

OCEAN LIFE INSTITUTE



2010 REPORT

Woods Hole Oceanographic Institution

Director's Message



Photo of Cabell Davis by Tom Kleindinst, WHOI

The Ocean Life Institute supports ground-breaking basic research covering the full range of marine organisms, from bacteria to whales. Over the past year, OLI funded research in a number of important areas through a combination of research grants and fellowships to scientists, postdoctoral investigators and graduate students. OLI research grants supported studies of anti-cancer, anti-viral and anti-grazing compounds in phytoplankton, nutrient cycling in a dominant but poorly understood group of planktonic

bacteria, and use of the blue mussel as a sentinel for coastal pollution. Research fellows continued their cutting-edge research on ancient DNA in marine sediments and protein studies of ocean carbon and nitrogen cycling. Postdoctoral research has focused on coral-associated microbes and coral disease using DNA analysis as well as movements of tagged humpback whales in the Gulf of Maine. Student research has included studies of planktonic larvae of coastal invertebrates and the importance of predatory bacteria in controlling marine microbial communities.

In addition to supporting individual-based research, OLI has worked on two new initiatives:

- Ecosystem-based management (EBM) of the ocean: OLI's efforts to stimulate research in the area of EBM and modeling-observing systems helped to establish a new multi-institutional NOAA-funded Cooperative Institute for the North Atlantic Region, for which WHOI is the lead institution.
- Coral reef research: The Coral Reef Initiative sponsored collaborative agreements with Academia Sinica (Taiwan) and the University of the Virgin Islands. Coral research supported by OLI has included studies of how global warming and ocean acidification impact coral skeletal growth.

The future work of OLI also looks bright thanks to my colleague Simon Thorrold, who took the reins as OLI director in October. A New Zealand-born biologist with expertise in the migration and population dynamics of marine invertebrates and fish, and a passion for conservation science, he has embarked on strengthening existing initiatives and creating bold new partnerships to support the innovative ideas born in the labs of WHOI and funded by OLI.

—Cabell Davis



Photo of Simon Thorrold by Tom Kleindinst, WHOI



Above: A Mushroom coral (Herpolitha limax) from a Red Sea reef afflicted with disease lesions. Below it is a healthy coral. Photo by Kathryn Furby.

On the cover: A humpback whale with its offspring (Megaptera novaengliae).

Microbial communities linked to marine animal health

The human body contains more microbial cells than human cells, and these microorganisms play important roles both in maintaining and compromising our health. The same is true for marine animals; for example, microbes provide the nutrients and defenses that support the high rates of coral productivity necessary to build reefs, but can also play a role in disease.

In collaboration with Konrad Huguen and Tracy Mincer (Marine Chemistry and Geochemistry), postdoctoral scholar Amy Apprill is studying the microbiology of Red Sea corals to understand the microbial community composition of coral displaying symptoms of lesions that are visually similar to yellow band disease (YBD). Recognizable by a pale-yellow lesion band on the surface of corals, YBD was formally described on corals in the Caribbean, and is attributed to a consortium of bacterial pathogens. By comparing the bacterial communities associated with healthy corals, lesion-afflicted corals and reef seawater, with samples from eight diverse reef locations in the Red Sea, Apprill and her team hope to determine if the YBD-associated pathogens, or other bacterial pathogens, are associated with the corals or the reef waters.

“Bacterial pathogens are thought to cause the disease state, and the real harm of YBD-associated pathogens is that they disrupt photosynthesis by the coral’s symbiotic algae,” Apprill explained. “Without functioning algal symbionts, the coral cannot meet its metabolic needs and dies. Thus, yellow band disease affects the survival of important reef-building corals.”

Apprill’s study of microbiology extends to marine mammals, including the skin bacterial flora of humpback whales.

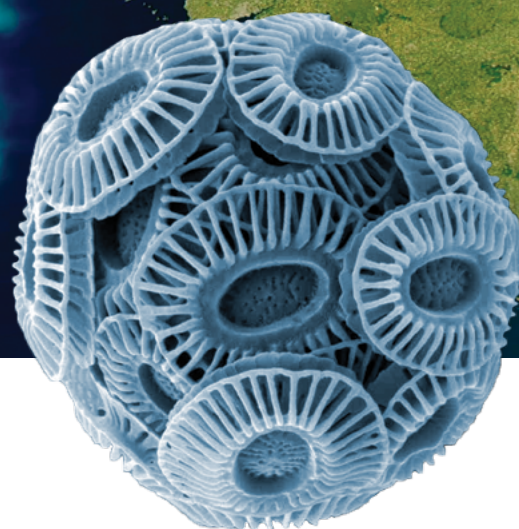
With collaborators in Hawaii, she and WHOI postdoctoral scholar T. Aran Mooney have newly identified bacterial communities that differ between healthy and unhealthy animals. They are excited about this particular finding because it indicates that skin-associated microbial communities may offer clues to the health status of humpbacks, and these data could be useful for conservation management of the endangered populations.

Using a combination of DNA-based analyses that fingerprint and identify bacterial community members, Apprill found that North Pacific humpback whales possess bacteria on their skin that is dominated by two groups of previously undescribed bacteria.

“Results from the whale-bacteria study appear to be analogous to human patterns of individual skin bacterial community signatures that were recently proposed as a useful tool for forensic identifications,” Apprill said. “Assessing the health of free-ranging marine mammals is a challenging endeavor, and this study indicates that ‘bacterial signatures’ may provide important information about the health and life history of endangered marine mammals.”

Beginning in the fall of 2009, OLI has been providing funding for project development and data analysis as Amy Apprill continues to study associations between microorganisms and marine animals and identifying microbial biomarker indices for coral health. OLI is supporting Apprill for 18 months and her total award is \$87,350.

Unleashing the power of phytoplankton



Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC

In massive blue-green blooms large enough to be seen from passenger jets and even space, *Emiliania huxleyi* appears to be cloud-like and peaceful. WHOI scientists have found quite a different reality. These phytoplankton play a role in a microbial arms race that could ultimately impact the global carbon cycle as well as a host of human viral diseases.

The team of WHOI Research Associate Helen Fredricks and Associate Scientist Benjamin Van Mooy of the Marine Chemistry & Geochemistry Department has been working toward determining the exact molecular structures of two specific membrane lipid molecules, or fatty compounds, from *E. huxleyi*. These lipids appear when *E. huxleyi* become infected by viruses, which can be fatal to the phytoplankton's cells and are hypothesized to contribute to the collapse of large blooms. When the blooms collapse, the cells can sink into the deep sea, carrying abundant carbon with them.

A bloom off Brittany, France, coloring the water of the Atlantic Ocean bright blue. Like other types of phytoplankton, coccolithophores are a source of food for marine organisms. Though coccoliths are small, they often form large, concentrated blooms that are visible from space.

E. huxleyi performs photosynthesis—"just like plants," says Van Mooy. "They suck up carbon dioxide." In doing so, they reduce the amount of CO₂ released into the atmosphere. They form a calcium carbonate shell, also helping to regulate the carbon cycle.

If viruses are killing off phytoplankton, this can increase greenhouse emissions, Van Mooy suggests. "That's important because if viruses infect a whole bunch of cells, then they can't perform photosynthesis; they can't take up carbon dioxide."

After isolating the viral lipids, the WHOI team, working in collaboration with researchers from Rutgers University, found that the lipids alone were able to bring about the symptoms of viral infection in the phytoplankton. "Seeing this viral lipid appear during the course of infection was amazing, and then we found it in the ocean, too," Fredricks said.

This alone was enough to excite the team. "Now we have a biological marker that we can go out on a ship and look for and identify where this [infection of phytoplankton] is happening and learn how to study it better," Van Mooy says.

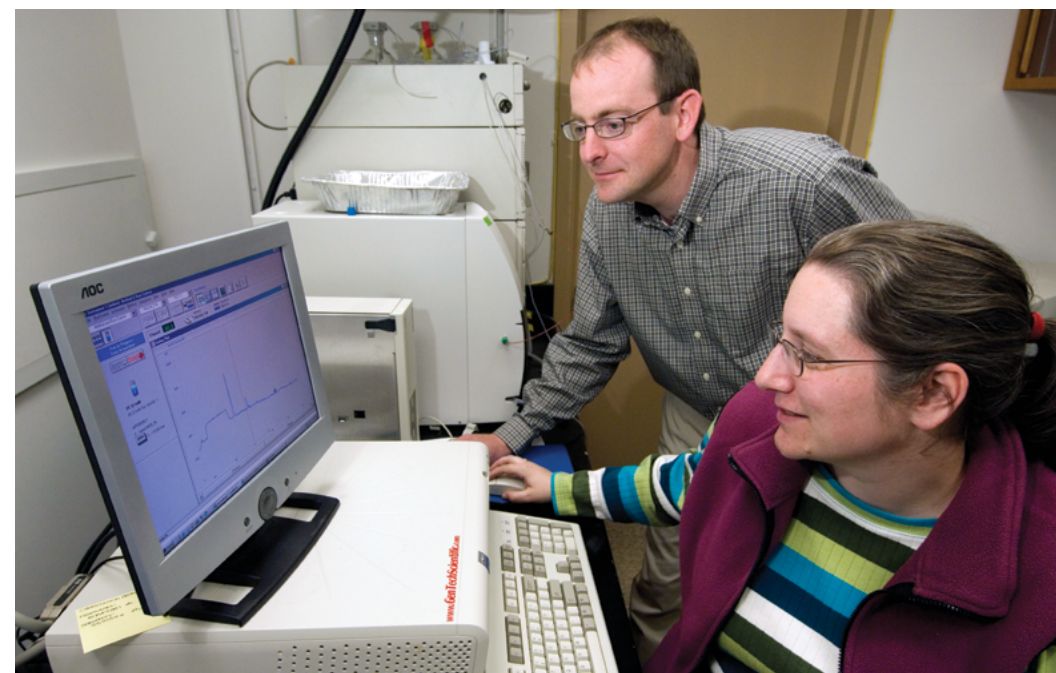
This same study holds unexpected promise for research in human viral diseases. One of the lipid molecules originates from the virus itself and appears to be used by the virus to kill *E. huxleyi*; the second lipid molecule appears to be used by *E. huxleyi* to fight off the viruses. Scientists hope that understanding how these molecules either kill or defend *E. huxleyi* will shed light on

the mysteries of cancer and many other diseases.

Van Mooy sees it as a struggle between two mighty forces. "The phytoplankton are at one end of the boxing ring and they're taking up carbon dioxide, and the viruses are at the other end, and they're out to kill them. And how that works out controls how much carbon dioxide is taken up.

"We're very interested in understanding what controls these phytoplankton," he says. "I didn't know that much about viruses until I started working on this project, and the Rutgers researchers didn't know that much about lipids. So now we're both really onto something here.

"We have found other interesting lipids from these viruses," said Van Mooy. "There are probably more out there. And who knows what kind of activities they may be involved with. They may hold a cure for a human disease or they may play an unknown role in...phytoplankton."

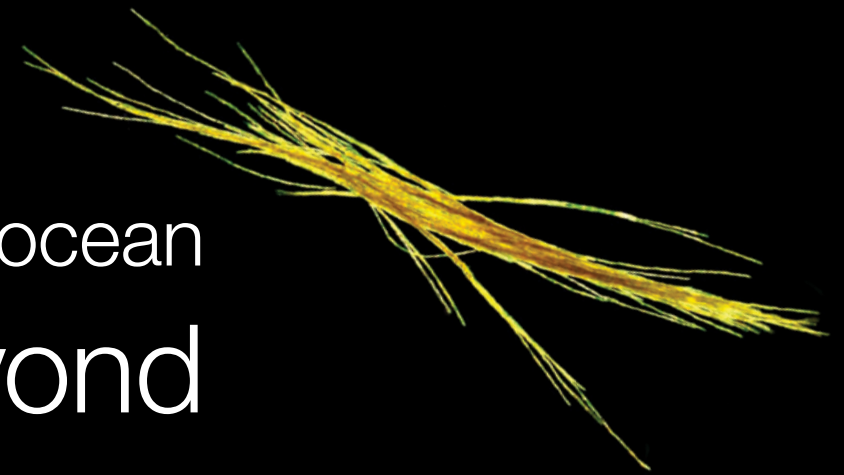


Tom Kleindinst, WHOI

OLI provided \$49,932 in 2009 to Helen Fredricks and Benjamin Van Mooy (above) to analyze samples collected in the field and continue their collaboration with Rutgers University on this project. In 2010 the pair submitted a multimillion dollar proposal to the National Science Foundation to return to the sea and search for molecular signs of viral infection.

Life and death

in the deep ocean and beyond



Like their colleagues, chemists Helen Fredricks and Benjamin Van Mooy, biologist Matthew Johnson and chemist Tracy Mincer are fascinated with the inner workings of the marine phytoplankton *Emiliana huxleyi*. They have found that small molecules produced by certain bacteria can be significant in influencing photosystem health or growth of major bloom-forming phytoplankton, like *E. huxleyi*, and thus may play a role in structuring phytoplankton composition in the water column.

The life cycle of *E. huxleyi* is of interest on a number of levels, and one of its most important functions is in the transport of carbon and nutrients to the deep ocean during its demise. These phytoplankton gather nutrients during their short life, where under optimal conditions they rapidly grow into massive surface blooms that can be seen from space. However, when they die, they either release nutrients, creating a feast for other organisms, or sink in large aggregates to the deep. Thus, the way in which *E. huxleyi* die makes a difference in the ocean's carbon transport.

Johnson and Mincer's project focuses on identifying and isolating allelopathic compounds—ones which negatively influence the survival and reproduction of other organisms—produced from various bacteria that coexist with *E. huxleyi* in Atlantic and Pacific waters.

By using a new bioassay (a procedure in which a representative cell culture or enzyme is used to screen various pure chemicals or chemical cocktails based solely upon function) that they developed, Johnson and Mincer identified extracts from cyanobacteria *Trichodesmium erythraeum* (pictured at right) which generated the greatest toxicity toward *E. huxleyi*. They saw that the toxicity of extracts toward *E. huxleyi* was manifested by dramatic declines in photosynthetic efficiency and ultimately death, generally within 24 hours. The cyanobacteria *Microcoleus* sp. and the heterotrophic bacterium, *Rheinheimera aquimaris*, also produced strong allelopathic effects on *E. huxleyi*. Together, these findings have revealed previously unknown chemical warfare among some of the ocean's major microbial players, raising new questions of what constrains phytoplankton productivity.

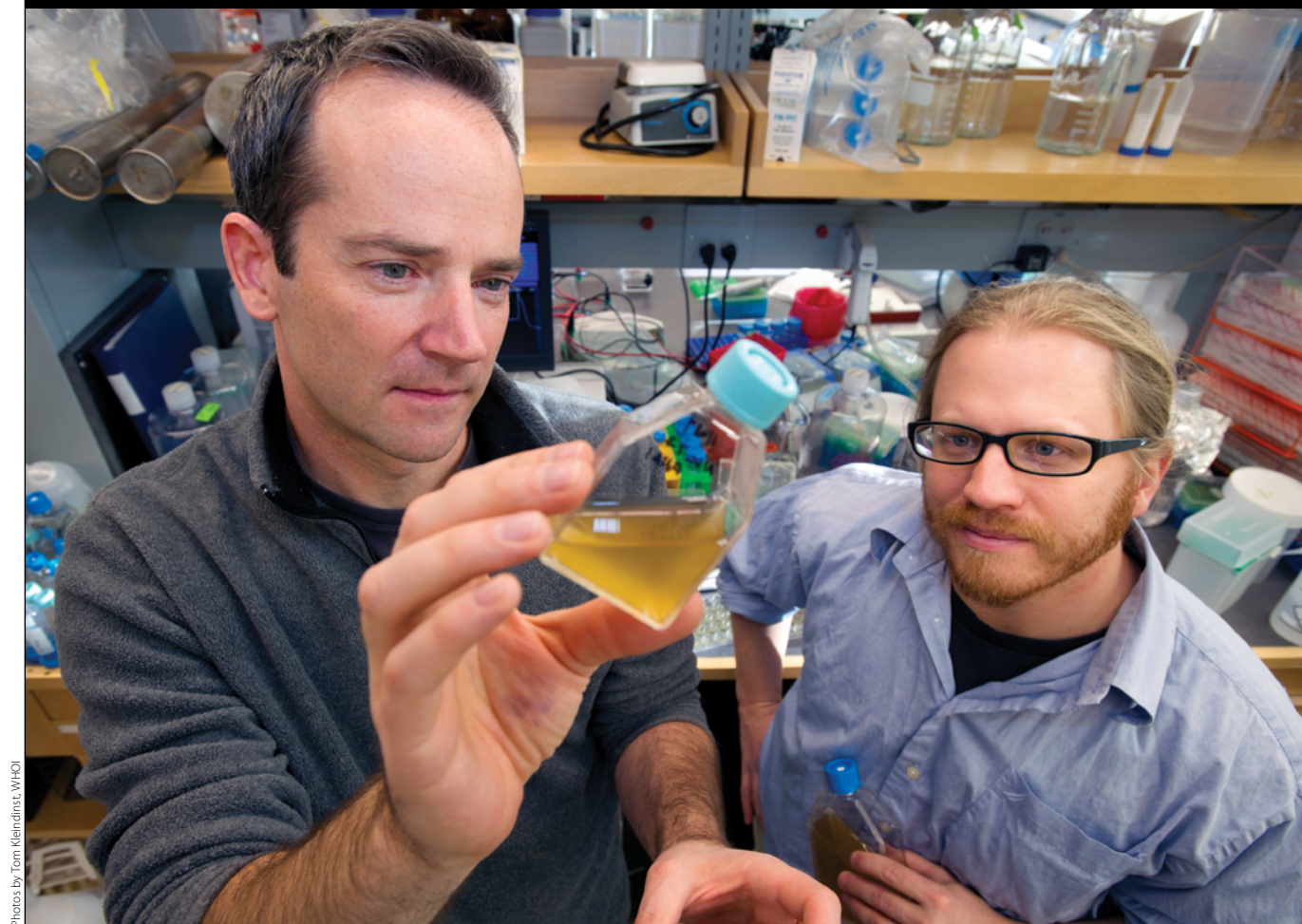
"This new bioassay is very exciting," Johnson said. "It's allowed us to look at this issue in ways we've never looked before, and allows us to imagine greater possibilities."

"We're just scratching the surface," Mincer added. "We believe these toxins are far more common in nature. This is just the first look."

Because these toxins are highly specialized—they can knock out specific cellular machinery of an organism in order to kill it—Johnson and Mincer believe they can turn on or off a "switch" in an organism to initiate death. This

switch, they said, may open new doors in chemistry. A natural yet efficient herbicide, for example could result from the mysteries they unlock.

OLI provided \$49,934 in 2009 to Matthew Johnson and Tracy Mincer for the proposal, "Allelopathic and Antigrazing compounds in marine cyanobacteria and dinoflagellates: characterization, community effects, and mode of action."



Photos by Tom Kleindinst, WHOI

Marine archaea and the tree of life

in the tree of life. They used enrichment cultures (cultivated microbial communities grown in a medium with qualities that favor the growth of these particular microorganisms) to determine their physiology and metabolism. In particular, they were interested in the nitrogen and oxygen isotopic discrimination of marine ammonia-oxidizing archaea. Isotopes are forms of the same element that have different masses and isotopic discrimination, or an “isotope effect,” which arises in enzymatic reactions due to the mass difference. Isotope effects are key parameters for interpreting isotope measurements in the ocean to understand how nitrogen cycles in the ocean.

Their research has resulted in two presentations at national meetings, including the Marine Microbiology Gordon Research Conference and the International Society of Microbial Ecology meeting, and a submitted manuscript. Maintenance of the cultures has also facilitated collaborations with other scientists at WHOI, including Associate Scientist Mak Saito, with future plans to characterize their genome and proteome.

Ongoing work is focused on examining the role of marine archaea in production of nitrous oxide, a powerful greenhouse gas. Continued maintenance of these enrichments will allow Casciotti and Santoro to pursue outside funding for genomic characterization to help answer lingering questions about the placement of ammonia-oxidizing archaea on the tree of life.

OLI provided \$38,700 in 2009 to allow Karen Casciotti and Alyson Santoro to maintain and study stable enrichment cultures of three strains of the ammonia-oxidizing marine archaea Crenarchaeota in their laboratory.

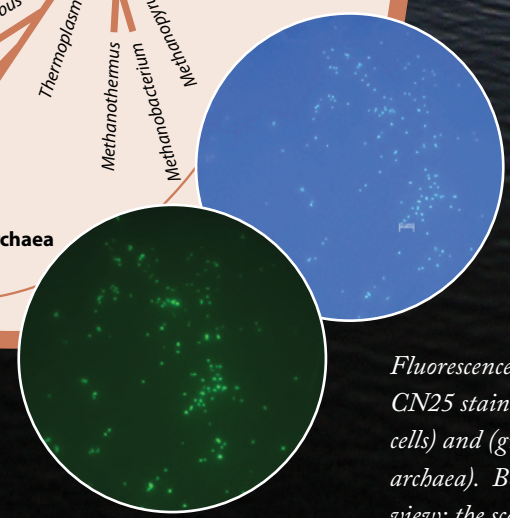
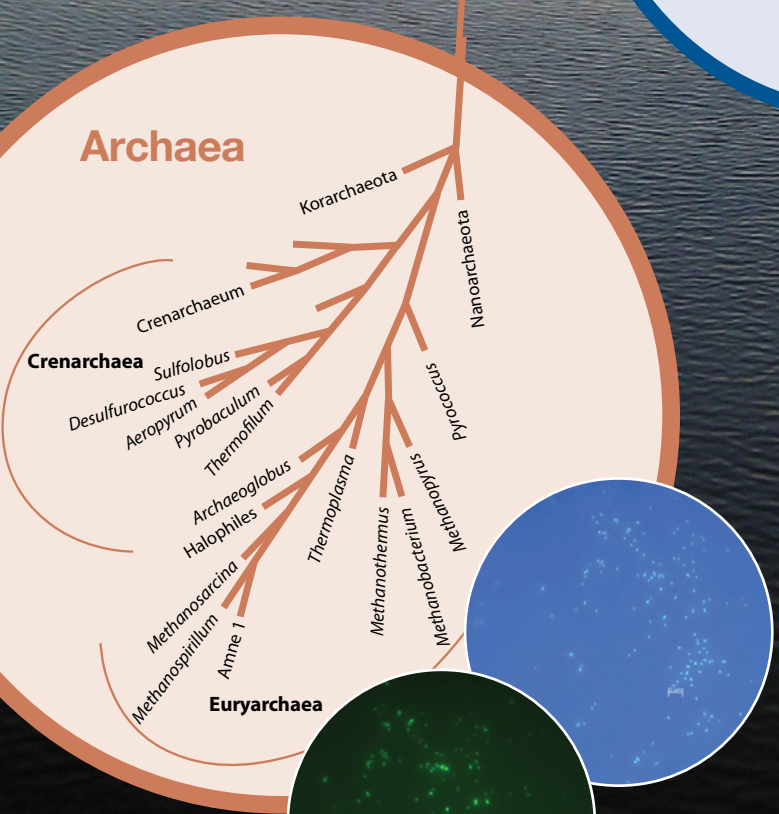
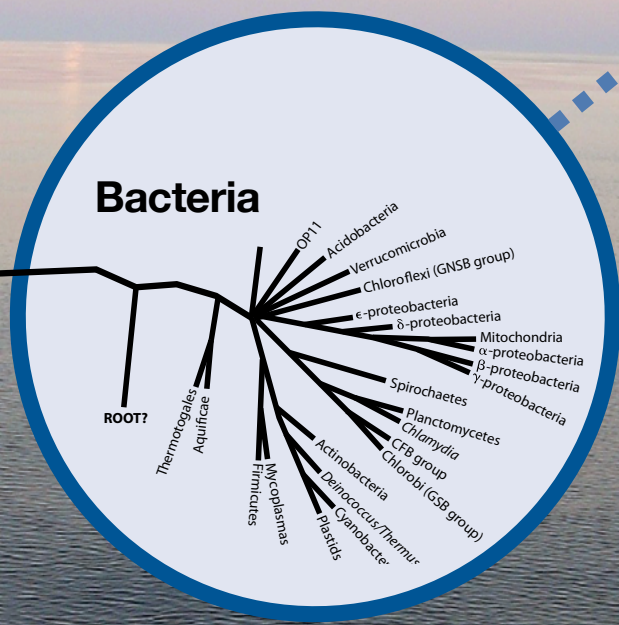
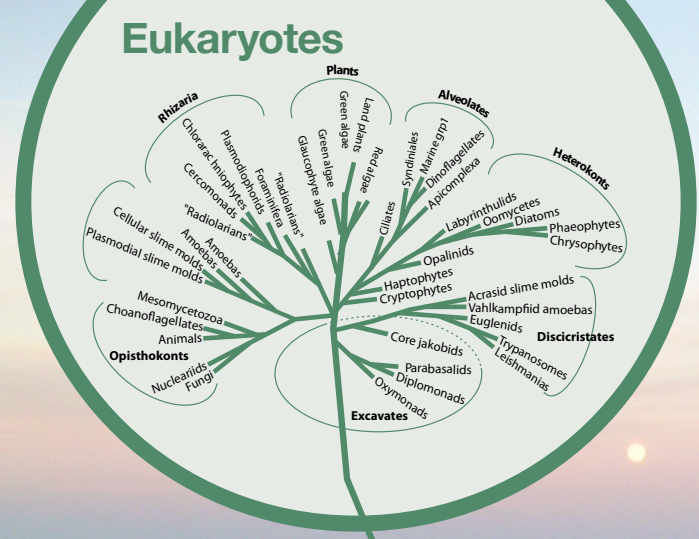
Archaea are single-celled microorganisms distinct from bacteria. Marine archaea comprise up to 40 percent of the deep ocean plankton, and by some estimates represent the most abundant cell type on the planet. Both their number and their ability to fix carbon and oxidize ammonia for energy make them important organisms in the biological flow of carbon and nitrogen in the deep ocean.

With Ocean Life Institute funding, biogeochemists Karen Casciotti, associate scientist, and Alyson Santoro, postdoctoral researcher, were able to maintain and study stable enrichment cultures of three strains of the ammonia-oxidizing marine archaea *Crenarchaeota* in the laboratory. These are the only known open-ocean strains currently in lab culture. It was no easy feat, Casciotti explained.

“These slow-growing organisms are difficult to cultivate and are rare in culture collections,” she said. “The work of studying them is a perfect example of a high-risk project we would not have been able to pursue through conventional funding sources.”

Genetic characterizations of the enrichments place them in a recently identified new archaeal kingdom, underscoring their value in filling gaps

WHOI has the only known open-ocean strains of *Crenarchaeota* currently in lab culture.



Fluorescence microscopy images of enrichment CN25 stained with (blue) DAPI (staining all cells) and (green) CARD-FISH (staining just archaea). Both images are from the same field of view; the scale bar represents 5 μm.

Microscopy images courtesy of Karen Casciotti, WHOI; Open ocean photo by John Lund, WHOI; Tree of life adapted from Jonathan A. Eisen, UC Davis.

What's coming for OLI

In 2010, OLI awarded approximately \$300,000 to new research projects. Here are some of the projects and the people making them happen.



Geologist **Virginia Edgcomb** will track and enumerate fungi in the Delaware Bay system using molecular methods to confirm whether previously recovered fungal sequences come from living cells and to determine whether the marine sedimentary fungal biosphere is seeded by adaptable, opportunistic, terrestrial organisms or fungi that are truly marine in origin. OLI provided \$68,965 to support this work.



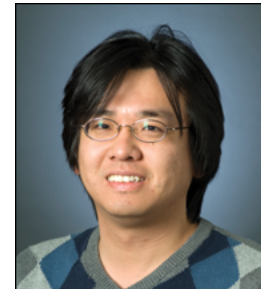
Houshuo Jiang of the Applied Ocean Physics & Engineering Department will study the movement of planktonic copepods—small crustaceans found drifting in sea waters—to provide important insight into the role of swimming bodies on the creation of various water flows. The \$58,600 project will develop a high-speed, time-resolved planar Particle Image Velocimetry (PIV) system for zooplankton flow field measurements in the lab.



Physical oceanographer **Terrence Joyce**, along with colleagues Xujing Jia Davis and Young-Oh Kwon, is studying significant changes in Silver Hake (northern and southern) that are correlated with the Gulf Stream path, and path changes that may precede changes in hake distribution and biomass. They believe that the Gulf Stream path changes appear to lead changes in hake distribution by about a year. With \$74,978 in OLI funding and a partnership with the National Marine Fisheries Service, they will gather data, perform analyses, and publish their joint results. This project was co-funded by the Ocean and Climate Change Institute.



Accurate target discrimination remains one of the outstanding challenges for human-made sonar systems. Understanding the toothed whale's broadband biosonar system, which has evolved a sophisticated ability to discriminate biological targets successfully, could guide future developments in effective target discrimination techniques for human-made sonar systems. Scientists **Wu-Jung Lee**, with colleagues James Preisig, Alessandro Bocconcelli and Peter Tyack, will investigate the toothed whales' echolocation-based target discrimination process by implementing a novel experimental setup, similar to the natural process by which toothed whales select prey. OLI provided \$44,083 in funding.



Passive acoustic listening has been shown to be very effective and environmentally friendly for remotely monitoring marine mammals. It is also important to incorporate complete sound propagation physics into such technology for better localization and tracking performance. To evaluate and validate an advanced whale monitoring and tracking method they developed, **Ying-Tsong Lin** and colleagues Arthur Newhall and Mark Baumgartner will conduct both numerical simulations of and fieldwork in Cape Cod Bay, an important seasonal habitat of the North Atlantic right whale. OLI provided \$60,070 in funding.

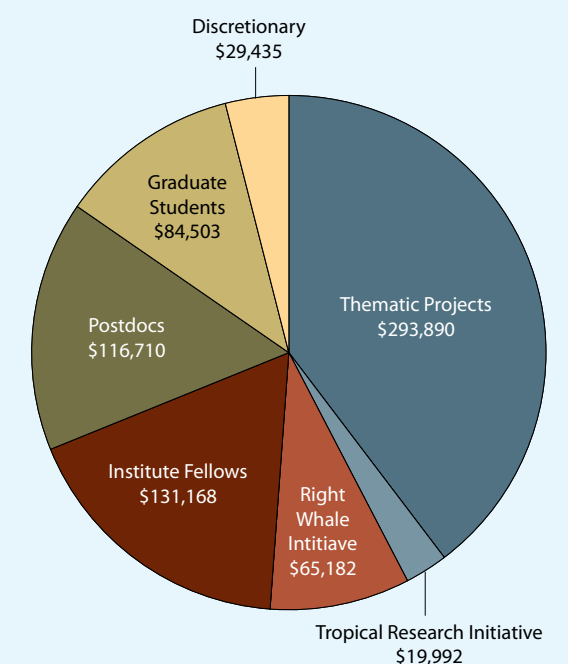


Biologist **Peter Wiebe**, with colleagues Nancy Copley and Raymond Schmitt, will analyze previously collected samples from a unique stratification regime in an area of the tropical N. Atlantic where temperature and salinity profiles display a remarkably regular staircase structure, with thin interfaces where temperature and salinity change rapidly alternating with well-mixed layers. The staircase structure might be an area of unique biology, but this has not been previously studied. OLI provided \$24,683 in funding for this project.

Funding highlights

The total budget for OLI in 2010 was \$740,880. Although the majority of OLI's funds supported research grants for six projects, the Right Whale Initiative and the Tropical Research Initiative, additional support included two OLI fellowships that provide three months of salary support for Mak Saito and Marco Coolen. Funds also provided support for educational activities ranging from investigating Trojan horses to *Trichodesmium* abundance and nitrogen fixation. Researchers supported include Postdoctoral Scholars Matt First, Amy Apprill and Kyungmin Baik, and MIT/WHOI Joint Program Ph.D. students Joanna Gyory, Maya Yamato and Elise Olson.

2010 OLI Spending: \$740,880





About the Ocean Life Institute

The Ocean Life Institute's mission is to launch high-risk, high-reward research that would not otherwise get off the ground—or in the water. The OLI builds bridges between different scientific disciplines to catalyze innovative thinking and collaboration that can open up wholly new scientific vistas. A center of action and source of information about the ocean, the OLI focuses its activity on research themes. It convenes meetings of key scientists and leaders from academia, government and industry to delve into research issues that have significant bearing on society.

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