PROFILE

Profile of Edward DeLong

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Every year, gray whales travel up and down the Pacific coast, migrating between the Bering Sea and Baja California. In the mid-1970s, Northern California amateur skin diver Edward DeLong tried to swim out to meet them. With his sights set on some of the ocean's largest creatures, DeLong was oblivious to the microecosystem swirling around him in the cool water. Instead, his fascination for the vast and mysterious ocean impelled him to reach for the huge, shadowy whales in the distance.

But the unseen marine world—the microorganisms that were then largely unknown to DeLong and to science—became the ultimate object of his fascination. Today, DeLong is a marine microbiologist at the Massachusetts Institute of Technology and a member of the National Academy of Sciences. Over the years, he has probed genetic clues to uncover long-held secrets of the sea, including the composition and function of microbial communities from Hawaii to Antarctica. DeLong has learned that studying a reservoir of life as large and diverse as the ocean can lead to unexpected discoveries. "We're continually being surprised," he says.

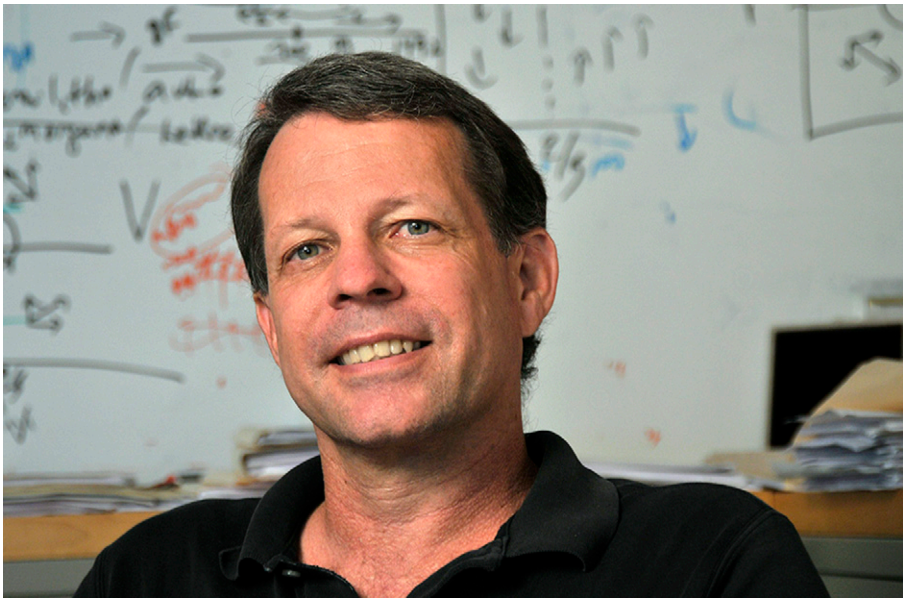
Finding Himself

Born in 1958, the third of six children, DeLong grew up in Sonoma, California on an "overdose of Jacques Cousteau," he says. As a teenager, he encountered sea lions and sea otters on skin diving expeditions with friends, and attempted to reach gray whales. "We never actually met them face to face," he says.

DeLong's father, a high school English teacher, encouraged his children in academics, but 18-year-old DeLong did not feel ready for college. He went to Alaska for a year to "find himself," he says. But the Alaskan job market in 1977, shortly after completion of the Trans-Alaska Pipeline, was flooded with other young men eager for work. After waiting tables and clerking at a convenience store, DeLong returned to California to enroll in school.

At the University of California, Davis DeLong majored in bacteriology, hoping to apply his fascination with biology in a career as a medical technologist. However, an undergraduate research experience with marine bacterial taxonomist Paul Baumann changed his path. The project aimed to compare enzymes among four genera of marine bacteria and infer evolutionary relationships.

"That's where the inkling started that I could combine my interests in biology and my passion for the ocean," DeLong says. "I hadn't even realized up until that point that research was an option." The findings were published in the *Archives of Microbiology* with DeLong as first author (1).



Edward DeLong. Photo by L. Barry Hetherington.

Setting His Compass

DeLong arrived at the Scripps Institution of Oceanography in 1982 to begin graduate school. Under biophysicist Art Yayanos, DeLong studied pressure-adapted microorganisms and discovered polyunsaturated fatty acids in deep-sea bacteria that were produced as antifreeze to counteract the effects of the cold, high-pressure environment of the deep ocean (2). Furthermore, the discovery pointed to a new source of these essential nutrients for deep-sea fish and invertebrates (3). DeLong's biochemical study had produced a new ecological hypothesis.

"Sometimes you end up hitting a target you didn't know you were shooting at," DeLong says.

Nearing graduation in 1986, DeLong read a PNAS study (4) authored by Norman Pace and colleagues, then at Indiana University in Bloomington, about a new approach to microbiology. In 1977, evolutionary biologist Carl Woese had defined a kingdom of microorganisms, called archaea, in a study using 16S ribosomal RNA as a phylogenetic tool (5). Pace had developed methods to rapidly sequence ribosomal RNAs, allowing for genetic profiling of entire microbial populations. Before this effort, microbiologists could study only what they could grow in the laboratory. "We had a real gap in our understanding," DeLong says. Pace's work opened up a new method of cultivation-independent microbiology, which later developed into community genome sequencing, also called "metagenomics." DeLong wanted to be a part of the field.

DeLong began his postdoctoral fellowship with Pace in 1986, and applied his experience with molecular biology to ribosomal

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Edward DeLong conducting fieldwork on skis in Antarctica in 1995. Photo by Alison Murray.

phylogeny. With his colleagues, DeLong developed fluorescent oligonucleotide ribosomal RNA probes that could be tailored to attach only to cells of specific microbial taxa (6). "Basically, you could color-code and count different microbial cell types under the microscope," DeLong says.

In 1989, DeLong accepted a position as an assistant scientist at Woods Hole Oceanographic Institution. For the first year, he worked alone in the laboratory, running experiments, washing laboratory dishes, and writing grant proposals. Feeling insecure at the prospect of finding all of his own funding, DeLong strove to define a unique research program and set his research compass.

After nearly a year, DeLong secured an Office of Naval Research Young Investigator Award to study the microorganisms clinging to sinking bits of detritus, often called "marine snow." DeLong set out to characterize the distinction between microbial populations on these particles and those in the free water column using metagenomics. He planned to explore the hypothesis that methanogenic archaea lived in the anaerobic interior of marine snow.

"I got exactly the opposite result," he says. DeLong found little evidence of archaea in detritus particles, but instead found the surrounding ocean to be teeming with them (7). Archaea, he discovered, were not limited to deep-sea vents and other extreme environments.

DeLong's Young Investigator award gave him confidence and direction. "I felt like I'd been able to define a unique question," he says. "I felt like the compass has been set."

Seeking to teach, DeLong moved to the University of California, Santa Barbara in 1992. Inspired by microbial samples from Antarctica, composed of up to 30% archaea, he traveled to Antarctica to study the unusual microorganisms in a cold-water environment. But his research vessel, the Norwegian icebreaker Polar Duke, became trapped in ice en route. DeLong and his colleagues were stuck.

"I like to tell people that I biked 500 miles to Antarctica," DeLong says, referring to the time he spent on an exercise bike while the ship was beset by ice. Others passed the time producing a daily newspaper, the "Dukie News," to which DeLong contributed an anonymous advice column.

After 10 days, the Polar Duke broke free of the ice. DeLong's subsequent research revealed that the planktonic archaea *Crenarchaeota* (now called *Thaumarchaeota*) accounted for up to 20% of recoverable ribosomal RNA in the −2 °C Antarctic waters, and that archaea and bacteria engage in a seasonal tug-of-war, with bacteria outnumbering archaea in the summer and archaea gaining the upper hand during winter (8).

A Secret Source of Energy

DeLong moved to the Monterey Bay Aquarium Research Institute (MBARI) in 1997. He began developing high-throughput cloning and sequencing methods, borrowed from the Human Genome Project, to explore the genetics and physiology of marine microbes. DeLong planned to collect large chromosomal segments from bacterioplankton, identify their origins from ribosomal RNA, and determine what genes were associated with individual species.

MBARI president Chris Scholin recalls DeLong reassuring him that these efforts would pay off. "There was clearly a solid line of reasoning behind the work, but it wasn't clear from the outset what [lay] ahead—as if setting sail to find lands unknown," Scholin says. The payoff did not take long to materialize.

"The second clone we sequenced," DeLong says, "had a rhodopsin gene, which had never been seen in bacteria before." Rhodopsins are light-sensitive proteins that change their conformation when struck by a photon. The change causes protons to be pumped out of a cell, setting in motion an energy-generating system similar to that in mitochondria. Previously, bacteriorhodopsin in halophilic archaea was the only proton-pumping rhodopsin known. But the proteorhodopsin genes discovered by DeLong and postdoctoral researcher Oded Béjà implied that rhodopsins were more widespread and could support phototrophy throughout surface ocean waters, a process they deemed "globally significant" in their paper published in *Nature* in 2001 (9).

"That substantially changes our notion of what energy sources are available to marine microbes," DeLong says. Previously, microbiologists thought that bacterial heterotrophs gained energy exclusively from organic carbon. "Now we know they're a little like a hybrid car; they're able to tap into light energy as well."

From Genes to Ecosystems

DeLong moved to the Massachusetts Institute of Technology in 2004 to stay at the forefront of developing genomic technologies. But his past accomplishments had already caught the attention of his peers. On April 29, 2008, DeLong received a phone call in his office from microbial ecologist and National Academy of Sciences member Jim Tiedje, announcing DeLong's election that morning as a member of the Academy.

"The most exciting thing was getting e-mails from colleagues whom I have such tremendous respect for, congratulating me. These are people who are my role models and heroes. To get a pat on the back from those sorts of folks—I can't think of a better honor."

DeLong's inaugural article (10), published in 2010, explored how marine microbes participate in the energy and carbon cycles associated with dissolved organic carbon (DOC) in the ocean. DOC, composed of carbohydrates, amino acids, and other complex organic molecules, represents a vast reservoir of carbon in the ocean, DeLong says. With Dan Repeta, a marine chemist at the Woods Hole Oceanographic Institution, DeLong and colleagues used metagenomics to determine which genes microbes use to consume long-chain polysaccharides introduced into seawater samples. As time went on, consumers of small single-carbon molecules became dominant, despite the large size of the DOC molecules. The microbes were apparently chipping single-carbon molecules off the polysaccharides, playing a role in global carbon cycling.

DeLong will continue exploring those cycles of carbon and energy when he moves to the University of Hawaii in 2014, joining the Center for Microbial Oceanography: Research and Education. He hopes to integrate oceanography, biogeochemistry, and genomics to continue exploring microbial processes at work in the ocean.

"This kind of research takes a village," DeLong says. "In this era of the Anthropocene, it's our duty as scientists to more accurately define how the natural world around us works, and how human activities are affecting it."

Outside the laboratory, DeLong spends most of his free time with his 17-year-old son. Parenting, DeLong says, has informed his interaction with graduate students, and vice versa. He has learned to be patient, he says, and to let go of preconceptions of his son's or his students' capabilities as they grow. "You have to leave room for that new person who's evolving," he says.

When advising new graduate students, DeLong tells them to set their compass by following their passion, advice that he lives by; every decision in his career, beginning with leaving Alaska to begin school, has been motivated by his drive to explore the natural world.

"The big rush," DeLong says, "is when you know you've teased a little secret out of nature—because she doesn't give them out easily—and you've gotten a peek at something that nobody's been able to see before that tells us a little bit more about how the natural world works."

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