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PRESS RELEASE (2026/09/10)

Under pressure: How a deep-sea protein adapts to an extreme environment

Researchers uncover the molecular strategy that enables PoXeR, a light-driven protein found in deep-sea microorganisms, to adapt to extreme pressure

Fukuoka, Japan—Life in the deep sea is under immense pressure—literally. Such extreme conditions can disrupt the delicate structures of proteins essential to life. Yet somehow, the proteins in deep-sea creatures remain functional. This raises an intriguing question: how?

A research team, led by Professor Gaku Fukuhara of Kyushu University's Institute for Materials Chemistry and Engineering (IMCE), has uncovered a molecular strategy that enables a deep-sea protein to remain stable under extreme pressure. They found that as pressure increases, the protein assembles into groups of three, called a trimeric structure, and stabilizes itself through a process known as oligomerization-mediated structural stabilization. The findings were published in *Scientific Reports* on July 8, 2026.

"For a long time, no one really understood how organisms adapted to the extreme conditions of the deep sea. Understanding that adaptation on a molecular level is the motivation behind our study," explains Fukuhara.

He designed an experimental study that brought together researchers from different institutions and took a multidisciplinary approach to find the answer. Researchers from the Institute for Solid State Physics at the University of Tokyo prepared the protein samples, while researchers from the Department of Chemistry at the Institute of Science Tokyo executed the experiments.

Together, the team focused on a group of proteins called microbial rhodopsins. Microbial rhodopsins are light-driven proteins, meaning they use light energy to perform biological functions. Although they have been extensively studied under ordinary environmental conditions, far less is known about those originating from extreme environments such as the deep sea.

The researchers compared two microbial rhodopsins from different organisms. The first, Parvularcula oceani xenorhodopsin (PoXeR), is derived from a deep-sea bacterium that has adapted to high-pressure conditions. The second, Gloeobacter rhodopsin (GR), comes from a terrestrial bacterium that normally inhabits atmospheric-pressure environments.

Using a custom-built apparatus, the team subjected both proteins to hydrostatic pressures ranging from 0.1 to 120 MPa (megapascals)—equivalent to pressures at sea level to the deepest point in Earth's oceans. To observe how the protein structure changes under increased pressure, they then used spectroscopic techniques, which monitored how the proteins interacted with light.

The difference between the two proteins was striking.

"When GR was pressurized, its structure became unstable, essentially causing the protein to denature," says Fukuhara. "Then after the pressure was released, GR's absorption spectrum, which is its light-absorption ability, did not return to its original state. The protein had undergone irreversible structural changes.”

PoXeR, in contrast, proved remarkably resilient. “It adapted to the extreme pressure and maintained a stable structure”, Fukuhara noted. After depressurization, its absorption spectrum returned almost entirely to its original state, with no visible signs of denaturation. These results demonstrate that PoXeR possesses significantly greater structural stability than GR under high-pressure conditions.

Most importantly, the researchers revealed a key adaptive strategy behind PoXeR’s resilience. The protein strengthened itself through a process known as oligomerization-mediated structural stabilization.

As Fukuhara explains, “As pressure increases, the molecules adapt to the high-pressure environment by forming groups of three, known as a trimeric structure. This structure is highly suited to the extreme conditions of the deep sea. This is how PoXeR remains stable under pressure.”

Beyond improving our understanding of how life adapts to the deep sea, this discovery could also contribute to the development of light-responsive protein materials capable of functioning under harsh conditions.

“Now, our next step is to move into the medical field. We want to understand how the human body responds to increasing hydrostatic pressure and explore how this might affect the development and treatment of cancer and other diseases,” Fukuhara concluded.

(Written by Science Communicator Intern, Pidot Javier)

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For more information about this research, see “Hydrostatic pressure spectroscopy reveals the adaptation of microbial rhodopsins to high-pressure environment,” Tomoyuki Hamachi, Iori Okamura, Lyu Zikun, Kentaro Mannen, Yoshitaka Kato, Takashi Nagata, Keiichi Inoue & Gaku Fukuhara, *Scientific Reports*, https://doi.org/10.1038/s41598-026-61129-x

About Kyushu University
Founded in 1911, Kyushu University is one of Japan's leading research-oriented institutions of higher education, consistently ranking as one of the top ten Japanese universities in the Times Higher Education World University Rankings and the QS World University Rankings. Located in Fukuoka, on the island of Kyushu—the most southwestern of Japan’s four main islands—Kyushu U sits in a coastal metropolis frequently ranked among the world’s most livable cities and historically known as Japan’s gateway to Asia. Its multiple campuses are home to around 19,000 students and 8,000 faculty and staff. Through its VISION 2030, Kyushu U will “drive social change with integrative knowledge.” By fusing the spectrum of knowledge, from the humanities and arts to engineering and medical sciences, Kyushu U will strengthen its research in the key areas of decarbonization, medicine and health, and environment and food, to tackle society’s most pressing issues.

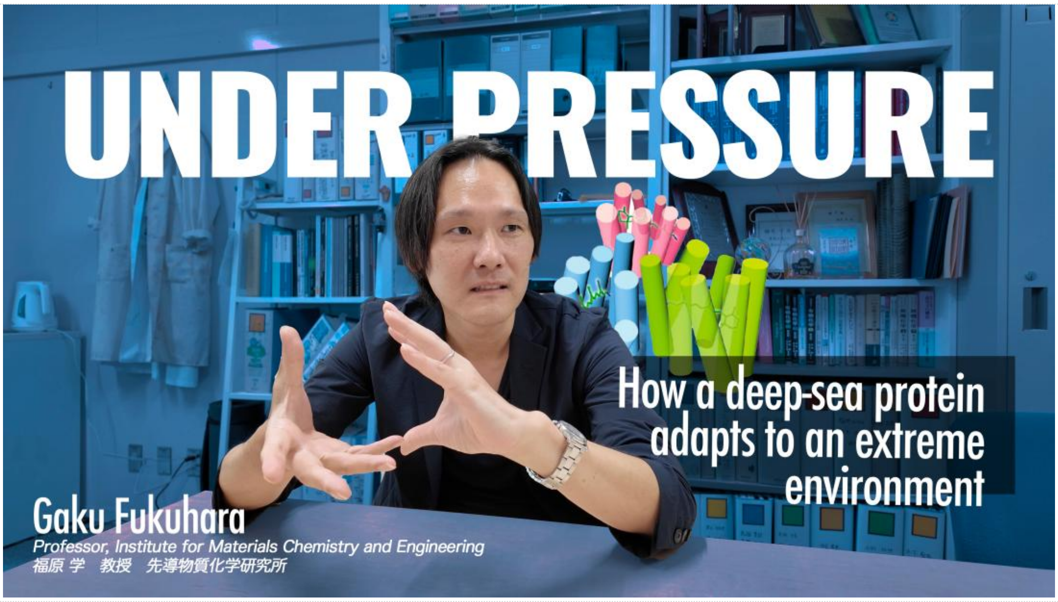

Fig. 1. How can deep-sea organisms survive under extreme pressure? A research team led by Professor Gaku Fukuhara of Kyushu University's Institute for Materials Chemistry and Engineering (IMCE) investigated this biological phenomenon. They focused on PoXeR, a protein from a deep-sea bacterium. Using a custom-built apparatus, they subjected the protein to increasing pressure. The researchers found that as pressure increased, PoXeR stabilized itself by assembling into groups of three, called trimers. This trimeric structure is well suited for high-pressure environments, enabling the protein to remain stable and functional in the deep sea. (Kyushu University)

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