Woods Hole Marine Biological Laboratory

Introductory article

Article Contents

- Introduction

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The Marine Biological Laboratory (MBL) in Woods Hole, Massachusetts, has had a long history of excellence in research and education. An independent institution for the first 125 years, it has been an affiliate of the University of Chicago since 2013. Internationally acclaimed courses, summer visiting researchers and year-round research centres make up this vibrant laboratory in a small village at the southwestern tip of Cape Cod. Over 50 Nobel Prize winners have spent time at the MBL, and the courses have trained the leaders in fields such as embryology and physiology. Public lectures, a history of biology seminar and the Logan Science Journalism Program extend the MBL's reach beyond scientific discovery, and the location serves as an attractive convening place to bring together researchers and students around diverse topics especially related to the MBL's core areas.

Introduction

The Marine Biological Laboratory (MBL) in Woods Hole, Massachusetts, was established in 1888 as a summer institution for biological research and teaching. The MBL's history of excellence in research and education is apparent in the awards granted to its affiliates: over 50 scientists who have worked at the MBL, either as a part of a course or as an investigator, have been awarded Nobel Prizes. Beginning in 1947, the MBL began to transition to a year-round institution and now supports a core of more than 20 resident scientists, plus fellows, post docs, students and assistants, spread across three main research centres: the Ecosystems Center, the Josephine Bay Paul Center for Comparative Molecular Biology and Evolution and the Eugene Bell Center for Regenerative Biology and Tissue Engineering. Hundreds of scientists spend their summers as researchers or students, and thousands more visit for conferences and other events each year. The MBL remained an independent institution until 2013, when it became an affiliate of the University of Chicago.

The local waters off Cape Cod contain a rich biodiversity and have a steady salinity year-round. The large range of organisms available was a major factor in the 1870s establishment of a research centre for the US Fisheries Commission (Galtsoff, 1962). The nearby Annisquam Laboratory on the shores north of Boston and the Penikese Island School on the nearby Elizabeth Islands had provided precedents in introducing students to the region's natural history. These educational and scientific precedents led a board of founding trustees, including Boston-area philanthropists and scientists, to choose the small village of Woods Hole, on the Cape's southwesternmost point, as the location of the newly incorporated MBL (Maienschein, 1985). The trustees established the MBL as a summer institution with a dual mission – to serve as a laboratory for scientific study and to provide instruction in biology and natural history. **See also**: **Agassiz, Jean Louis Rodolphe**

The trustees appointed Charles Otis Whitman, director of the Allis Lake Laboratory in Milwaukee, Wisconsin, and head of the biology department at Clark University in Worcester, Massachusetts, to serve as the first director (**Figure 1**; for a list of directors from 1888 to 2017, see **Table 1**). Whitman, who would go on to found the biology department at the University of Chicago in 1892, was a zoologist and embryologist by training and pioneered the study of cell lineage as a means to investigate early development in embryos. His work in this area helped during the formative years of the MBL to attract scientists who would become world-renowned, such as Thomas Hunt Morgan, Edmund Beecher Wilson and Edwin Grant Conklin. Morgan, who returned to the MBL nearly every summer as an investigator for decades, famously earned the Nobel Prize in Physiology or Medicine in 1933 for his work on the roles that chromosomes play in heredity (**Figure 2**). Meanwhile, Wilson and Conklin helped to establish the field of cell biology and bring experimental practices to the study of embryology (Maienschein, 1991). Under Whitman's guidance, the MBL rapidly became a convening place for biological investigation and education, drawing and nurturing scientists from around the world. **See also**: **Morgan, Thomas Hunt**; **Wilson, Edmund Beecher**; **Conklin, Edwin Grant**

When the MBL opened in July 1888, eight students and seven investigators worked within the newly built 'old main' – a two-storey, wooden laboratory building. In keeping with the MBL's mission, the first floor was devoted to teaching, and the second floor was outfitted with space for investigators. Even as the MBL grew over the years, the proximity of education and research remained intact, and many students returned as both

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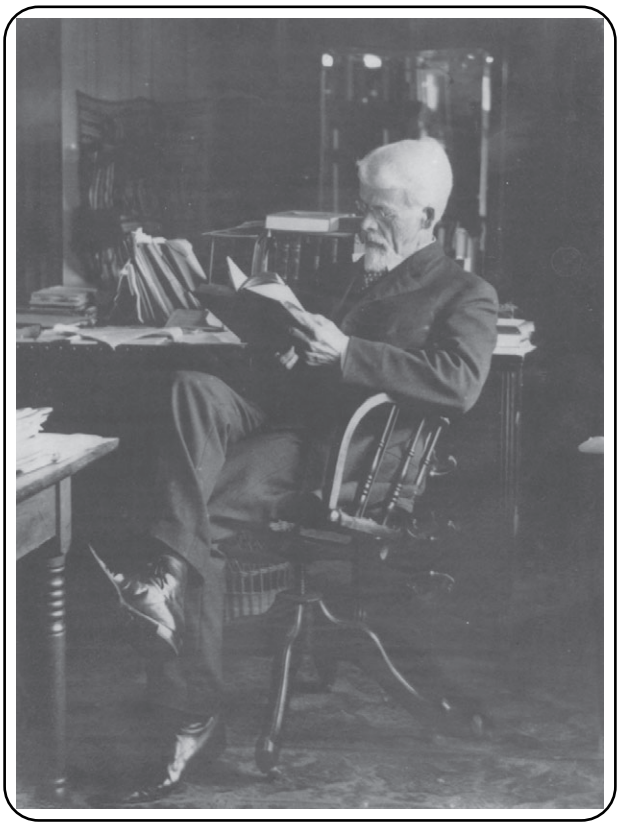

Figure 1 Charles Otis Whitman. Digitized by the MBL History Project. Courtesy of the HPS Repository.

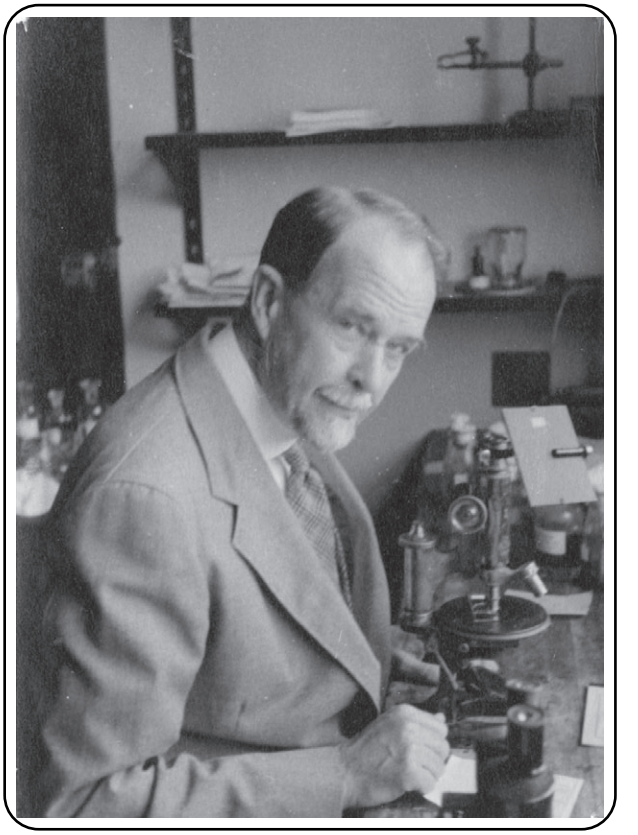

Figure 2 Thomas Hunt Morgan seated at his microscope in his office at the MBL. Created by Alfred Huettner, 1930. Digitized by the MBL History Project. Courtesy of the HPS Repository.

Table 1 Table of former MBL directors from 1888 to 2017

Former MBL directors	
Years	Name(s)
1888–1907	Charles O. Whitman
1908–1925	Frank R. Lillie
1926–1937	Merkel H. Jacobs
1938–1949	Charles Packard
1950–1965	Philip B. Armstrong
1966–1969	H. Burr Steinbach
1970–1975	James D. Ebert
1976	Keith R. Porter
1977	James D. Ebert
1978–1985	Paul R. Gross
1986	Richard D. Whittaker
1987–1991	Harlyn O. Halvorson
1992–2000	John E. Burris
2001–2005	William T. Speck
2006–2012	Gary G. Borisy
2012–2014	Joan V. Ruderman
2014–2015	Arthur M. Sussman
2015–2017	Huntington F. Willard
2017–2018	Melina Hale and Neil Shubin

course instructors and summer investigators. Women, in particular, made up large numbers of the student body and also came to the MBL as investigators (MacCord, in press). In fact, the first person to show up for the opening season was Cornelia Clapp, who came first as a student, then over the years following as a researcher, librarian and eventually as a Trustee (**Figure 3**).

While local fishermen helped to supply some of the specimens, a large component of the courses involved collecting organisms. During the early years of the MBL, students would frequently roll up their pants (or tuck up their skirts), grab buckets and head to the nearby beach or boat to collect organisms for use in the classroom (**Figures 4** and **5**). Investigators followed suit, collecting many of their own research subjects themselves.

Summer investigators also often served as course instructors, granting students access to the most cutting-edge research of the day. For instance, Bryn Mawr and then University of Chicago professor Jacques Loeb conducted research at the MBL and instructed the physiology course from 1892 to 1903. Loeb is most remembered for his experiments on artificial parthenogenesis, conducted during his summers at the MBL, which fuelled newspaper headlines around the world (Elliott, 2010; Pauly, 1987). During the first season, the MBL offered only instruction in zoology, but by the early 1890s expanded their course offerings to

Figure 3 Cornelia Clapp seated at a desk at the MBL, 1934. Digitized by the MBL History Project. Courtesy of the HPS Repository.

include botany, embryology, physiology and zoology. Of these early courses, the embryology and physiology courses are still offered every summer. **See also**: **Loeb, Jacques**

From the first year, the MBL has held a series of public lectures designed to bring scientists to visit and speak about topics of wide interest. Speakers during these years were some of the best scientific minds of the day, including the embryologist Wilhelm Roux and the paleontologist Henry Fairfield Osborn, who gave lectures alongside MBL regulars such as Whitman, Morgan, Wilson, Conklin and Clapp. The lectures were published through the 1890s as *Biological Lectures Delivered at the Marine Biological Laboratory of Wood's Holl* (Available: https://www.biodiversitylibrary.org/bibliography/4963#/summary) (Maienschein, 1987). The lecture series that Whitman established has continued throughout the history of the MBL and is now known as the Friday Evening Lectures, which continue to bring in a diverse range of scientists, as well as historians and philosophers of science, to give lectures to wide public audiences. Today's lectures are available online (http://www.mbl.edu/friday-evening-lectures/). **See also**: **Roux, Wilhelm**; **Osborn, Henry Fairfield**

By the turn of the twentieth century, course attendance was skyrocketing, and researchers continued to take their families each summer to the MBL, but the MBL was in dire financial straits. The cost of supporting a summer laboratory proved too high for the original financial model that relied largely on student fees. The MBL had followed the model of the Naples Stazione Zoologica, in which institutions could subscribe by paying an annual fee and then were allowed to send some number of participants to work there. But this was not enough to support the growing institution. Looking for partnerships that might help, the trustees sought support from donors. At various points through the 1890s and into the early 1900s, it looked like the Carnegie Institution of Washington, Rockefeller Foundation, or University of Chicago might take control of the MBL, but Whitman and some of the leading trustees were passionately committed to remaining independent (Turriziani Colonna, 2016). **See also**: **Stazione Zoologica Anton Dohrn**

In 1909, Frank Rattray Lillie, the assistant director and professor at the University of Chicago, took over as the director of the MBL. Lillie trained in embryology under Whitman at Chicago and is best known for his research on fertilisation. Under Lillie's guidance, the MBL attracted financial support from private donors, including most notably Charles R. Crane (Lillie's brother-in-law). This generous support kept the laboratory open and running during the summer season and also helped the institution to begin to replace its outdated infrastructure. Until 1914, the MBL consisted of a series of wooden buildings, constructed in haste to meet the expanding demand of students and investigators (Conklin, 1988). With safety and science at stake, Lillie headed a fundraising campaign that led to the first brick laboratory building on the campus – what is now the Crane wing of the Lillie building (the main part of the Lillie building was constructed in 1924) (**Figure 6**).

The new brick building was dedicated in July 1914, just over 2 weeks before the start of WWI in Europe. Although the United States did not enter the war until 1917, the spectre of the war throughout Europe hung over the MBL, resulting in decreased annual attendance. The rebound in the numbers of investigators and students in 1919 was tremendous – surpassing any previous attendance. And, while the war years affected turnout, it did not affect the quality or breadth of the science and teaching.

The MBL attracted a diverse group of students and researchers, with interests spanning embryology and genetics, neurobiology, physiology and also ecological sciences. Ernest Everett Just, one of the foremost African American biologists of the early twentieth century and PhD student of Lillie at the University of Chicago, conducted his research on the mechanics and reaction of fertilisation for over a decade at the MBL beginning in 1909 (Manning, 1985) (**Figure 7**). Thomas Hunt Morgan's student, Alfred Sturtevant, who is best known for his contributions to the concept of genetic crossing-over and the development of the first gene map, began to conduct research at the MBL in 1913 and returned every summer for decades (**Figure 8**). In addition to their investigations, both of these men lectured in the embryology course for years. Other equally renowned scientists

Figure 4 Faculty and students in the 1895 Botany course collecting specimens in Woods Hole. Created by Baldwin Coolidge, 1895. Digitized by the MBL History Project. Courtesy of the HPS Repository.

Figure 5 Woman on a collecting boat, harvesting starfish, 1890. Digitized by the MBL History Project. Courtesy of the HPS Repository.

Figure 6 Southern view of the Crane building. Created by Norman W. Edmund, 1923. Digitized by the MBL History Project. Courtesy of the HPS Repository.

Figure 7 Ernest Everett Just pitching horseshoes behind the Old Main building at the MBL. Created by Alfred Huettner. Digitized by the MBL History Project. Courtesy of the HPS Repository.

Figure 8 Alfred Sturtevant collecting flies, 1961. Digitized by the MBL History Project. Courtesy of the HPS Repository.

attended the summer seasons without participating in course work. For instance, Warder Clyde Allee, a professor at University of Chicago who is recognised as one of the founders of American ecology, started his research at the MBL in 1913, and over subsequent summer seasons developed many of his ideas about cooperation behaviours as the result of his time in Woods Hole (**Figure 9**). **See also**: **Sturtevant, Alfred Henry**

Lillie stepped down as the director in August 1926. The interwar period was one of unprecedented growth; each year, more students and investigators applied to the MBL. Although Lillie resigned from the director position, he maintained an active presence within the MBL community until his death in 1947 and was critical for establishing the nearby Woods Hole Oceanographic Institution in 1930 (Burstyn, 1980). Lillie and his wife Frances Crane Lillie had met when Frank was an instructor and Frances was a student in the MBL Embryology course in 1894, and their meeting played a major role in making the institution and development of Woods Hole a success (Lillie Papers, MBL Archives). Research at the MBL throughout the interwar period continued to lead to groundbreaking discoveries, particularly in neurobiology.

In the summer of 1933, Haldan Keffer Hartline, a neurophysiologist at the University of Pennsylvania, was working on isolating individual optic fibres from the horseshoe crab in order to measure their voltage signals (**Figure 10**). After many failed attempts, Hartline successfully frayed the optic nerve down to a single fibre using adult specimens (all previous attempts had used juvenile horseshoe crabs) (LaTourelle, 2015). Hartline's work at the MBL that summer led to a Nobel Prize in Physiology or Medicine for him in 1967 and decades of research and novel discoveries using the horseshoe crab as a model for visual systems.

In 1936, while working with MBL neurobiology luminaries such as H. Keffer Hartline, John Z. Young became the first person to record the squid giant axon's potential (**Figure 11**). Although some credit Young with discovering the squid giant axon, that anatomical structure was first noted by Leonard W. Williams while working at the MBL in 1909. Following from Young's work, and in collaboration with Alan Hodgkin from the Marine Biological Association in Plymouth, England, in 1938, MBL researcher and biophysicist Kenneth Cole introduced a preparation method for the squid giant axon that allowed scientists to insert electrodes inside the nerve fibre of the axon (LaTourelle, 2016). This new technique allowed researchers to record electrical impulses from within the axon and led to Hodgkin's codevelopment of an action potential theory that got him a shared Nobel Prize in physiology or medicine in 1963. Following Young's work, the squid became a major model organism for neurobiological research. **See also**: **Young, John Zachary**; **Hodgkin, Alan Lloyd**

The advent of World War II brought rapid changes to the MBL. Early in 1942, the Navy commandeered a number of MBL buildings (the 'Mess' where everybody ate, the Homestead dorm, the old Lecture Hall, Rockefeller Hall, the Botany Building and the Apartment House) and constructed a high wire fence around the structures, which also blocked Water Street and access to the US Fish Commission (Packard, 1942). The number of investigators dropped by nearly half from 1941 to 1942, and the courses became much smaller as instructors and students felt the effects of gas and rubber rationing and involvement in the war efforts (Hamburger, 1942). Despite these changes to the physical institution and the size of the research community, the courses and research endured.

Shortly after the end of the war, the MBL charted a new path towards becoming a year-round institution. In 1947, Albert Szent-Györgi, a Nobel Prize in Physiology or Medicine recipient in 1937 for his discovery of vitamin C, established the Institute for Muscle Research at the MBL to study the biophysics of muscle movement. This was the MBL's first year-round institute, and Szent-Györgi became the MBL's first resident scientist. In

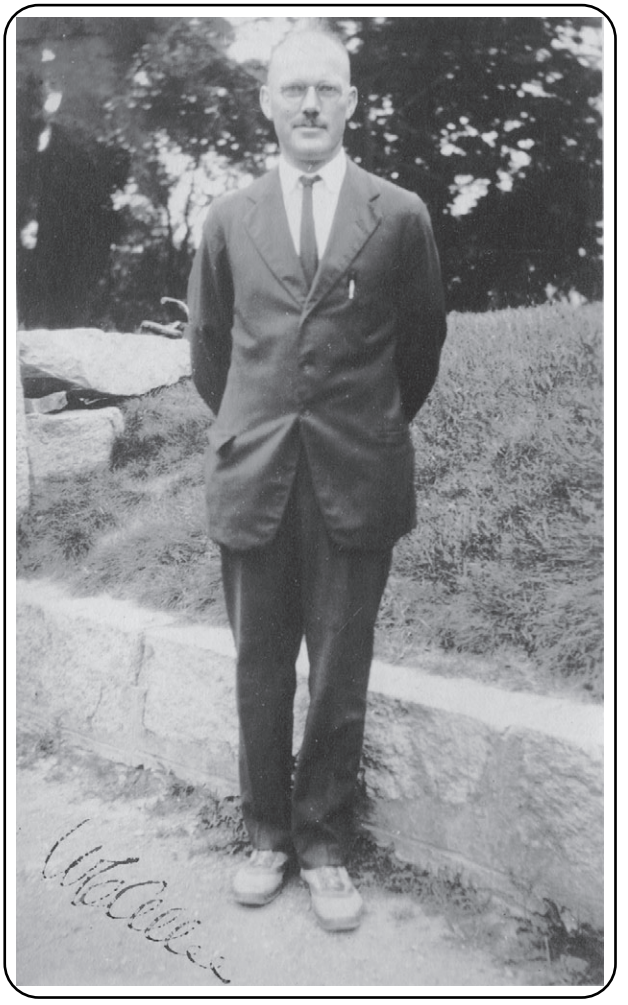

Figure 9 Warder Clyde Allee at the MBL, ca. 1920s. Digitized by the MBL History Project. Courtesy of the HPS Repository.

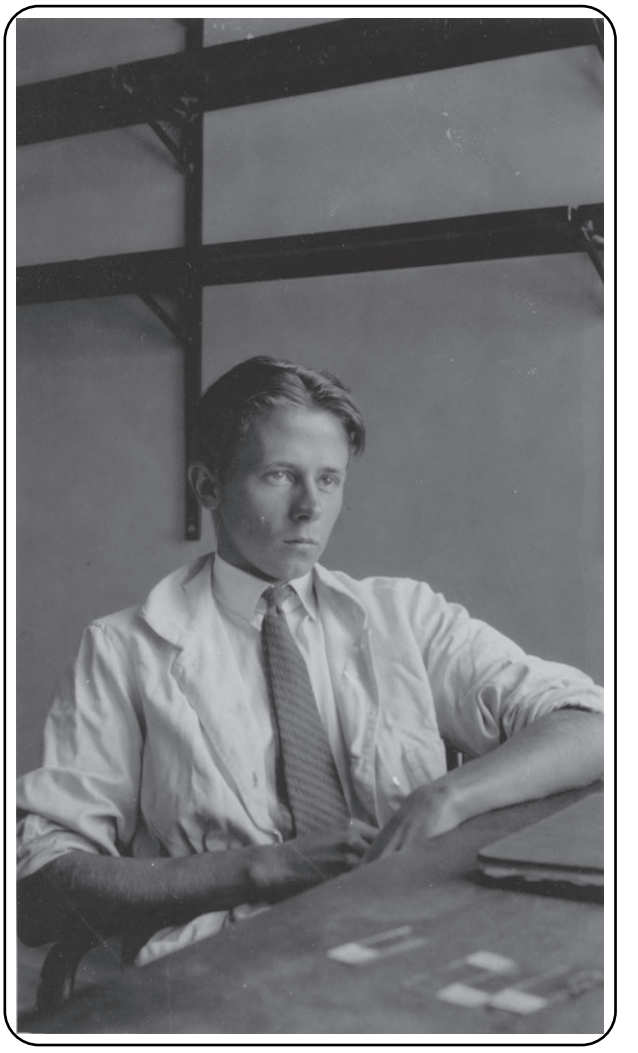

Figure 10 Haldan Keffer Hartline seated in a lab at the MBL, 1925. Digitized by the MBL History Project. Courtesy of the HPS Repository.

addition to running the Institute for Muscle Research at the MBL, Szent-Györgi instructed in and sometimes directed the MBL's physiology course from 1951 to 1980. It would take nearly three decades for the next large-scale year-round initiative, in ecosystems research, to begin at the MBL.

While the MBL is known for its summer courses and research excellence, one of the main factors for its success since opening in 1888 has been its convening power. Scientists often return year after year in order to partake in a uniquely diverse community of biologists. One example of this is the fortuitous meeting of Matthew Meselson and Franklin Stahl during the summer of 1954. Meselson was at the MBL working as a research assistant for James Watson, who, along with Francis Crick and Rosalind Franklin, discovered the structure of DNA (deoxyribonucleic acid) the previous year. Watson had been recruited to teach in the MBL's physiology course, in which Stahl was a student. Over the course of that summer, Meselson and Stahl began to plan an experiment to sort between the three competing models of DNA replication (semiconservative, conservative and dispersive) (Abir-Am, 2015). The experiment, known as the 'Meselson-Stahl experiment', was conducted at CalTech in 1958 and supported Watson and Crick's hypothesis that DNA replication is semi-conservative (i.e. that the two strands of DNA separate during replication, and each act as a temple for a new strand). **See also**: **The Meselson–Stahl Experiment**

By the time Frederik Bang, from Johns Hopkins University, first came to the MBL in the summer of 1954, the horseshoe crab was a popular research subject (owing, in part, to Hartline's work beginning in the early 1930s). Unlike Hartline, Bang was interested in understanding circulation in the horseshoe crab, which have semiclosed circulatory systems (unlike mammals, whose circulatory systems are closed). During his research that summer, Bang noticed a disturbance in the coagulation of the horseshoe crab's blood when it was infected with *Vibrio* bacteria – a reaction that other types of bacteria had not produced. Bang published his observations of the reaction in 1956 (Bang,

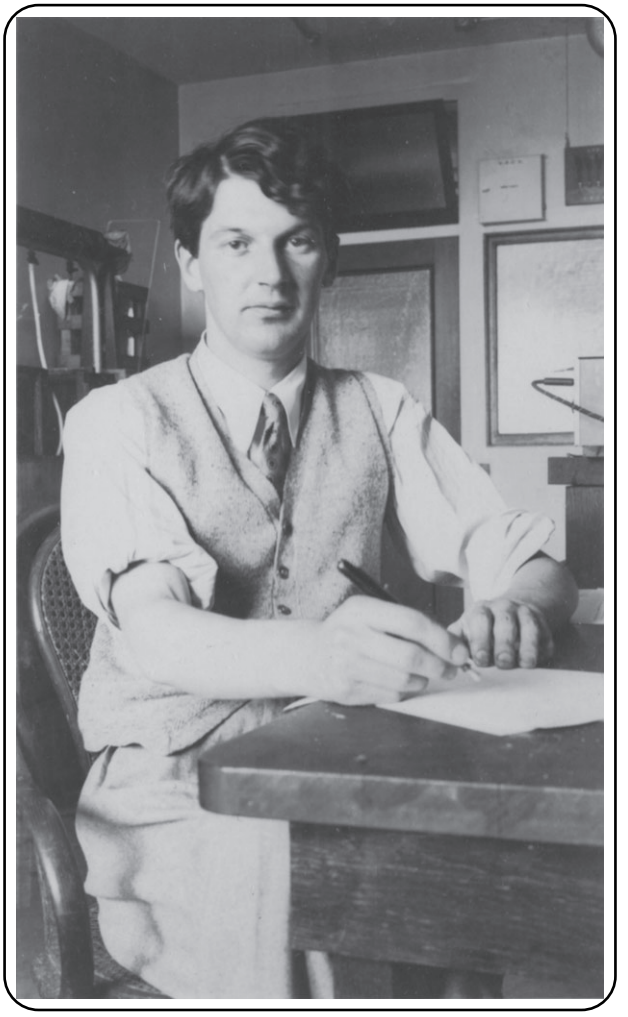

Figure 11 John Z. Young at the MBL, 1936. Digitized by the MBL History Project. Courtesy of the HPS Repository.

1956). As a result of his further exploration of this phenomenon with Jack Levin (also an MBL researcher), they discovered that horseshoe crab blood could be used to detect endotoxins that are dangerous to people. Horseshoe crab blood continues to be harvested and used for this purpose.

While the content of the courses offered every summer is continually updated by instructors to be at the cutting edge of research in the field, for the first 70 years the course listings were limited almost exclusively to botany, physiology, embryology and zoology. Beginning in the mid-1960s, the MBL began to expand its summer repertoire, giving students the options of programmes in comparative physiology, marine ecology and fertilisation and gamete physiology (**Table 2**). By the end of the decade, the MBL had added courses in neurophysiology/neurobiology, systematics–ecology and excitable membrane physiology and biophysics. In the intervening years, the MBL has offered dozens of different courses to meet new demands within the biological sciences. For instance, Eric Davidson, a long-time director of the embryology course, started a course on gene regulatory networks in 2008. The MBL has also hosted a seminar in the history of biology since 1987, which has brought together historians, philosophers and scientists in intensive study of different aspects of the life sciences (http://history.archives.mbl.edu/info/investigator-dataset). And since 1986, what is now called the Logan Science Journalism Program has brought science writers to the MBL to work in labs and gain hands-on experience with the discovery process (http://www.mbl.edu/sjp/).

On 1 January 1975, the Ecosystems Center, the first research centre at the MBL, opened its doors. The Ecosystems Center was formed to support basic ecological research, to strengthen education at the MBL and to find practical applications of science for the management of natural resources (Baranski, 2015). Planning for the Ecosystems Center began several years earlier when then-MBL Director James Ebert approached ecologist George Woodwell to start a fundraising campaign to open the newly conceived centre. Woodwell managed to raise the funds, and he became the Ecosystems Center's first director. Woodwell left the Ecosystems Center in 1985 to open the Woods Hole Research Center, a climate change think tank located just up the street from the MBL. The Ecosystems Center has served as the lead institution for several major NSF-funded Long-Term Ecological Research sites and continues to provide insights into environmental science and management for the region and for more far-flung areas such as the Arctic.

The MBL has a long and storied history of innovation in microscopy and imaging, of which long-time MBL scientist Shinya Inoué is a prime example (**Figure 12**). Inoué, who is known for his demonstration of the mitotic spindles in a living cell using polarised light microscopy, first came to the MBL in the summer of 1949. Inoué began his scientific career working with MBL scientist Kastuma Dan in 1941 at Musashi Kotoh-Gakko, a private 3-year liberal arts prep college in Tokyo, and later worked with him at the Misaki Marine Biological Station on Moroiso Bay in Japan (**Figure 13**). Following his move to the United States, Inoué worked during the summers at the MBL, developing new ways of using polarised light microscopy to look at how the mitotic spindles function during cell division. In the summer of 1980, Inoué started the Analytical and Quantitative Light Microscopy course at the MBL. Along with MBL regulars Bob and Nina Allen, Inoué used video equipment attached to microscopes to demonstrate features of the cell and microscopic techniques to students. Through a series of fateful events, Inoué and the Allens noticed that by using the video equipment attached to the microscope, they could enhance the contrast between structures of interest and the rest of the cell, allowing them to identify structures and processes that would otherwise have been too faint to distinguish with the microscope alone (Lowe, 2016). Following this discovery, the Allens and Inoué continued to develop video microscopy, leading Inoué to publish a highly regarded textbook (Inoué, 1986). **See also**: **Polarized Light Microscopy**; **Video Microscopy**

Many researchers have taken advantage of the excellent microscopic facilities at the MBL, including MBL senior scientist Osamu Shimomura. While at Princeton University, Shimomura discovered green fluorescent protein (GFP) in

Table 2 Courses offered at the MBL in 1888, 1892, 1968, 1988 and 2018

1888	1892	1968	1988	2018
Zoology	Botany	Embryology	Analytical and Quantitative Light Microscopy in Biology, Medicine, and Materials Science	Analytical and Quantitative Light Microscopy
	Embryology	Experimental Botany	Biology of Parasitism	Biology of Parasitism: Modern Approaches
	Physiology	Marine Ecology	Cell and Molecular Biology of Plants	Brains, Minds, and Machines
	Zoology	Physiology	Embryology: Cell Differentiation and Gene Expression in Early Development	Embryology: Concepts and Techniques in Modern Developmental Biology
		Systematics–Ecology Program	History of Biology	Frontiers in Reproduction: Molecular and Cellular Concepts and Applications
			Mariculture: Culture of Marine Invertebrates for Research Purposes	Frontiers in Stem Cells and Regeneration
			Marine Ecology	Gene Regulatory Networks for Development
			MBL Logan Science Journalism Program	History of Biology
			Methods in Computational Neuroscience	Immunohistochemistry and Microscopy
			Molecular and Cellular Immunology	MBL Logan Science Journalism Program
			Neural Systems and Behavior	Methods in Computational Neuroscience
			Neurobiology	Microbial Diversity
			Optical Microscopy and Imaging in Biomedical Sciences	Molecular Mycology: Current Approaches to Fungal Pathogenesis
			Physiology: Cell and Molecular Biology	Neural Systems and Behavior
			Workshop on Molecular Evolution	Neurobiology
			Workshop on Plant and Animal Cell Microinjection	Optical Microscopy and Imaging in the Biomedical Sciences
				Physical Biology of the Cell
				Physiology: Modern Cell Biology Using Microscopic, Biochemical and Computational Approaches
				Strategies and techniques for Analyzing Microbial Population Structures
				Summer Program in Neuroscience, Excellence and Success
				Workshop on Molecular Evolution
				Zebrafish Development and Genetics

Zoology was the first course offered at the MBL. By 1892, four courses were offered – botany, embryology, physiology and zoology. These four courses were offered until the mid-1960s, when the MBL began to offer a wider range. Since this time, the MBL has continued to expand its education programme.

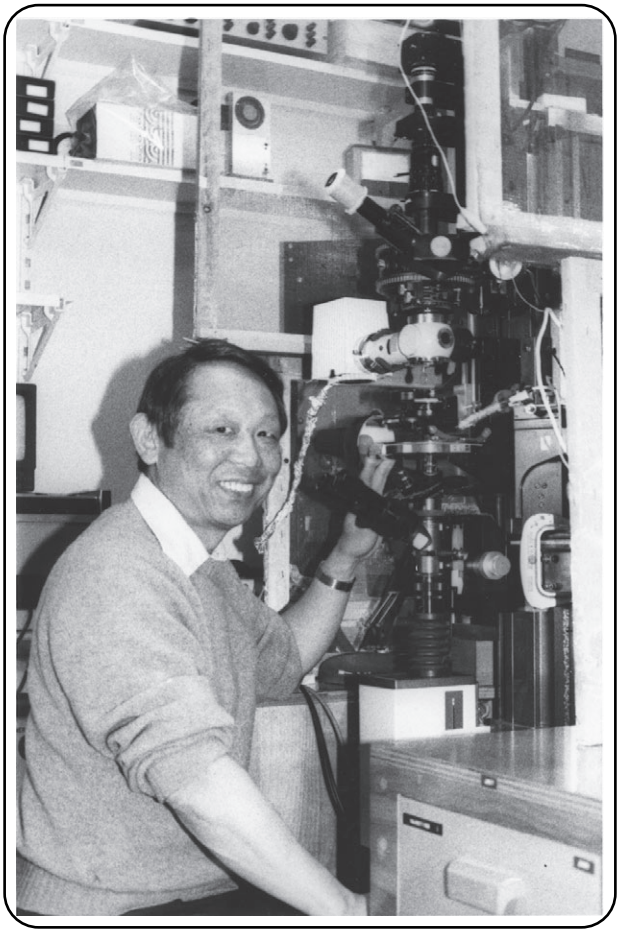

Figure 12 Shinya Inoué seated in front of a microscope. Digitized by the MBL History Project. Courtesy of the HPS Repository.

Figure 13 Katsuma Dan seated in a lab at the MBL, ca. 1931. Digitized by the MBL History Project. Courtesy of the HPS Repository.

the jellyfish *Aequorea* while also studying bioluminescence. He moved to the MBL and continued to develop the green fluorescent protein techniques that many see as having revolutionised abilities to see inside organisms. Shimomura received the Nobel Prize for Chemistry in 2008 for this work (see http://comm.archive.mbl.edu/news/features/shimomura.html).

The Josephine Bay Paul Center for Comparative Molecular Biology and Evolution became the MBL's second research centre, officially established by director Mitchell Sogin in 1996, thanks to an endowment from the Josephine Bay Paul and C. Michael Paul Foundation. Known informally as the 'Bay Paul Center', the research conducted by the faculty explores the evolution and interactions of genomes of diverse organisms that play significant roles in environmental biology and human health.

The MBL's third research centre, the Eugene Bell Center for Regenerative Biology and Tissue Engineering, was established in 2010 through gifts from Millicent Bell and John and Valerie Rowe. Research within what is informally called the 'Bell Center' investigates the molecular, genetic and cellular mechanisms underlying the growth and replacement of tissues during development, physiological turnover and repair following injury. Regeneration across diverse organisms has been a focus of investigation at the MBL since the early years, when scientists such as Thomas Hunt Morgan and Jacques Loeb began to dissect marine organisms and watch how they would repair and grow new body parts or even wholly new bodies.

The year after the Bell Center opened, the MBL became the host for the National *Xenopus* Resource (NXR). NXR serves as a national stock centre for the frogs *Xenopus laevis* and *Xenopus tropicalis*, which are key model organisms for biomedical research. The NXR acts as a facility for research, training and the development of new experimental tools and technologies for use on *Xenopus*. **See also**: ***Xenopus* as an Experimental Organism**

The MBL has had a long and vibrant history of internationally acclaimed courses, evolving research, financial ups and downs and a strong commitment to scientific discovery and public engagement. In 2013, it became clear that such an institution could no longer sustain its quality programmes alone. Science is expensive, and providing support for and regulatory management

of scientific research and education requires an infrastructure that is very difficult for a small institution to provide on its own. The MBL Trustees entertained proposals for partnerships with other institutions, and in June 2013, the MBL Corporation of scientists who make up the lab voted to accept the University of Chicago's offer to manage the lab. The significant change from fierce independence to ownership by a well-established university has required adjustments. Yet the alliance is the most appropriate possible, given the close connections of the first two directors with Chicago and given that the MBL almost became affiliated with the University of Chicago in its early years. Over a century of close relationships provides a strong basis for future sustainability of the MBL and its dynamic and rich history.

Glossary

Artificial parthenogenesis The development of an egg into an embryo stimulated not by fertilization, but by artificial means, such as treating with acid, mechanical damage, etc.

Bioluminescence The biochemical emission of light by living organisms.

Endotoxin A toxin that is present inside of a bacterial cell and is released when the cell disintegrates.

Genetic crossing-over The process in which homologous pairs of chromosomes pair up with each other and exchange different segments of their genetic material to form recombinant chromosomes.

Mitotic spindle A macromolecular structure within the cell that segregates chromosomes to two daughter cells during mitosis.

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