Profile of Paul G. Falkowski

Sandeep Ravindran, Science Writer

Paul G. Falkowski spent much of his research career analyzing the activity of aquatic microorganisms, which captured his interest early in life. As a child, growing up in a New York City Housing Project in Harlem, he received a small fish tank from a family friend, and his father bought him a microscope, prompting Falkowski to observe the tank's microscopic inhabitants. Intrigued, he started borrowing books on fish and microbes from the local public library. "They were from the adult section, so my father had to take them out for me, and I started to become very interested in biology," he says. "I knew every tropical fish, where they came from, what they ate—I bred them and sold them to buy more fish," says Falkowski.

Falkowski translated his interest into pioneering work as a biologist and oceanographer, particularly on understanding photosynthesis and other chemical processes in marine organisms, such as phytoplankton and corals. He has developed new instruments and techniques that have helped researchers study biogeochemical cycles in the ocean, from both ships and satellites. More recently, Falkowski has turned his attention to deciphering the origins of life and the microbial biochemical reactions that transformed Earth's atmosphere.

Falkowski's work on the global biogeochemical cycles of the ocean won him the 2018 Tyler Prize for Environmental Achievement for his "fundamental contributions to Earth's geochemical processes" (1). He has published numerous papers and textbooks and also wrote a popular science book describing his research and experiences in science, Life's Engines: How Microbes Made Earth Habitable (2). Now, a Board of Governors professor at Rutgers University, Falkowski was elected to the National Academy of Sciences in 2007.

**Circuitous Path to Marine Sciences**

Despite his interest in biology, Falkowski spent his high school years mostly taking courses in physics, chemistry, and engineering. He went even further afield when he joined the City College of New York as an undergraduate, deciding to major in philosophy. However, his foray into the humanities was short-lived. "My first year, I had a professor of logic who pulled me aside one day and said, 'You know, you shouldn't be majoring in philosophy, you'll make a terrible philosopher. Why don't you major in science?'"

The professor, Kaikhosrov Irani, was once a student of Albert Einstein. "He was an amazing philosophy professor of logic, but he also knew the sciences very deeply," says Falkowski. Irani's advice prompted Falkowski to switch his major to chemistry and biology, a fortuitous move in the long term.

In the short term, however, Falkowski, faced hurdles. When he first applied to graduate school in marine sciences, he was rejected from all of them, prompting one of his biology professors to tell him, "Some of us are not cut out to go further in science, and maybe you should think of another career," recalls Falkowski. Undeterred, he completed a Master's degree at City College of New York and reapplied to graduate schools; this time around, he was admitted to several and chose the University of British Columbia.

During his doctorate, Falkowski took courses in biochemistry, biophysics, and physical oceanography, and became interested in fundamental biophysical questions about ion transport across cellular membranes. After graduating in 1975, he began postdoctoral research at the University of Rhode Island, but only spent 9 months there, thanks to an unexpected opportunity.

**Measuring Photosynthesis in the Ocean**

A few months into his postdoctoral stint, Falkowski attended a seminar where he met John Walsh, the director of the oceanographic sciences division at Brookhaven National Laboratory. Walsh promptly asked Falkowski to join Brookhaven. "I thought he was joking, so I went back to Rhode Island, and I didn't even think about it," says Falkowski. However, Walsh called him a few weeks later, asking why Falkowski had not responded, and invited him to deliver a seminar at Brookhaven. Falkowski did so and, a few weeks later, he was hired. He joined Brookhaven in 1976 and continued there for another 23 years.

"It was a very exciting place: You're sitting at lunch with several chemists, physicists, and biologists, and about two out of three people had worked on the atomic bomb project at Los Alamos," he says. "It was a very interesting time,"

This article is distributed under Creative Commons Attribution-NonCommercial-NoDerivatives License 4.0 (CC BY-NC-ND).

Published July 20, 2022.
and I learned a lot of biophysics and what we would today call structural biology there,” says Falkowski.

Within a month of being at Brookhaven, Falkowski attended a symposium on plant molecular biology, with presentations by several of the field's pioneers. “After that, I became much more interested in how plants evolve oxygen,” he says, adding “To this day, we still don’t really understand how plants split water to make oxygen.”

Falkowski spent the next decade or so focused on developing new technologies that could measure photosynthesis in the ocean. He developed variable fluorescence methods to measure photosynthesis rates and worked with engineers and physicists to make the techniques more sophisticated. “We made instruments that are still the top of the line,” says Falkowski. “They're super sensitive, and you can measure photosynthetic rates in real time, every minute of every day, as you travel thousands of kilometers on a ship,” he says. Falkowski deployed the instruments on cruises all over the world, and the fluorescence techniques have played a crucial role in analyzing photosynthetic processes in the ocean (3).

In 1992, Falkowski received a Guggenheim fellowship, which he spent in France studying satellite oceanography. Upon returning to Brookhaven, he used a grant from NASA to develop algorithms that could determine the photosynthetic rates for the ocean from space using satellites. This work led to a 1998 article in Science on the productivity of the oceans and the land (4). “It became one of the bestsellers, if you will, in that it established for the first time that even though the ocean has less than 1% of the photosynthetic biomass, it produces almost half of the photosynthetic oxygen on the planet,” says Falkowski. “So, a very small amount of biomass can produce a huge amount of oxygen, whereas the vast amount of biomass of land plants is wood and basically that's a plumbing system; it’s not producing oxygen,” he says.

Falkowski’s work has led to the understanding of fundamental processes, including how cells of unicellular algae sense light intensity and alter their pigment composition through what became later known as the retrograde signaling pathway (5). “We were one of the first groups to identify that the signaling molecule is an electron transport component in the photosynthetic pathway that somehow signals to the nucleus to turn on genes,” he says. “So, you have a plastid-to-nuclear signaling pathway based on a signal from the electron transport chain in the plastid. That was a pretty fundamental discovery.” Falkowski’s decades of work on studying photosynthesis led to the publication of a textbook with John Raven in 2007, Aquatic Photosynthesis (6).

**Spending Time at Sea**

In 1998, Falkowski moved to Rutgers University to continue developing programs in remote sensing and biophysics of the ocean. “The entire oceanographic sciences division at Brookhaven National Laboratory was effectively defunded by the Department of Energy because it was considered irrelevant to the Department of Energy's mission,” he says. Staying on at Brookhaven would have meant a drastic change in Falkowski’s research. “I looked around for jobs because I didn’t want to stand at a lab bench for the rest of my life. I like being out in the real world, in the open ocean, on a ship,” he says. “I love being at sea because it is, for me, the most mysterious part of this planet,” says Falkowski.

Falkowski’s interest in being on the water is deep-seated, and research vessels have been a constant feature of his career. As a junior at City College, Falkowski went up and down the Hudson River on a 60-foot catamaran, and during his doctorate, he traveled on ships from Vancouver to the Queen Charlotte Islands and to various glacier-fed fjords. His seafaring would continue at Brookhaven, as he went out on ships in the Atlantic and Pacific oceans. “Oceanographers live cheek to jowl with each other for weeks and weeks on end, and it is large-scale collaborative research,” says Falkowski.

Falkowski says he treasures the time he has spent on the open sea. “It’s very difficult to explain the beauty of watching a sunset in the ocean and watching flying fish and dolphins chase your ship, and watching whales jump,” he says. “You get an appreciation that you’re just a very new creature that’s trying to understand how the world evolved, and that’s to me one of the most humbling experiences you can have.”

**New Challenge**

Falkowski recently embarked on an ambitious project: deciphering the origin of life. “When you get older, you can do things that are a little bit more daring. The evolution of life is what I’ve occupied myself with for the last few years,” he says.

Falkowski’s experience working on photosynthesis and metabolism led him to postulate that it must be proteins that formed the first metabolic processes of life because of their ability to generate electron flows. “I tend to think of the planet as a giant electrical circuit, with one power supply, which is the sun, and two main wires—the atmosphere and the ocean—that move electrons across the planet,” he says. “Then, all living creatures on the surface of the planet become essentially diodes or transistors on a breadboard electrical circuit,” says Falkowski. Different forms of life may have different body plans, but they fulfill the same basic roles in this planetary circuit.

Falkowski’s goal is to figure out how the first living components of this circuit evolved. He has focused on deciphering the origins of the first protein structures, trying to find simple proteins with a single fold or maybe two folds, just enough to create metabolism. “I became very interested in how molecules, such as oxidoreductases, move electrons and create metabolism,” he says. It is an ongoing project that could help answer fundamental questions about the evolution of life and of the first metabolic processes.

The project’s scope reflects Falkowski’s career-long focus on asking big, fundamental questions. “In my opinion, scientists are defined by the questions they ask, not necessarily those that they answer,” he says.

Falkowski loves teaching and encourages young scientists in his class to remember the kind of questions they asked when they were kids. “When you were 5, 6, 7, 8 years old, you looked at the stars and asked what they are. You asked, ‘Where did I come from? Why do the leaves on the tree turn colors?’ and other naïve questions,” he says. “But they’re not naïve; those questions are the ones that are fundamental to understanding life on Earth and how things work.”
1. Tyler Prize for Environmental Achievement, 2018 Tyler Laureates, (2018). https://tylerprize.org/laureates/past-laureates/2018-tyler-laureates/
2. P. G. Falkowski, Life’s Engines: How Microbes Made Earth Habitable (Princeton University Press, 2015).
3. H. Lin et al., The fate of photons absorbed by phytoplankton in the global ocean. Science 351, 264–267 (2016).
4. C. B. Field, M. J. Behrenfeld, J. T. Randerson, P. Falkowski, Primary production of the biosphere: Integrating terrestrial and oceanic components. Science 281, 237–240 (1998).
5. J. M. Escoubas, M. Lomas, J. LaRoche, P. G. Falkowski, Light intensity regulation of cab gene transcription is signaled by the redox state of the plastoquinone pool. Proc. Natl. Acad. Sci. U.S.A. 92, 10237–10241 (1995).
6. P. G. Falkowski, J. A. Raven, Aquatic Photosynthesis (Princeton University Press, 2007).