomedicine is nonetheless experiencing dynamic development. We can expect to see the creation of new and effective applications and methods of treatment here, for example with the help of nanodrones. That's a good reason for the Foresight team at Creavis to keep an eye on this area. After all, more than 20 years ago the first project house at Creavis was already doing research on nanomaterials and their possible applications in electronics, cosmetics, and the coatings and pharmaceutical industries. This area still plays an important role at Evonik today. Creavis is now researching the nanomaterial graphene and identifying potential fields of application—in the area of medical devices, for example.

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