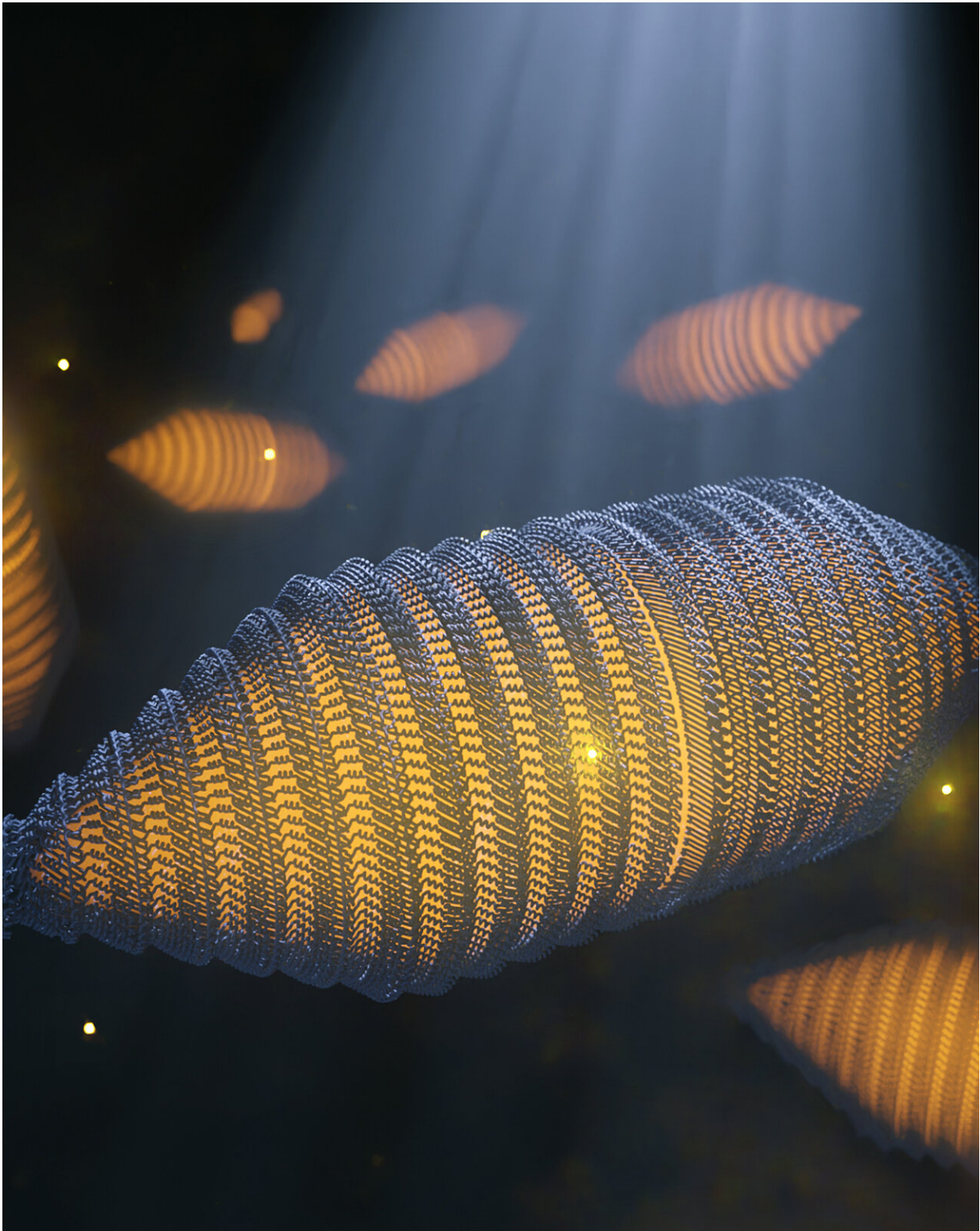


Scientists reveal molecular structure of bacterial gas vesicles

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This picture shows a detailed molecular model of a gas vesicle, a buoyancy device for microbes filled with gas. The vesicle has large pores in its wall to let

gas through, but prevents water from entering due to its extremely water repellent interior. The model is available for researchers in a public data repository (zenodo.org/record/6458345). Credit: TU Delft

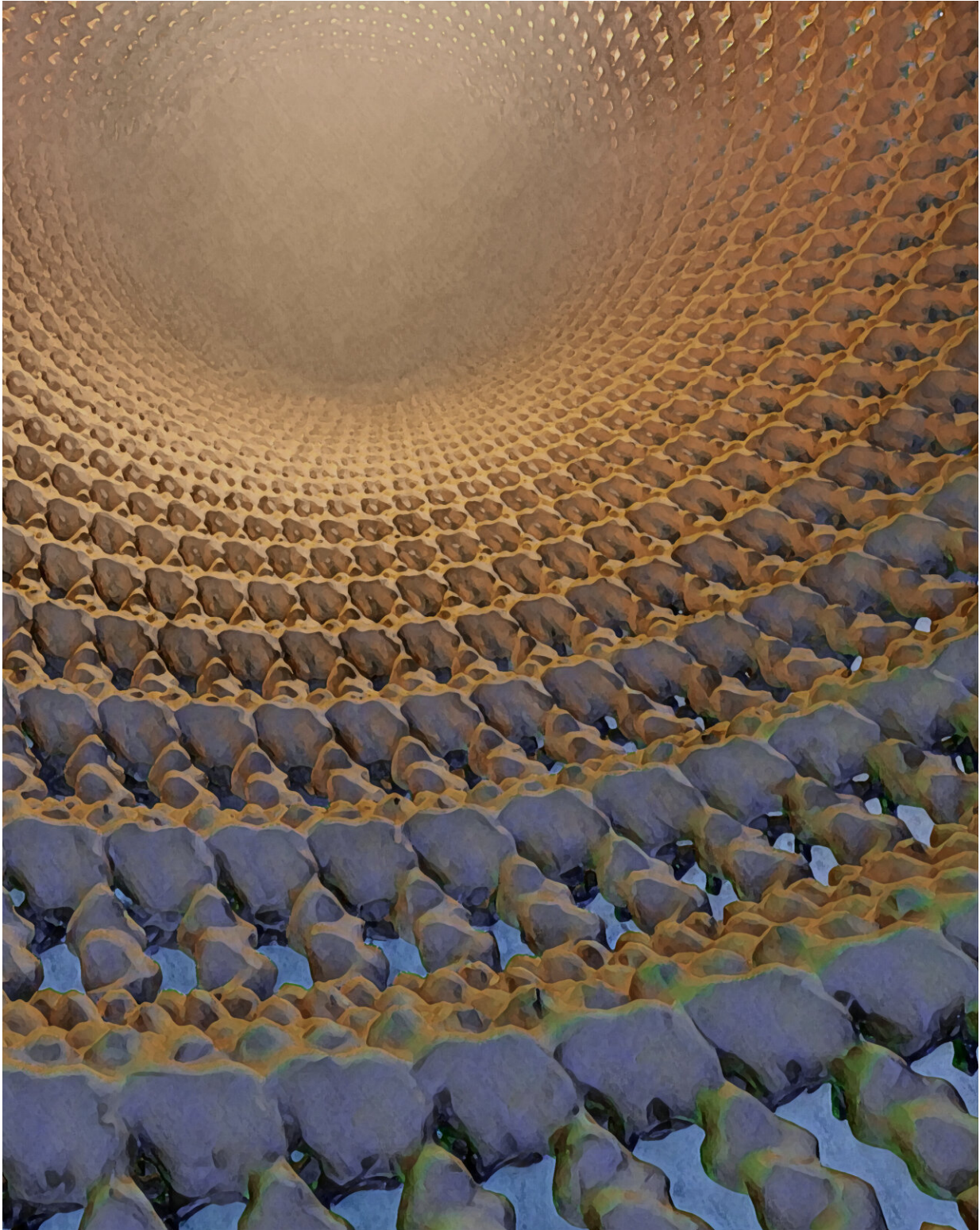
Similar in function to ballast tanks in submarines or fish bladders, many water-based bacteria use gas vesicles to regulate their floatability. In a new publication in *Cell*, scientists from the Departments of Bionanoscience and Imaging Physics now describe the molecular structure of these vesicles for the first time. These gas vesicles were also recently repurposed as contrast agents for ultrasound imaging.

Gas vesicles (GVs) are hollow, cylindrical nanostructures made of a thin protein-based shell and filled with gas. Similar in function to ballast tanks in submarines or fish bladders, many water-based bacteria use these structures to regulate their floatability. "For example, certain cyanobacteria use gas vesicles to float to the surface in order to harvest light for photosynthesis, a phenomenon sometimes seen at enormous scale in toxic algal blooms," says Arjen Jakobi, Assistant Professor at the Department of Bionanoscience.

Stay afloat

There are very specific requirements for such structures: for bacteria to stay afloat, GVs must occupy a substantial proportion of the cell, which involves forming compartments that extend over hundreds of nanometers in size. To maximize floatability, the shell must be constructed from minimal material. At the same time, the shell needs to provide resistance to the pressure from the surrounding water to maintain the ability to float with changes in water depth. GVs have therefore evolved as rigid, thin-walled structures composed of a single protein that repeats many thousands of times to form the GV shell.

"Despite intensive efforts, the molecular structure of GVs and therefore a molecular level understanding of their distinctive properties, has remained elusive," says Stefan Huber, Ph.D. Candidate in Jakobi's lab. "But the very recent development of highly advanced electron microscopy hardware and image processing algorithms has allowed us to solve this structure at almost atomic detail. We can now present the cryogenic electron microscopy (cryo-EM) structure of the GV shell, providing detailed insight into how GVs grow and into the unique evolutionary adaptations that make bacteria float."



The cryo-EM reconstruction shows gas vesicles viewed from the interior gas space. The viewing direction highlights the peculiar features of gas vesicles first

observed by the presented article, such as the smooth water-repellent interior and the pores enabling exchange of gaseous molecules with the outside. Credit: TU Delft

Tin food cans

The gas [vesicle](#) protein GvpA features a corrugated wall structure, typical for force-bearing thin-walled cylinders, similar to the ribbed metal sheet of tin food cans. Small pores enable gas molecules to move through the shell, while the chemical properties of the gas vesicle's interior surface effectively repel water. This design allows the GVs to selectively fill with gas. Comparison across a broad range of different bacterial species showed that the elementary design of gas vesicles remained unchanged throughout evolution.

The structure provides fascinating insight into the peculiar molecular features that bacteria have evolved to enable them to float in a watery environment, and it sheds light on the ingenious engineering principles—at the nanoscale—that are required to maintain thin hollow structures under pressure.

Ultrasound

The study will also facilitate molecular engineering of gas vesicles for ultrasound imaging. "In this study we have collaborated with the lab of David Maresca at the Department of Imaging Physics, who approached us to visualize gas vesicles produced in his lab," says Jakobi. In Maresca's lab, Ph.D. Candidate Dion Terwiel aims to use gas vesicles contrast agents for ultrasound imaging, by tweaking their genetic code. The [high contrast](#) in density between gas-filled GVs and surrounding cellular structures makes them bright in ultrasound images and their

particular properties are a potential improvement over current contrast agents. "The insights we have gained allow me to re-engineer these acoustic biomolecules more precisely," says Terwiel.

"Since 2014, there has been a renewed interest in gas vesicles as these can serve as the '[green fluorescent protein](#)' for ultrasound. Knowing the gas vesicle structure will help us to design acoustic biosensors in order to 'spy' on [biological processes](#) deep into tissues," adds Maresca.

More information: Stefan T. Huber et al, Cryo-EM structure of gas vesicles for buoyancy-controlled motility, *Cell* (2023). [DOI: 10.1016/j.cell.2023.01.041](#)

Provided by Delft University of Technology

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