MBL

Catalyst

Biological Discovery in Woods Hole

Founded in 1888 as the Marine Biological Laboratory

SUMMER 2013
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IN THIS ISSUE

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THE MBL'S 125TH ANNIVERSARY: *Celebrating the Next Generation*

MBL Catalyst

SUMMER 2013 Volume 8, Number 1

MBL Catalyst is published twice yearly by the Office of Communications at the Marine Biological Laboratory (MBL) in Woods Hole, Massachusetts. The MBL is dedicated to scientific discovery and improving the human condition through research and education in biology, biomedicine, and environmental science. Founded in 1888, the MBL is an private, nonprofit institution and an affiliate of the University of Chicago.

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Images: *Inside cover:* Microbial Diversity course students at Little Sippewissett Marsh, Falmouth, Mass. (Daniel Buckley); Joan Ruderman (Joel Bissell/*Cape Cod Times*). *P.1*: Aerial of Woods Hole village (Woods Hole Oceanographic Institution); Shinya Inoué (Tom Kleindinst); MBL visiting scientists Len Kaczmarek and Elizabeth Jonas (Tom Kleindinst). *Pp. 2-3*: top, Lillie pediment (Elizabeth Armstrong); Embryology course students (Tom Kleindinst); MBL Timeline, left to right: Gertrude Stein in 1897 MBL course (MBL Archives); 1974 Embryology course with Joan Ruderman in front row, second from right (MBL Archives); 1998 Semester in Environmental Science students (Toby Ahrens); Brown-MBL Graduate Program student Yuko Hasegawa (Tom Kleindinst). *Pp. 4-5*: Dyche Mullins in the library of the Stazione Zoologica (Dyche Mullins); Katsuma Dan's Misaki marine station note (MBL Archives). *Pp. 6-7*: clockwise from left, Harvard Forest experimental soil-warming plot (Jerry Melillo); American Society for Microbiology plaque to Microbial Diversity course (Merry Buckley, artist); embryo of the dwarf cuttlefish, *Sepia bandensis*, taken in 2012 Embryology course (Maggie Rigney and Nipam Patel; courtesy of *The Node*); embryonic shark showing skeleton of the jaw and gill arches (Andrew Gillis); squid (Roger Hanlon). *Pp. 8-9*: clockwise from top, Woods Hole with Eel Pond at right (Tom Kleindinst); MBL Founding Director C.O. Whitman (MBL Archives); Zoe Cardon of MBL, Stefan Sievert of WHOI, and Anne Giblin of MBL (Tom Kleindinst); MBL visiting scientists Rodolfo Llinás and Mutsuyuki Sugimori (Tom Kleindinst); *Pp. 10-11*: from left: Jonathan Gitlin (Tom Kleindinst); Jacques Loeb (MBL Archives); clockwise from top left, Roger Hanlon (Tom Kleindinst); Rhonda Dzakpasu (courtesy Rhonda Dzakpasu); Tomomi Tani (Tom Kleindinst); Shinya Inoué (MBL); Osamu Shimomura (Tom Kleindinst); Ed McCleskey (Lubert Stryer); Keith Porter (A. Maher); *Pp. 12-13*: Mitchell Sogin (Tom Kleindinst); background, 3D graphical representation of compositional similarities and differences between microbial communities in the Earth's deep subsurface (Mitchell Sogin); *P. 14*: Plum Island Estuary in northern Massachusetts (Christian Picard); expressed neuron (MBL Cellular Dynamics Program); MBL Summer course (Tom Kleindinst). *P. 15*: Thomas Hunt Morgan's 1933 Nobel Prize diploma (Diana Kenney); T.H. Morgan's grandchildren in Woods Hole, 1937 (MBL Archives). *P. 16*: Christopher Neill (Tom Kleindinst). *P. 17*: Lillie pediment casting (Shepley Bulfinch Archives). Back cover: University of Chicago campus (University of Chicago).

ABOUT THE COVER: MBL Microbial Diversity course students conduct fieldwork at Little Sippewissett in Falmouth, Mass., one of the best studied salt marshes in the world (Daniel Buckley); inset, child on Woods Hole beach, 1921 (Alfred Francis Huettner).

Online extras: For full image descriptions, supplemental materials, and other information related to this issue, visit:

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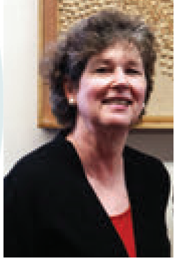

From the Director

Dear Friends,

As the MBL celebrates its 125th anniversary, many of us have been thinking about what makes the MBL special. While relatively small in size, we are known internationally in several different ways: as a center for world-famous advanced, research-based courses; a destination for visiting scientists, many of whom come in the summer months to carry out collaborative research projects; and the home of several distinguished year-round research programs. Work at the MBL has a vast span, ranging from molecular evolution, cell division, embryonic development, and neural networks to nutrient cycling, deep-sea microbial communities, nitrogen impacts on coastal processes, and global environmental change.

We also share Woods Hole with several other renowned institutions: the Woods Hole Oceanographic Institution (which had its origins in 1930 at the MBL), the Woods Hole Research Center (founded in part by MBL scientists in 1985), the National Marine Fisheries Service of NOAA, the United States Geological Survey, and the Sea Education Association. Collaborations among scientists at these institutions occur as well and increase the overall impact of work done here. I suspect that Woods Hole has one of the highest levels of scientific-specific activities of any place in the world.

Most MBL stories begin with "I first came to the MBL as a …" and mine starts that way, too. I first came to the MBL as a student in the 1974 Embryology course, which was directed by Eric Davidson of Caltech. I had read his pioneering book *Gene Activity in Early Development* while doing my thesis work at MIT on translational control of gene expression in sea urchin embryos in the lab of Paul Gross (who later served as MBL Director). The course was exciting for reasons that still make MBL courses exciting: Nearly every major player in the field came to lecture and meet with course students; we were introduced to a wide variety of experimental organisms and systems; and everyone in the class had an independent research project. Moreover, studies done by a group of the students made such progress that the work led to a very nice publication. My partner and I continued the work over the next year, leading to two more papers.

I was thrilled to be invited back later to teach in the Embryology course, and then lead it. During each of these years I was able to bring some of my lab members with me, and we worked on a range of problems that eventually led from fertilization to developmental specification of cell fate to the cyclins and how they regulate cell division. I also began to participate in MBL committee work, including the group that organized the parent-run MBL summer daycare and ultimately helped establish the MBL-run summer camps for children (Periwinkle and Satellite Clubs).

I urge each of you to share your own MBL memories in the wonderful MBL Community Archives Project led by historian Jane Maienschein (see page 15).

Many thanks to Garland Allen of Washington University, who served as Guest Science Editor for this issue of *MBL Catalyst*. Gar was one of the first scholars to record the MBL's major contributions to the biological sciences, and his insights were of great value in shaping this anniversary issue.

Joan Ruderman

Joan Ruderman, *President and Director*

Catalyst

MBL 125 *Celebrating the Next Generation*

In this Issue

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MBL 125

THE MBL'S 125TH ANNIVERSARY: *Celebrating the*

All summers at the MBL feel celebratory, but this one is especially so: The MBL is commemorating the 125th anniversary of its birth. In 1888, seventeen intrepid scientists and students came to the MBL's first summer session, perhaps not sure what they would find or take part in creating. Today, we know: Led by founding MBL Director Charles Otis Whitman, they launched a laboratory for all biologists to share, one that plays a vital, international role in scientific training and research.

For the 125th year, biologists from around the globe are gathered at the MBL for an exhilarating season of intellectual exchange and scientific discovery.

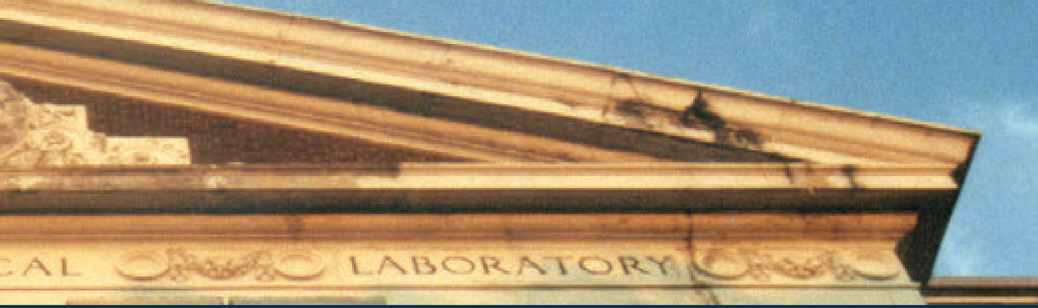
In the advanced courses in Loeb Laboratory, more than 550 students are taking a deep dive into leading-edge research, guided by faculty culled from the world's top universities and institutions. Working with the latest microscopes and laboratory instruments, students and faculty push the edges of biological investigation, often generating important new findings and launching many a career. Taking an MBL course is a life-altering experience for many students, who often give back by returning years later as MBL faculty to inspire a new generation.

While the courses generate a nearly nonstop stream of scientific activity, investigators from many nations are interacting in the MBL's Whitman Center for Visiting Research. These cell biologists, neuroscientists, marine ecologists, and other life scientists

MBL TIMELINE

1888 MBL founded
1888-1907 Charles Otis Whitman, MBL director
1888 MBL Library established
1888 Zoology course begins (renamed Invertebrate Zoology 1969; Neural Systems & Behavior 1978)
1890 Friday Evening Lectures begin
1891-1967 Botany/Marine Botany course
1892 Physiology course founded
1893 Embryology course founded
1897 (*Zoological*) *Biological Bulletin* founded

1908-1925 Frank R. Lillie, MBL director
1926-1937 Merkel H. Jacobs, MBL director
1938-1949 Charles Packard, MBL director
1950-1965 Philip B. Armstrong, MBL director
1951 Grass Fellowship Program founded
1966-1969 H. Burr Steinbach, MBL director
1970-1974 James D. Ebert, MBL director
1970 Neurobiology course founded
1971 Microbial Diversity course founded
1975-1976 Keith R. Porter, MBL director



Next Generation

are at the MBL for a focused period of research, often with collaborators they don't see during the academic year. Besides a beautiful marine setting, the MBL has much to offer to them: excellent facilities, access to the expertise in the MBL courses, and the kind of collaborative company that inspires scientific growth.

Alongside the MBL's summer activities are its resident research and educational programs, the first of which was established in 1975. Some of them, such as the Cellular Dynamics Program, evolved naturally from the historical interests of MBL summer investigators and courses. Others, such as the Ecosystems Center and the Bay Paul Center, are world-class research centers that interact extensively with the other scientific institutions in Woods Hole and elsewhere.

Today, these three components of the MBL—its educational programs, Whitman Center for Visiting Research, and resident research centers—are deeply intertwined aspects of the lab's identity. As we celebrate the MBL's 125th anniversary in this issue of *MBL Catalyst*, we also celebrate the core values shared by everyone who engages in science at the MBL: open inquiry, a collaborative spirit, and an unwavering dedication to the pursuit of knowledge for the benefit of human health and a sustainable planet.

The MBL Welcomes President and Director Joan V. Ruderman

In November, Joan V. Ruderman was named the MBL's 14th President and Director. She is the first woman to direct the MBL in its 125-year history.

Dr. Ruderman was previously the Marion V. Nelson Professor of Cell Biology at Harvard Medical School. She also served as Senior Science Advisor at the Radcliffe Institute for Advanced Study. She received her BA from Barnard College and her PhD from MIT, where she also did postdoctoral work. She joined the faculty at Harvard Medical School in 1976; moved to Duke University in 1986; and returned to Harvard in 1989.

Ruderman's major leadership positions include: Ellison Medical Foundation Scientific Advisory Board (2013-); Howard Hughes Medical Institute Medical Advisory Board (2000-2009); Whitehead Institute at MIT Scientific Advisory Board (1999-2002).

A longtime associate of the MBL, Ruderman's prior positions include: MBL Board of Trustees (1986-2012); Speaker of the Corporation (2008-2012); Visiting Scientist (1976-2000); and Embryology course student (1974), instructor (1976, 1982) and co-director (1978).

Discoveries: Ruderman is best known for her work on fertilization and on the molecular mechanisms that regulate mitosis, the last part of the cell division cycle. At the MBL in 1979, Ruderman, Tim Hunt, and Eric Rosenthal, working with clam eggs, first observed the synthesis of proteins later called the cyclins, key regulators of the cell division cycle. In seminal work at the MBL in the 1980s and 1990s, Ruderman's group cloned and expressed the first cyclin genes; demonstrated that cyclins regulate the cell division cycle; and discovered how cyclins work at the molecular level. With Avram Hershko, she identified and purified components of the ubiquitin ligase system that is responsible for the programmed destruction of cyclins during mitotic exit. Ruderman's later research investigated environmental contaminants that mimic estrogen. She has also focused on the role of water in areas ranging from human health to climate change.

1975 Ecosystems Center established
1977 James D. Ebert, MBL director
1978-1985 Paul R. Gross, MBL director
1980 Biology of Parasitism course founded
1986 J. Richard Whittaker, MBL director
1987-1991 Harlyn O. Halvorson, MBL director
1992-2000 John E. Burris, MBL director
1992 Cellular Dynamics Program founded
1997 Josephine Bay Paul Center established
1997 Semester in Environmental Science program founded

1998 Frontiers in Reproduction course founded
2001-2005 William T. Speck, MBL director
2003 Brown-MBL Graduate Program established
2006-2012 Gary G. Borisy, MBL director
2007 Encyclopedia of Life partnership established
2010 Eugene Bell Center for Regenerative Biology & Tissue Engineering established
2010 National *Xenopus* Resource established
2012 Program in Sensory Physiology & Behavior founded
2012- Joan V. Ruderman, MBL director

traveling on a Woo

By Dyche Mullins

This summer, Clare Waterman and I once again relaunched the MBL Physiology course with a pair of orientation lectures. As has beeen our custom as course co-directors, Clare explained the nuts and bolts of the course and I described its history and philosophy. The students, primed by our tales of long hours and difficult experiments, listened nervously—their attention broken only by occasional attempts to get comfortable in the charming but uncompromising wooden chairs of Lillie Auditorium. This is an annual, Proustian, madeleines-in-weak-tea moment—one that recalls a Sunday evening in 1993, when I sat with a similar cadre of incoming students and listened nervously as Physiology faculty explained what would happen over the next two months. The recollection is jarring, probably because the Physiology course forms a kind of barrier that separates who I am now from who I was then. If my life could be described by a mathematical function, those two months would be a discontinuity, or even a singularity. I began the course as a student of mathematics and engineering but I ended it on a track that led to being a cell biologist.

The Physiology course has, over the years, facilitated many such transformations. It was founded in 1892 by Jacques Loeb of University of Chicago to explore his principle that "Living organisms are machines and … their reactions can only be explained according to the same principles which are used by physicists." While the course has always welcomed the occasional physical science student who ventured in among the biologists, fully half of today's participants are drawn from physics, mathematics, engineering, or computer science.

Yet you do not have to change careers, as I did, to be transformed by the MBL. As far as I can tell, all you have to do is work very hard, with a group of very smart people, on a very hard problem. Clare Waterman and I met in 1993 as students in the Physiology course, where we learned—among many other things—microscopy from Ted Salmon (University of North Carolina, Chapel Hill) and kinetics from Tom Pollard (Yale University). We tackled basic cell biological problems, we met our future postdoctoral mentors, and we became close friends and colleagues. We are like most people who have taken a course or done research at the MBL: If you mention Woods Hole, our faces assume a misty, nostalgic expression and we start talking about the "magic" of the place. To some listeners, this can sound like religious fanaticism. To me, it feels more like an expatriate recalling fond memories of home. This is why I have come to think of my opening lecture to Physiology students as a sort of citizenship class: the first step in becoming a member of a worldwide community.

Woods Hole, Massachusetts, occupies less than four square miles and is defined by a small cluster of buildings clinging to a bend in the coastline. According to the 2010 census, it has a population of 781; in reality, Woods Hole has three populations. There are the 780-odd souls who brave the winter months.

Then there are the expatriates: the thousands whose lives have been altered by spending time at the MBL. They live in a diaspora, as citizens of a worldwide community whose capital is Woods Hole.

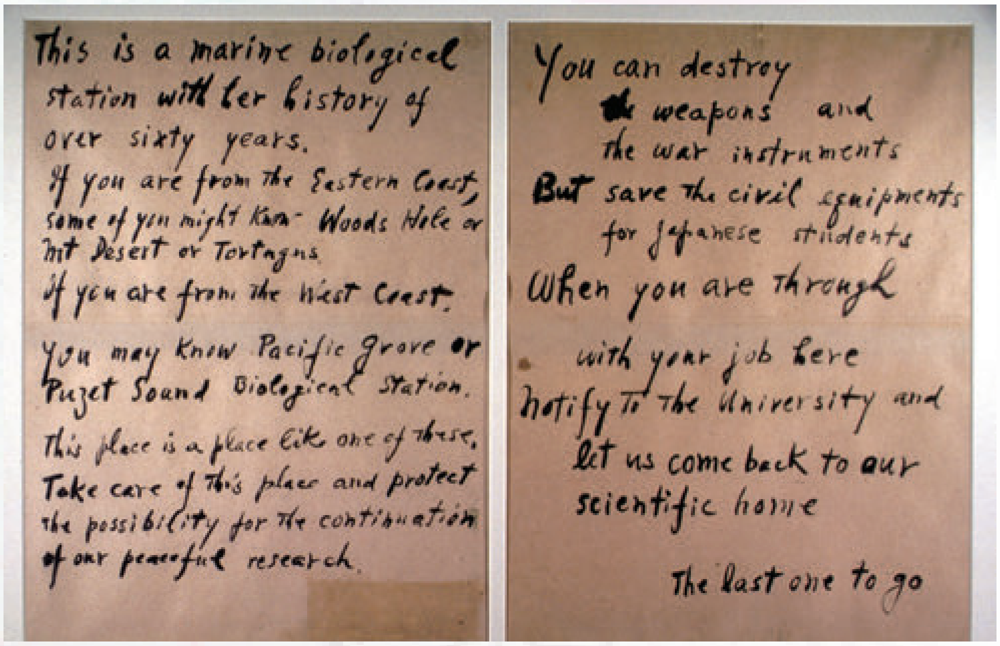
Dyche Mullins (Howard Hughes Medical Institute/University of California, San Francisco) and Clare Waterman (National Heart, Lung, and Blood Institute) will complete their five-year term as Physiology course co-directors this summer.

ds Hole passport

Thousands more come in the summer to vacation, take courses or conduct scientific research. And then there are the expatriates: thousands more whose lives have been altered by spending time at the MBL. They live in a diaspora, as citizens of a worldwide community whose capital is Woods Hole.

I have experienced the hospitality of this community many times, including during a recent visit to Naples, Italy. One morning I decided to show up, unannounced, at the door of the Naples Marine Station (*Stazione Zoologica*) —a forerunner and sister institution of the MBL. I lurked by the front door and eventually buttonholed a woman entering the building. I presented her with a somewhat sketchy-looking letter of introduction, printed on MBL stationary. She disappeared into the building and I half expected the *Carabinieri* to roll up and take me away for questioning. Instead, she returned a few minutes later with one of the station's principal investigators, Salvatore d'Aniello. Salvatore studies the evolutionary development of marine invertebrates, specifically the worm-like amphioxus, and is an alumnus of the MBL Embryology course. Any animosity he might have felt over the outcome of the annual Embryology vs. Physiology softball game had clearly faded from memory and he welcomed me into the Stazione. He gave me a tour of the entire place —including the magnificent library and the damply atmospheric 19th-century aquarium. He also spent some time describing his research and latest experiments. For those few hours, I was no longer a tourist in a foreign city; I was back home among my people.

By far, the most potent symbols of the international Woods Hole community are two yellowed sheets of paper that are now displayed in the MBLWHOI Library. At the end of World War II, a lieutenant in the U.S. Navy found them tacked to the door of a small, Japanese naval installation on the Miura peninsula, south of Tokyo. The pages turned out to be a note, addressed in neat, black brush strokes, to approaching American forces:


This is a marine biological
station with her history of
over sixty years.
If you are from the Eastern Coast,
some of you might know Woods Hole or
Mt Desert or Tortugas.
If you are from the West Coast
You may know Pacific Grove or
Puget Sound Biological Station.
This place is a place like one of these,
Take care of this place and protect
the possibility for the continuation
of our peaceful research.

You can destroy
the weapons and
the war instruments
But save the civil equipments
for Japanese students
When you are through
with your job here
notify to the University and
let us come back to our
scientific home

The last one to go

The buildings were actually the Misaki Marine Biological Laboratory, converted for naval use during the war, and the "last one to go" was Katsuma Dan, a Japanese embryologist who had spent several summers at the MBL. Remarkably, the American naval officer who found the note also was familiar with the MBL. He understood at once what sort of place this laboratory was, and he helped ensure that it was spared destruction. Moments like this, when the shared value of peaceful pursuit of knowledge links people in a way that cuts through their fear and hostility, give me hope for humanity. They may not be frequent enough to inspire outright optimism but, thankfully, they are common enough to preserve some hope. •

At left: Dyche Mullins in the library of the Stazione Zoologica in Naples, Italy.

Above: At the close of World War II, embryologist Katsuma Dan tacked this note to the door of the Misaki Marine Biological Laboratory in Japan. The note eventually found its way to the MBL.

MBL's Jerry Melillo Leads National Climate Assessment

MBL Distinguished Scientist Jerry Melillo has been spending time in Washington, D.C., chairing the federal advisory team that is delivering the Third National Climate Assessment. This comprehensive report presents the most up-to-date science about the current and projected effects of climate change across the United States, based on input from 240 scientist-authors. A draft of the report was released in January for public comment and review by the National Academy of Sciences.

"Climate change is with us now. It is not in the future. Every sector of society is already being affected, and will continue to be affected in the future. Studies clearly indicate that human [activities] are driving climate change at this time," Mellilo says, delineating the report's major findings.

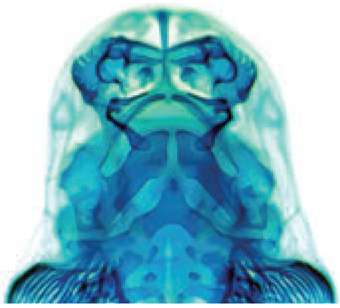
The report details the climate change impacts on U.S. regions and on cross-cutting sectors, including agriculture, human health, urban infrastructure, and oceans. "Certain types of weather events have become more frequent and/or intense, including heat waves, heavy downpours, and, in some regions, floods and droughts. Sea level is rising, oceans are becoming more acidic, and glaciers and sea ice are melting," the draft states. The national assessment, which is required periodically by the Global Change Research Act of 1990, also describes some of the actions being taken to mitigate and adapt to climate change; decision support strategies for developing policy; and a research agenda for climate change science. The final assessment will be submitted to the federal government in early 2014. (ncadac.globalchange.gov) •

Collaboration Yields Insight Into Lou Gehrig's Disease

Arthur Horwich studies the role of protein misfolding in the neurodegenerative disease amyotrophic lateral sclerosis (ALS, or Lou Gehrig's disease) at Yale School of Medicine, where he is a Howard Hughes Medical Institute Investigator. He typically uses the roundworm or the mouse as model organisms for his studies. But he has always wanted to test the effects of a certain mutant protein associated with ALS (SOD1) in the squid, a classically studied system in neuroscience. Last summer, Horwich had his chance. He teamed up at the MBL with visiting scientist Scott Brady (University of Illinois at Chicago) and Brady's former graduate student, Yuyu Song (Boston Children's Hospital and Harvard Medical School). They found that misfolded SOD1, which in mice clumps together to form new signs of ALS, activated a series of cellular chemical reactions in the squid that caused a drop in anterograde axonal transport (the shuttling of proteins along the axon, or nerve fiber, toward the synapse, where communication with other neurons occurs). Moreover, they were able to identify a chaperone (a molecule that can guide proteins to fold into their proper working shapes) called Hsp110 that reversed the axonal transport defect produced by SOD1. "I think this is the first time a chaperone has been shown to essentially reverse a process like this," Brady says. (*PNAS* 14: 5428-5433, 2013) •

Microbial Diversity Course Designated "Milestones in Microbiology" Site

The MBL Microbial Diversity Course has been honored as the 2013 "Milestones in Microbiology Site" by the American Society for Microbiology (ASM). This designation recognizes places where major developments in microbiology occurred and/or where outstanding microbiologists made seminal discoveries. "The MBL Microbial Diversity course has trained many outstanding microbiologists from around the world, providing scientific tools that they have used to make many important discoveries," says Stanley Maloy, a past president of ASM. "MBL has been a major place where scientists have gathered (mostly over the summer) to discuss and do research on marine biology, ecology, and development—and microbiology has influenced and been influenced by each of these areas. MBL, including the Microbial Diversity course, has had an important impact on our understanding of the critical role that microbes play in the environment, from the characterization of microbes that use unusual sources of nutrients to the discovery of microbes that live in unique ecosystems in the depths of the ocean." The Microbial Diversity course was initiated in 1971 by Holger Jannasch of Woods Hole Oceanographic Institution. •



Getting a Bite: Fish Study Probes the Evolution of the Vertebrate Jaw

The emergence of the biting jaw is one of the major novelties in the evolution of vertebrates. One classical hypothesis (by Karl Gegenbauer) is that the jaw evolved from the gill skeleton, a series of cartilaginous arches that support the gills in fishes and which, in embryos of higher vertebrates, become modified into ear and neck structures. In a study using the embryos of sharks, skates, and paddlefish, MBL visiting scientist Andrew Gillis of Dalhousie University and colleagues show that nested expression of the Dlx genes (the "Dlx code" that specifies upper and lower jaw identity in mammals and teleosts, or bony fishes) is actually a primitive, shared feature of the jaw and gill arches of jawed vertebrates. This evidence that the upper and lower jaw are embryologically and anatomically equivalent to the upper and lower gill cartilages, respectively, supports Gegenbauer's hypothesis, and demonstrates that these structures were primitively specified by a common Dlx blueprint. (*Nature Comm.* 4:1436, 2013). •

Embryology Course Turns 120

"I don't know what generates the enthusiasm and energy at the MBL. We engage in science almost every hour of every day. Perhaps it's the access to the best scientific equipment around—the sheer quantity of reagents and quality of microscopes available is stunning. However, more likely it's being removed from my regular graduate school environment. There is no pressure to generate data, no lab meetings to prepare. There is only active experimentation. I am encouraged to ask my own questions and take ridiculous risks. At the same time, there is enough structure to ensure that I am learning the principles of developmental biology at an alarming pace."

—Andrew Mathewson, 2012 Embryology student, blogging at The Node (thenode.biologists.com)

This summer brings another MBL anniversary to celebrate: the 120th session of the Embryology course. The course was founded in 1893 by MBL Director Charles Otis Whitman, who taught it with his student, Frank Rattray Lillie, both of whom hailed from the University of Chicago's Zoology Department. According to a course description written by some of its former directors, Whitman and Lillie were among the "leading figures in the newly formulated cellular science of developmental biology" which posited that "the mysteries of the process by which an egg turns into an embryo would yield to a comparative approach," with the embryos of marine organisms being of particular interest, since "the sea provides the greatest biological diversity."

The course today still embraces this comparative approach, now incorporating a wide variety of developmental systems, including genetic models such as the fruit fly, mouse, and zebrafish. Currently directed by Alejandro Sánchez Alvarado (Howard Hughes Medical Institute/Stowers Institute) and Richard Behringer (MD Anderson Cancer Center, University of Texas), the course brings together leading faculty and students in an intensive research experience that explores the latest paradigms, problems, and technologies in modern developmental biology. "MBL Embryology is considered the premier course on animal developmental biology anywhere," says historian Jane Maienschein of Arizona State University, director of the History of the MBL Project.

The Embryology course is presenting a commemorative symposium this summer at which former directors, faculty, and students will discuss their research, and consider the course's role in shaping the practice of science. "Throughout its existence, the Embryology course has served as a continuum in which many minds have been connected to a timeline by a common thread: love of learning for the sake of learning," says Sánchez Alvarado. "Given the immense opportunities for the exploration of biological diversity afforded by current technologies, we expect the Embryology course to continue its pedagogical and scientific leadership, but most importantly to carry on inspiring the minds of all of its participants for at least another 120 years." •

A COLLABORATION CALLED THE MBL

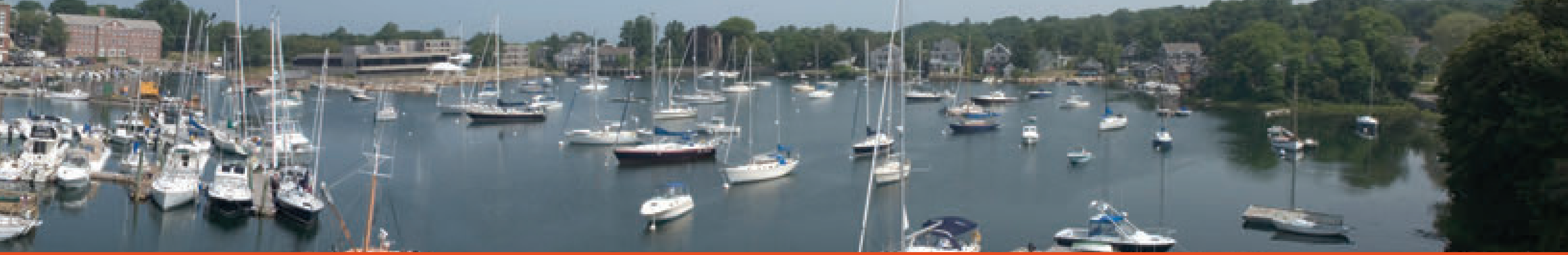
For more than a century, the world's biologists have known they can come to the MBL, meet up with colleagues from far-flung institutions, roll up their sleeves and accomplish much in an environment devoted to scientific inquiry and discovery.

"We come to the MBL every summer for the squid, and also because the lab is beautiful, the facilities are superb, and the intellectual climate is second to none," says Rodolfo Llinás of New York University School of Medicine, an MBL visiting scientist since 1970. Llinás investigates neural dysfunction and drug discovery in Alzheimer's disease, using the squid as a model system.

While Llinás plans to meet his longtime collaborators from other places at the MBL, as many scientists do, collaborations also spring up spontaneously in Woods Hole. This is especially true during the summer, when the Whitman Center for Visiting Research and the MBL courses are in full swing, and the campus is teeming with scientists doing and discussing science at a powerfully energized pace.

"The MBL is a full-immersion environment. We carry on 24 hours a day," says resident scientist Jennifer Morgan, who previously was an MBL visiting scientist and Grass Fellow. "In the lab, at evening lectures, at Stony Beach—we are intersecting with other scientists, on a formal and informal basis, nonstop. You can randomly run into a colleague on the street and say, 'Hey, I read this paper today,' and a collaboration is born right there."

Morgan's current research focus is a result of one such fruitful encounter. Four summers ago, she came to the MBL from University of Texas-Austin to study vertebrate spinal cord repair along with Ona Bloom of Feinstein Institute for Medical Research. Their research model was the sea lamprey, a fish that has robust regenerative capacities. After severe spinal cord injury, the lamprey can regenerate damaged nerve cells and swim again within 10 to 12 weeks.



THE COLLABORATIVE SPIRIT DEFINES THE VERY WAY SCIENCE IS DONE AT THE MBL, AND IT ALWAYS HAS.

"The larger the number of specialists working together, the more completely is the organized whole represented, and the greater and the more numerous the mutual advantages."

— Charles O. Whitman, MBL Founding Director, 1890

At first, the team focused on aspects of regeneration relevant to Morgan's background in neurobiology and Bloom's in immunology. But then they happened to meet Joseph Buxbaum, an MBL visiting scientist from Mt. Sinai School of Medicine.

"Oddly enough, Joe had worked on a project to sequence lamprey genes several years earlier. So he had all this sequence information, and we had this problem we were studying but no sequences," Morgan says. "One day, while we were having lunch in the MBL's Waterfront Park, Joe said, 'We should really think about doing some genomic analysis with the lamprey.' There, sitting under a tree, our collaboration began." The three recently contributed to publishing the lamprey's whole-genome sequence, which provides an invaluable reference for their current focus.

The collaborative spirit upon which the MBL was founded also permeates its resident research program, which began in 1975. "I love working at the MBL," says Julie Huber, a microbial oceanographer in the Bay Paul Center. "It's small enough that you know everybody, and everyone's doors are always open. A lot of facilities are shared, such as the sequencing facility, and it creates a very open and generous scientific community. It's a very collaborative environment. I think that makes your science better."

The Micro-Eco Discussion Group at MBL, which includes about 45 scientists and graduate students, is a manifestation of the interdisciplinary spirit among resident researchers. The group meets weekly during the academic year to discuss microbes, ecology, and microbial ecology, the interface at which most of them conduct research.

"There is a real desire here to reach across those disciplinary boundaries. Actually, we don't even think of them as boundaries," says Zoe Cardon, an Ecosystems Center scientist who coordinates the Micro-Eco Group with Huber. "We start with the tiniest organism present, the microbes, and think about links all the way up the scale, to the ecosystems and even to the globe. The MBL is a really unique crucible for linking across scales."

The breadth of micro-eco research at MBL is large. Huber, for example, will lead a research cruise this year to Axial Seamount, an undersea volcano site off of Oregon, to obtain samples of the microbial and viral communities that live in its rocky outer layer. She is interested in how these communities alter the flow of carbon and nutrients in the subseafloor environment, also called the "deep biosphere."

Closer to home, Cardon is involved in "an incredibly exciting collaboration" to explore how a certain group of microbes, the sulfur oxidizers, may affect the fate of pollutant nitrogen in salt marshes. Cardon, Anne Giblin of the Ecosystems Center, and Stefan Sievert of Woods Hole Oceanographic Institution bring varied expertise to the project. "I love that this collaboration incorporates so many components that are central to MBL: imaging, microbial diversity, biogeochemistry of salt marshes, plant-microbe interactions—all in the context of a really pressing problem: coastal nitrogen pollution," Cardon says.

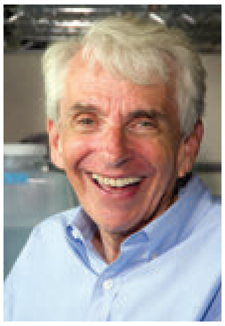
Yet collaborations across disciplines don't just happen magically, Cardon notes. "To even speak each other's language, you have to have time to learn the language. Otherwise it's just a chunk here, a chunk there, and the parts of the project aren't melded. " MBL scientists, she says, devote the time and effort to forging those links.

"There's an intellectual vibrancy here, but it's more than that," Cardon says. "It's a flexibility. People like thinking beyond the box." • — DK

INSPIRED TO A LIFE IN SCIENCE

NO SCIENTIST IS AN ISLAND. Each one belongs to a community of researchers, present and past, whose ongoing dialogue with nature builds a collective body of knowledge. Within the greater scientific community are lineages: investigators who are drawn to similar mysteries and who build upon each other's work.

We invited several MBL scientists to describe the research question that most intrigues them and asked whether a predecessor at MBL had inspired their work. Some of their responses were unexpected, and reach back to the MBL's earliest days.



JONATHAN GITLIN

Senior Scientist and Director, Eugene Bell Center for Regenerative Biology and Tissue Engineering

How animals acquire copper from the environment, metabolize and excrete it was Jonathan Gitlin's main research focus for years. Yet all along, a related problem kept tugging at his attention: the twilight state called "suspended animation" or "metabolic quiescence," such as during animal hibernation when heartbeat and respiration nearly cease, or when healthy cells temporarily stop dividing, sometimes for years. "It's very interesting to me how an organism can completely shut down its metabolic rate, and yet sustain life," Gitlin says. He is now studying the phenomenon in zebrafish embryos, which during their first 56 hours can become quiescent if oxygen is removed, and then reanimate when oxygen is returned. "Our hypothesis is that these are strongly evolutionarily conserved mechanisms, and what we find in the zebrafish embryo will hold true for human stem cells," Gitlin says. This is relevant to medical conditions that interest Gitlin, including cancer and tissue regeneration, both of which involve "stem cells that can sit quiescent in tissues for years until the correct stimulus wakes them up."

INSPIRATION: Gitlin first became interested in copper metabolism in high school, during visits to the MBL with his father, biologist David Gitlin. Another influence was Jacques Loeb, who described mechanisms of metabolic quiescence in the fish *Fundulus* more than 100 years ago. "But what we have now, and what Loeb could have benefited from, is a genetic model to study," Gitlin says. "Because the zebrafish genome has been sequenced and annotated, and because there are methods to manipulate the genome, we can ask what mutations prevent the embryos from entering, surviving, or exiting from a suspended state. We have the opportunity get at some questions that have intrigued scientists at the MBL and elsewhere for centuries."

Jacques Loeb: MBL visiting scientist 1892-1910; Founding director of the Physiology course, 1892-1906; Trustee 1898-1923

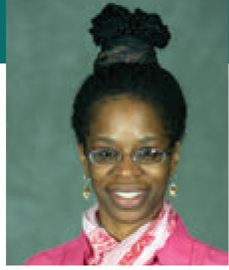
ROGER HANLON

Senior Scientist and Director, Program in Sensory Physiology and Behavior

Roger Hanlon studies camouflage and visual perception in marine animals, especially the squid, octopus, and cuttlefish. These creatures can swiftly change their skin color and pattern to "blend in" to the environment with astonishing accuracy. Hanlon's lab is describing the mechanisms that enable this rapid adaptive camouflage—how the skin neurally controls its pigments (chromatophores) and reflectors (iridophores). Hanlon also collaborates with engineers who aim to mimic the squid skin's optical characteristics in bio-inspired materials, which can have a range of applications, from digital display screens to changeable clothing fabrics.

INSPIRATION: In the early 1980s, while studying squid behavior at the University of Texas Medical Branch, Hanlon noticed that the skin iridescence of two fighting males turned on and off as the conflict escalated. That was striking, since "all the literature said iridescence doesn't change; it is only seen because of the angle of light," he says. That prompted Hanlon to study dynamic iridescence in squid skin, an idea that many neuroscientists at the time found bizarre. However, one scientist did offer encouragement: Keith Porter, a former director of the MBL. A pioneer in the 1940s of using electron microscopy to study the fine structure of cells, Porter had carried out early studies on iridophores and how they produce color. When Porter saw a Hanlon lab poster on dynamic squid iridescence at a meeting, "he was very complimentary to my colleague who was there," Hanlon says. "That meant a lot to us: a smart and established scientist giving us encouragement. It really motivated us to pursue our study of dynamic structural coloration in cells."

Keith Porter: MBL visiting scientist 1962-1975, MBL Director 1975-1976, Trustee 1976-1980



RHONDA DZAKPASU

Assistant Professor, Georgetown University and Georgetown University Medical Center; MBL visiting scientist 2013; Faculty, Summer Program in Neuroscience, Ethics and Survival (SPINES) 2009-2011; Alumna, Neurobiology course and SPINES

Rhonda Dzakpasu is asking one of the big questions in systems neuroscience: How do neurons communicate within a network? "There is an emergent dynamic when many neurons talk to each other, and those emergent properties can change," she says. "Neurons coordinate their electrical activity in order to process information; we see this under normal but also pathological conditions. When are 'talking together' neurons good, and when are they bad?" Dzakpasu records electrical activity from many neurons simultaneously, and investigates how perturbations at the synapses, *i.e.*, the junctions between neurons, modulate the dynamics of the network's output.

INSPIRATION: "If I had not spent time at the MBL as a student, I would not be doing research in neuroscience," says Dzakpasu, whose background is physics. "The MBL was a transformative experience." One major influence was Ed McCleskey, then co-director of the Neurobiology course. When Dzakpasu later accepted a faculty position at Georgetown University, she reconnected with McCleskey and "he has mentored me for the past five years," she says. "He has strongly impacted my research, but also my teaching at Georgetown. Ed and other scientists I met at MBL were really, really exceptional teachers. They didn't just show us how to use a technique: They showed us how to push it further, or combine it with something else, to produce something new. This really strong integration of teaching and research is what makes the MBL so unique."

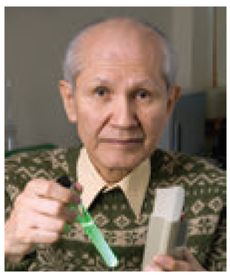
Ed McCleskey: Senior Scientific Officer, Howard Hughes Medical Institute; Co-director, MBL Neurobiology course 2004-2007

TOMOMI TANI

Associate Scientist, Cellular Dynamics Program; Alumnus, Optical Microscopy and Imaging in the Biomedical Sciences course

A single molecule is vanishingly small—smaller than the resolution limit of light microscopy. Yet Tomomi Tani is developing a fluorescent imaging system that will reveal how single molecules are oriented in living organisms. He and his colleagues hope it will let them observe as proteins assemble into working "machines" in living cells. But the system may also tell them more. "Orientation is very important in life," Tani says. "Watching how molecules interact in this way, one by one, may contribute to a better understanding of how life systems work in general." Tani's collaborators are MBL scientists Rudolf Oldenbourg and Shalin Mehta and visiting investigator Amy Gladfelter of Dartmouth College.

INSPIRATION: "I realize how lucky I am," says Tani, whose research builds on major contributions by scientists who are in residence at MBL. To visualize individual proteins, Tani uses green fluorescent protein (GFP), the jellyfish molecule discovered in 1961 by Osamu Shimomura.



Osamu Shimomura: MBL Senior Scientist 1982-2001; Distinguished Scientist 2008-present; 2008 Nobel Prize in Chemistry

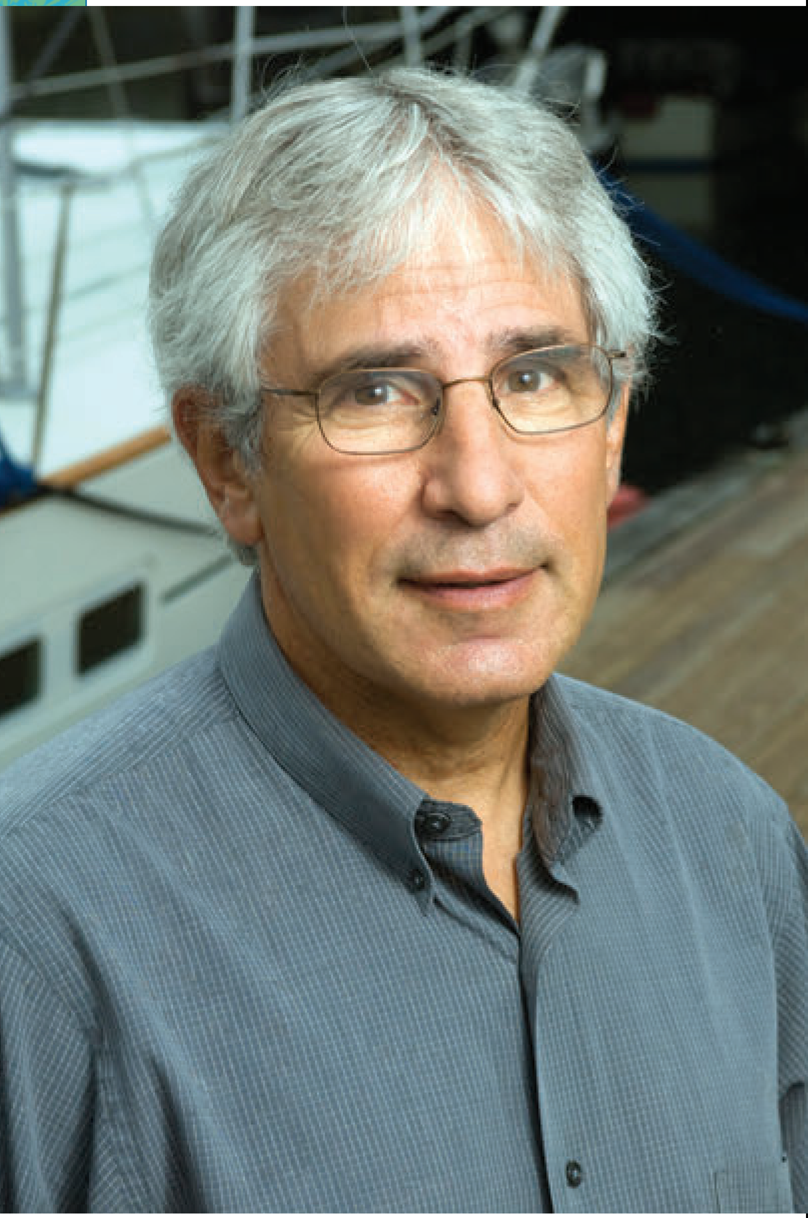
Shinya Inoué: MBL Senior Scientist 1980-1986; Distinguished Scientist 1986-present

And orientation-based imaging is based on polarized-light optics developed at the MBL by Shinya Inoué since the 1950s, and more recently by Oldenbourg and Michael Shribak. "Ever since I was an undergraduate, the MBL has been the true target of my dream," Tani says. • — DK

MBL Moment

with …

Mitchell Sogin
Founding Director, Josephine Bay Paul Center for Comparative Molecular Biology and Evolution



The Evolution of Immense Diversity

As director of the MBL's Bay Paul Center, Mitchell Sogin oversees a flourishing range of research on the evolution and diversity of microorganisms, and how they interact with other life forms and the planet. Sogin has played key roles in landmark, large-scale collaborations including the first International Census of Marine Microbes and surveys of microbial populations in the human body. He was recently named co-chair of the Deep Carbon Observatory's Deep Life Directorate, an international program to explore the microbes that live beneath the subseafloor and continental surfaces. With his Bay Paul Center colleagues, Sogin has made major methodological contributions to the study of the microbial world, and has offered fundamental insights on its structure and evolution.

Mitchell Sogin joined the MBL in 1989 and eight years later founded the Bay Paul Center. He is also on the faculty of the Brown-MBL Graduate Program in Biological and Environmental Sciences. Sogin earned his PhD in Microbiology and Molecular Biology in 1972 at University of Illinois, where his adviser was Carl Woese, the first scientist to demonstrate that evolutionary relationships could be inferred by comparing ribosomal RNA gene sequences across all organisms. He was a postdoctoral fellow with Norman R. Pace at the National Jewish Center in Denver, and then joined the faculty of University of Colorado Health Sciences Center. A fellow of the American Academy of Arts and Sciences, the American Academy of Microbiology, and the American Association for the Advancement of Science, Sogin is also the recipient of the Stoll Stunkard Award and the Roger Porter Award from the American Society for Microbiology.

Why is it important to explore the microbes that live beneath the ocean floor, which is a major recent focus at the Bay Paul Center?

Microbes in the ocean drive the planet and its cycles, and a significant fraction of them live in sediments or beneath the sea floor and deep beneath continental surfaces. We want to know what is down there and, for the Deep Life Directorate, what is their role in cycling the hydrocarbons that end up in your car's gas tank. Also, we want to know how extreme the conditions are under which these microbes live: how hot, how much pressure, and how they adapt. If you are thinking about the origins of life, these are the kinds of questions you ask. And the deep biosphere is just an unexplored domain; it's still very mysterious. We know far less about it than we do about the surface of the moon.

When you first came to the MBL in the late 1980s, you were working on the evolution of microbes. When did you start thinking about microbes in an ecological context, such as in the oceans?

My first microbial ecology paper, looking at bacterial diversity in an Arctic lake, was a 1996 collaboration with Michelle Bahr and John Hobbie of the MBL Ecosystems Center. That was followed by a study with Holger Jannasch and Virginia Edgcomb of Woods Hole Oceanographic Institution in 2002. We looked at microbial diversity in the sediments of Guaymas Basin, a hydrothermal vent site off California. We looked at microbial diversity then in essentially the same way as today: We took samples from the site and sequenced evolutionarily conserved genes from the microbial DNA, to find out "who" was there. The technology was older, but it was the same game. From that point on, I was still thinking about molecular evolution, but we got more and more into microbial diversity. And that field just exploded. It eventually evolved, for us, into genomics and high-throughput DNA sequencing.

How has DNA sequencing changed over the course of your career?

When we sequenced a small part of a Bacillus gene in the mid-1970s, it took us *two years* to sequence 100 nucleotides. Today, we sequence millions of nucleotides in one day. The cost has also come way down. It cost $10,000 to sequence a million nucleotides in 2001; now, we can sequence the same amount for less than a nickel.

What led to your leadership of the International Census of Marine Microbes (ICoMM)?

I attended an early meeting of the Census of Marine Life, an international survey of ocean life that began in 2000. The scientists there were talking about the Barcode of Life: the idea of using differences in mitochondrial DNA to distinguish between marine organisms that are hard to differentiate otherwise. I told them that was a big mistake, because bacteria don't have mitochondria, so the census would miss all the bacteria. From that conversation, Jesse Ausubel of the Sloan Foundation orchestrated ICoMM, which Jan de Leeuw (now at UCLA) and I co-directed. We engaged as many people around the world as we could to collect ocean samples. That pushed me to start thinking about how to handle all these microbial sequences with greater efficiency. We were fortunate, because next-generation DNA sequencing was invented around the same time. In 2006, we published the first paper that took advantage of next-generation sequencing to describe microbial diversity. That paper (*PNAS* 103: 12115-12120) has now been cited about 3,000 times.

That paper also introduced the "rare biosphere"—the discovery that marine environments contain a few dominant kinds of microbes and thousands more rare or low-abundance types.

Yes, and today I'd say the number of microbes that are rare is even greater than I thought was possible in 2006. At that time, when we saw sequences that were almost identical, we would have said they are from the same microbe. But then we started to look at microbial abundances at different times of the year by sampling regularly from Little Sippewissett Marsh in Falmouth. We also developed a new computational method called oligotyping (invented by A. Murat Eren in my laboratory), which is very powerful for discerning small differences between sequences. And we found nearly identical microbes that fluctuate in dominance over the year: some become dominant in the winter, others in the summer. These are organisms that by other criteria would have been the same, but the ecology is telling us they are different. Once again, we have underestimated microbial diversity.

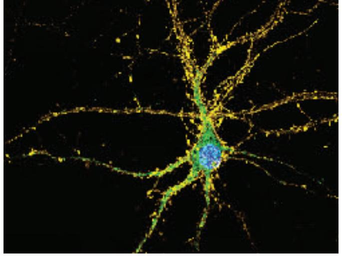
The Bay Paul Center played a key role in the recent Human Microbiome Project, a national collaboration to survey the microbial communities in the human body. Was this a natural extension of your ICoMM work?

The technology we developed for looking at microbes in the ocean was immediately adopted by the Human Microbiome Project. Scientifically, the questions are the same: We are asking what microbes are there, what are they doing, and how did they get there. It doesn't matter if we are looking in the human body or in the oceans or anywhere else.

The microbes that live inside us are very different than the microbes in the ocean. But in both cases, we find microbial populations that are very rare, others that are more abundant, and they shift under environmental conditions. That phenomenon happens everywhere we look. If you take an antibiotic, for example, microbes in your gut that were very rare can become dominant, with perhaps unintended consequences for your health. • — DK

Background image is a 3D graphical representation of compositional similarities and differences between microbial communities in the Earth's deep subsurface.

Gifts & Grants



The National Science Foundation awarded $2,940,000 for a project titled "The PIE-LTER: Interactions Between External Drivers, Humans, and Ecosystems in Shaping Ecological Process in a Mosaic of Coastal Landscapes and Estuarine Seascapes." Anne Giblin is the principal investigator.

The National Institutes of Health awarded $2,461,584 for a project titled "Spatial Organization of the Oral Microbiome." Gary Borisy is the principal investigator.

The National Institutes of Health awarded $1,605,918 for a project titled "Fluorescent Single Molecule Orientation Imaging in Living Cells." Tomomi Tani is the principal investigator.

The G. Unger Vetlesen Foundation awarded $850,000 in support of the Josephine Bay Paul Center for Comparative Molecular Biology and Evolution.

The National Science Foundation awarded $681,534 for a project titled "Time Series Particle Flux Measurements in the Sargasso Sea." Maureen Conte is the principal investigator.

The Burroughs Wellcome Fund awarded $568,000 to the Frontiers in Reproduction course and symposium and the Embryology course. •

Accolades

John Gurdon (Embryology course faculty and Lillie Fellow in 1983) was awarded the 2012 Nobel Prize in Physiology or Medicine "for the discovery that mature cells can be reprogrammed to become pluripotent."

MBL Distinguished Scientist and 2008 Nobel Laureate **Osamu Shimomura** was elected to the National Academy of Sciences.

Ecosystems Center scientists **Jerry Melillo** and **Gaius Shaver** were in the first cohort of Fellows of the Ecological Society of America, who were recognized for "the many ways they contribute to ecological research and discovery, education and pedagogy, and to management and policy."

Mónica Bettencourt-Dias of Instituto Gulbenkian de Ciência (former MBL visiting scientist and Physiology course faculty) received the Keith R. Porter Award from the American Society for Cell Biology. This award recognizes the outstanding work of a cell biologist at the beginning or middle of his or her scientific career.

Dyche Mullins of University of California-San Francisco, current co-director of the MBL Physiology course, was named a Howard Hughes Medical Institute (HHMI) Investigator.

Christopher Neill, MBL senior scientist and the Phyllis and Charles M. Rosenthal Director of the Brown-MBL Partnership, was named director of the Ecosystems Center.

Jonathan Gitlin, MBL senior scientist, was named director of the Bell Center for Regenerative Biology and Tissue Engineering.

Shelby Riskin, Susanna Theroux, Anupriya Dutta, and **Yuko Hasegawa** successfully defended their PhD dissertations in the Brown-MBL Partnership and Graduate Program in Biological and Environmental Sciences.

William Jeffery, adjunct scientist in the Bell Center for Regenerative Biology and Tissue Engineering, was awarded the 2012 Alexander Kovalevsky Medal from the St. Petersburg Society of Naturalists.

John Hobbie, Ecosystems Center Distinguished Scientist, co-authored *Land of Extremes: A Natural History of the Arctic North Slope of Alaska*, a comprehensive guide to the natural history of the only arctic tundra in the United States. •

Making History at the MBL

Barbara Morgan Roberts remembers when there was a Nobel Prize kept in a secret place in her childhood home. It had belonged to her grandfather, the genetics pioneer Thomas Hunt Morgan, a longtime MBL trustee and visiting scientist from Columbia University. Morgan was very modest, Roberts says, and he never spoke about his prize. “We never showed it to anyone because that would be bragging!” she recalls.

Last summer, when Roberts and her sisters gathered in Woods Hole, as they have for decades, the conversation turned to where to archive Morgan’s Nobel Prize medal and diploma. “We were struck by this brilliant idea. What better place than the MBL?” she says. “Woods Hole has had a central place

in the hearts and lives of the Morgan family for over 122 years. By leaving these symbolic mementos at the MBL, we have the sense that we will all be in Woods Hole forever.”

Like the Morgan family, many members of the MBL community have “pieces” of the MBL’s history in their homes and in their memories. Does your attic, garage, or desk contain photographs, letters, or notebooks about life at the MBL? If so, the MBL Community Archives Project needs you!

The diploma for Thomas Hunt Morgan's 1933 Nobel Prize in Physiology or Medicine, given to the MBL Archives by his granddaughters, Barbara Roberts, Connie Allard, and Pamela Jacobsen. At left, the Morgan grandchildren in Woods Hole circa 1937.

This summer, as part of the MBL’s 125th Anniversary celebration, the MBL Community Archives Project is collecting materials that help document the history of all aspects of MBL life. In the project’s “intake studio” in the Lillie Building, historians are on hand to digitize your MBL memorabilia and video-record your most vivid MBL stories. These will be added to the MBL Community Archives, a digital heritage and preservation web portal that is part of the MBL History Project.

On an ongoing basis, the MBL History Project will present historical features about people and events that have shaped the life of this unique institution in the history of biology.

Help make the MBL’s history come alive! Whether it’s your correspondence with an MBL collaborator, photos of course life, or even a Nobel Prize, your contributions will help illuminate the history of a cherished, international center for scientific discovery. •

PLEASE BRING YOUR MBL MEMORABILIA AND MEMORIES TO:

The MBL Community Archives Intake Studio
Lillie Building, Room 228
For studio hours, contact history@mbl.edu
history.archives.mbl.edu

This project is a collaboration between historians at the MBLWHOI Library, Arizona State University, Dartmouth College, and the University of Massachusetts, Amherst.

Christopher Neill was appointed director of the MBL Ecosystems Center in late 2012. A senior scientist at the MBL, Neill is also the Phyllis and Charles M. Rosenthal Director of the Brown-MBL Partnership and Graduate Program. Neill's research focuses on understanding how large-scale changes in land use—especially deforestation in the Brazilian Amazon and intensification of farming in the Amazon and in tropical Africa—alter soils, emissions of greenhouse gases, and the runoff of water and nutrients into streams and rivers. He also works on the ecology and restoration of ponds and grasslands in coastal Massachusetts. In addition, Neill publishes articles on ecology and the environment for general audiences, and serves as director of the MBL Logan Science Journalism Program's Hands-on Environmental Laboratory.

Neill received a BS from Cornell University and an MS and PhD from the University of Massachusetts at Amherst. He was awarded a Harvard University Bullard Fellowship in 2010 and a Fulbright Fellowship to Brazil in 2007.

Predicting the Future of a Much-Changed World

By Christopher Neill

In 1888, when the MBL's founding helped catapult Woods Hole beyond its whaling past and toward its future as a global scientific destination, the concentration of carbon dioxide (CO_2) in the Earth's atmosphere was 290 parts per million. Over the prior ten thousand years, the needle on the planet's CO_2 meter had barely budged.

Fast forward to today. Over the 125-year lifetime of the MBL, atmospheric CO_2 has skyrocketed to a current level of 395 parts per million.

When the Ecosystems Center became MBL's first year-round program in 1975, some of its scientists built a simple "Terrestrial Carbon Model" that calculated the carbon in the atmosphere from fossil fuels and forest clearing. In a 1983 paper in the journal *Science*, they predicted: "Recent rates of CO_2 accumulation have been high enough to produce, if continued, an atmospheric burden before the middle of the next century [that] can be expected to increase the mean global temperature by 2 to 4 degrees C. Polar regions will undergo the greatest changes; climate zones will shift, agriculture will be displaced, and the earth's major zones of vegetation will be disrupted."

This uncharted planetary future is arriving fast.

Work to understand climate change remains central to the Ecosystems Center's mission—but climate change is now only part of the story of what we do.

That's because while busily releasing fossil carbon, humans have reshaped nearly the entire land surface, and much of the water, of the planet. In one compelling analysis, Erle C. Ellis of the University of Maryland, Baltimore County calculated that 77 percent of the Earth's land surface now consists of new configurations of ecosystems that didn't exist when Harvard's Louis Agassiz encouraged his biology students in the late 1800s to "study nature, not books." Although Eastern forests had been largely cleared, there were few suburban lawns or vast suburban "savannas" around major cities, no recently burned Alaskan tundras, no U.S. Midwestern annual corn "grasslands," no Amazonian forest-soybean mosaics. And in the aquatic realm, there were few nitrogen-overloaded coastal salt marshes or eelgrass meadows and no large dams on western rivers, although the depletion of prized commercial fish from oceanic banks on the continental shelf had already been happening for more two centuries.

Our challenge as ecosystem ecologists today is to understand not only this natural and unnatural history, but how these new ecosystem arrangements will interact with climate change. We use modern computing power to run global models of carbon inputs and outputs over nearly every square kilometer of Earth. We use modern molecular techniques to learn how the microbes that are the engines of the planet's element cycles will respond and evolve under natural and altered conditions.

Most of all, though, we use Agassiz's same principle, which has been the hallmark of science at the MBL since its inception. We do large, bold, and long-term experiments—artificially warming soils, adding isotopes to trace food webs in streams, clearing tropical forest, enriching marshes with nitrogen—to ask questions of nature, and try to understand what the Earth's ecosystems, now far different from those in 1888, will look like in another 125 years. •

Seal of the Sea

The double-seahorse design on the MBL's seal is familiar to generations of biologists, but its origins are obscure. Its first known appearance was in 1925 on the façade of the newly constructed Main Brick Building, later renamed the Lillie Building in honor of the MBL's second director, Frank R. Lillie. The building was designed by architect Charles Coolidge of the Boston firm Coolidge and Shattuck, which today is known as Shepley Bulfinch. As that firm's archives reveal, original drawings for Lillie show a simple, cast-stone urn in the pediment. At some point during construction, however, the urn was replaced by the more ornate design of symmetrical seahorses encircled by marine organisms, with the head of Neptune, Roman god of the sea, centered below. This striking photo of the ornament, still in the artist's workshop, has been preserved, but the Shepley Bulfinch archives are silent on the designer or sculptor's name. It's interesting to note that the *Stazione Zoologica* in Naples, a scientific ancestor to the MBL, also has a seahorse in its logo. But as to the artist or scientist who presciently drew the core of the memorable MBL seal? It's a name yet to be discovered. • — MP and DK

MBL | Biological Discovery in Woods Hole

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Catalyst

In the Next *MBL Catalyst*

The Chicago Connection

The MBL began an exciting new chapter this year by formally affiliating with the University of Chicago. The next issue of *MBL Catalyst* will explore the partners' shared history, values, and missions of leadership and innovation in scientific research and education.