Marine Biological Laboratory

THE UNIVERSITY OF CHICAGO

NSF-REU Biological Discovery in Woods Hole
Summer Opportunity for Undergraduate Research

Marine Biological Laboratory
Department of Education
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Program Dates: June 9 – August 20, 2021

Application Deadline: Priority deadline – February 15, 2021; Final deadline – March 10, 2021

Please read the entire *Frequently Asked Questions* (FAQs) and the below *Program Details* before contacting the Marine Biological Laboratory (MBL) with questions. Any questions not covered in the Program Details and/or FAQs must be sent to NSFREU@MBL.EDU. Please do not contact the education office at MBL as that will only delay any response. Please Note: All application materials must be uploaded electronically.

PROGRAM DETAILS

The Marine Biological Laboratory (MBL) invites undergraduate students who are interested in pursuing careers in the life sciences to apply to the ***NSF-REU Biological Discovery in Woods Hole program***. Faculty with expertise in molecular and cell biology, neurobiology & behavior, physiology, developmental biology, and evolutionary biology will guide ten highly motivated undergraduate students in this National Science Foundation Research Experience for Undergraduates (NSF REU) program. Each undergraduate student will be placed in the laboratory of an MBL research scientist and fully participate in all laboratory exercises and activities. The program will provide a stipend, room and board for the duration of the program. For priority consideration, applications are due by February 15, 2021. Students from small colleges or from underrepresented groups are especially encouraged to apply. Although the admission committee may continue to review and accept applications up until March 10, 2021, it is strongly suggested that your completed application be received by February 15, 2021 to allow time for consideration of your entire file. The admission committee reserves the right to suspend admission any time after February 15, 2021 if the program is filled. Students will begin to be notified by the end of March, 2021.

The Program: The Biological Discovery in Woods Hole (BDWH) Program is designed as an intensive, 10-week research experience for undergraduates at the Marine Biological Laboratory (MBL) in Woods Hole, MA. The major portion of each student's time will be dedicated to an individual research project under the direction of one of the participating mentors (see list below). The program will be conducted from mid-June through mid-August each summer and will integrate the students with the marine setting and the unique intellectual blend of year-round and summer investigators at the MBL to provide a diverse and varied undergraduate research experience. The program will focus on the molecular, cellular and physiological processes that give rise to and regulate complex physiological systems, and which ultimately mediate organismal behavior. Investigators use both marine and non-marine models. The program's goal is to recruit highly motivated students, especially from under-represented groups and/or schools with limited research opportunities and immerse them in research programs under the guidance of mentors selected from visiting summer investigators, or year-round investigators at the MBL, who are fully committed to enhancing the undergraduate research experience. To augment the research experience, students will participate in field trips and attend weekly course meetings, seminars and/or luncheons that will explore a wide range of topics (e.g., graduate school application, ethics, career paths) to encourage the students to prepare and pursue a career in biological sciences. There will also be group activities, field trips and barbeques to provide peer interactions. Finally, the program will culminate with an undergraduate research symposium.

The Research Environment: The Marine Biological Laboratory is an international center for research, education, and training in biology. It was established in 1888 as an institute where marine organisms were used as model systems in the study of cell biology, neurobiology, and embryology. During the summer, the 270 year-round scientists and support staff of the MBL are joined by an additional 300 visiting scientists in our Whitman Center for visiting research, as well as 1200 graduate and postdoctoral students and faculty in our discovery courses, all from over 200 institutions throughout the world. Scientists are attracted to the MBL as well by the opportunity to collaborate with investigators at the other scientific institutions in Woods Hole. These include the Woods Hole Oceanographic Institution, the National Marine Fisheries Service, the United States Geological Survey, and the Woods Hole Research Center. In the small village of Woods Hole, this concentration of researchers and institutions results in a scientific community unparalleled in the world.

Research Facilities: The MBL houses a number of unique research facilities. These include a state-of-the-art Marine Resources Center, which provides for the latest approaches in husbandry and mariculture of marine organisms; advanced equipment for light microscopy combined with computer imaging; and the MBL/WHOI library, which is one of the most complete science libraries in the world. There are numerous opportunities to attend a variety of seminars and lectures. The MBL hosts many educational courses which run throughout the summer. Those courses draw their instructional faculty from leading researchers in the respective fields and each offers a daily lecture or seminar series which is open to the scientific community at large. The MBL Friday Night Lecture Series brings in speakers of particular note who are of interest to a wider audience. Additionally, a number of courses and groups sponsor informal evening or lunch-time seminars.

Eligibility: Undergraduate student participants will be supported with National Science Foundation funds and must be citizens or permanent residents of the United States or its possessions. An undergraduate student is a student who is enrolled in a degree program (part-time or full-time) leading to a bachelor's degree. Students who will have graduated from their institution prior to the summer program are not eligible to apply. Students who are transferring from one institution to another and are enrolled at neither institution during the intervening summer may participate. High school graduates who have not yet enrolled and students who have received their bachelor's degrees and are no longer enrolled as undergraduates generally are not eligible.

Stipend and Housing: Students will receive a stipend of approximately $5000 for the program. Room and board will be provided in MBL dormitories which are on the MBL campus, and a stone's throw from the ocean. The rooms are shared, and the BDWH students are usually assigned rooms together.

To apply: We strongly encourage students to apply by the priority consideration date of February 15, 2021, although applications may be accepted until March 10, 2021. Students will be notified of application status in late March 2021, at which time students accepted into the program will receive additional registration and housing information. The on-line application form can be accessed after December 10, 2020. Students from under-represented groups and/or small colleges are especially encouraged to apply.

Each student must submit a CV/resume, short essays (maximum one page each) describing his or her reasons for wanting to participate in the program, their expectations for participation in the program and specific research areas or mentors of interest. Additionally, each student will be asked to upload a copy of his/her unofficial transcript on the online application and name two references. These references will be sent an email with directions on how to upload their letters of recommendation. Students are selected based on their academic credentials, essays and letters, with the aim of ensuring a diversity of students with respect to race, gender, geography, and academic background. Students are matched with faculty mentors based on course work, experience, and/or expressed research interest, as well as availability of mentors. Please note - students are applying to the program, and not to a specific mentor. Mentor selection on the application form is for the purposes of placement of selected students and is not a factor in the selection process. Although most students are assigned one of their top three mentor choices, we cannot guarantee that students will be placed in these labs.

Acceptance and Mentor Assignments: Notices of acceptance into the program will be sent to applicants beginning in late March. After the students confirm their participation in the program, they will receive a schedule of orientation activities, as well as a roster of all student and research mentor participants in the program and information on the MBL, including travel and housing. The program co-directors will then make tentative assignments of each student to a research mentor. These assignments take into account any preferences for particular research areas that the students express in their applications and previous research experiences (if any). A synopsis of the student's background is sent to the proposed mentor for review and approval and the mentor is instructed to contact the student by e-mail and/or phone to provide the student with background information and materials to be read to prepare the student for the research project.

See participant mentors and their projects listed below

Participant mentors and the projects they pursue:

Veronica Martinez Acosta, University of the Incarnate Word, TX: Our laboratory utilizes an annelid model system, *Lumbriculus variegatus*, to study wound healing and regeneration within the central nervous system (CNS). *Lumbriculus* is capable of regenerating an entirely new worm from a fragment that is 1/50th the size of the original animal. Perhaps what sets *Lumbriculus* apart from other regenerating model systems is the ability to recover neural anatomy, physiology, and behavior following injury along any portion of the anterior-posterior body axis. Our overall laboratory goal is to identify the cellular and molecular events triggered as a result of injury within the central nervous system (CNS) which promote regeneration and recovery of function versus deterioration. We have investigated the neuroanatomical and proteomic changes associated with regeneration in *Lumbriculus*. While we will continue to characterize the regenerative process at the anatomical and proteomic levels, we would like to utilize transcriptomic data to clone and sequence candidate genes for use in genetic expression analyses in real time, including the use of RNA sequencing and *in-situ* hybridization. Our lab has successfully mentored primarily undergraduate students in the lab. Each student has the opportunity to be trained in confocal imaging, behavioral analysis, protein extraction, and genome level analysis in this unique model system.

Irina Arkhipova, MBL: "Mobile DNA and horizontal gene transfer in eukaryotic genome function and evolution". Our lab investigates a variety of biological models, including filamentous gliding bacteria, ascomycete fungi, and bdelloid rotifers. We apply molecular genetics, biochemistry, and bioinformatic methods to address fundamental questions in evolutionary biology and comparative genomics. Student projects in recent years included expression and purification of domesticated reverse transcriptases from bacteria and construction of their mutant versions; isolation and characterization of loss-of-function mutant strains from a Neurospora mutagenesis screen; studies of in vitro activity of hammerhead ribozyme motifs from rotifers; de novo identification and annotation of transposable elements in sequenced eukaryotic genomes; and studies of enzymatic activity of non-canonical rotifer methyltransferases. Future projects may include characterization of species-specific response to metal-induced stresses mediated by horizontally transferred genes and identification of extrachromosomal DNA forms corresponding to mobile genetic elements. Students gain experience in microbiology and aquatic culture, DNA/protein extraction and analysis, molecular cloning and biochemical assays, and exposure to cutting-edge high-throughput sequencing and bioinformatic methods. They will be co-mentored by the PI and resident research scientists in the lab and will be fully engaged in the Bay Paul Center and the broader MBL scientific community, participating in weekly lab meetings and in the end-of-summer MBL-wide undergraduate symposium.

Karen Echeverri, MBL: The Echeverri lab focuses on elucidating the molecular mechanisms of regeneration Our group has three main areas of research; the first is to understand at the molecular and cellular level how ***salamanders can regenerate a fully functional spinal cord after injury.*** In particular we focus on how the neural progenitor cells react to an injury signal and are activated to repair the lesion instead of forming inhibitory scar tissue. We aim to understand how these stem cells are guided to replace the correct number of lost neurons and reconnect the circuits to regain motor and sensory control. The second main focus of the lab is on ***scar free wound healing***. Axolotls regenerate without the formation of scar tissue. Our longstanding work on the "axolotl" salamander, the champion among such species, is identifying critical molecules, regulatory pathways and cellular processes underlying scar-free regeneration. We use transcriptional profiling and *in vivo imaging* to understand which cells respond to the injury signal, what the potential of these cells is and where cells come from to heal the wounds scar free. The third area of research in the lab is the ***evolution of regenerative ability***. We are using the ***local invertebrate sea anemone, Nematostella vectensis*** that has the natural ability to regenerate; to interrogate pathways conserved in invertebrates and vertebrate species. These findings will pave the way to begin to elucidate regulatory networks necessary to initiate and terminate regenerative growth and shed light on why some species can regenerate and others cannot.

Project titles:
1.Molecular mechanisms of brain regeneration in axolotl
2.The role of stem cells in scar free wound healing
3.Size control during regeneration in the sea anemone, *Nematostella vectensis*

André Fenton, New York University: The goal of my research is to identify the neurobiological mechanisms of persistent memory storage using approaches that integrate techniques and knowledge across multiple levels of biology. Undergraduate students can expect to understand the advantages and challenges of asking questions about biological mechanisms by simultaneously investigating multiple levels of biology, and have the opportunity to investigate memory persistence by conducting experiments that require techniques in computer-controlled mouse spatial behavior, animal sacrifice, brain removal, and the anatomically-precise tissue sampling required for region-specific transcriptomic and proteomic analyses. The students will have the opportunity to extract RNA from tissues, and single cell classes, and assess the electrophysiological functional properties of synapses within the entorhinal-hippocampus circuit. Students will have the opportunity to perform numerical bioinformatic analyses, to identify and compare correlation networks that are designed to identify the molecular mechanisms of memory persistence by determining the graph-theoretic inter-relationships between measures of memory as assessed by behavior, synaptic physiology, gene and protein expression.'

Roger Hanlon, MBL: "Rapid adaptive camouflage system of cephalopods." The Hanlon lab studies sensory systems and behavior in cephalopods involving (i) rapid adaptive camouflage in cuttlefish and octopus and (ii) sensory capabilities of the octopus' arms and suckers in relation to their peripheral vs. central brain control. The first system includes visual perception of backgrounds to determine which camouflage pattern to deploy; and a motor output system that produces a camouflaged body pattern. Behavioral experiments provide the experimental bioassay, and image analyses of the resultant camouflage body pattern provide a quantifiable proxy for motor output and pattern design. There is a refined neuromuscular control system of tens of thousands of pigmented chromatophore organs and iridescent cells in the skin to form the patterns, and we study the gross and fine structure of these skin cells and organs. In the second project, we train octopuses to grab objects, then test chemo and tactile sensing of suckers by applying different textures and tastes to the object and perform neuroanatomical and neurophysiological studies of the arm and suckers. Students are exposed to neurobiology, sensory biology, anatomy, image analysis and ethology. In the broader context, students read experimental and theoretical papers related to this system and discuss them in the context of their experiments to ensure that they understand why they are conducting these experiments, as opposed to solely learning how to conduct the experiment.

Marko Horb, MBL: "Genome editing in Xenopus". Advances in genome editing have made it possible to generate mutant animals in almost any organism. The current focus of the Horb lab is to create Xenopus mutants to model human disease using CRISPR-Cas. Undergraduate students will be given the opportunity to create an F0 Xenopus mutant using CRISPR-Cas as well as learn to work with Xenopus embryos, including embryological and molecular biology techniques. Students will learn to navigate the Xenopus genome, identify specific target sites for generating mutants, inject Xenopus embryos and genotype the resulting embryos. Students should expect to learn, in detail, about genome editing and its applications.

Elizabeth Jonas, **Yale University:** "Synaptic function, metabolic control and neuronal cell death". Dr. Jonas' current research concentrates on understanding synaptic function and neuronal cell death from the point of view of metabolic control, chiefly focusing on mechanisms of mitochondrial dysfunction in synapses within neurons undergoing developmental and neurodegenerative brain disorders. Projects in the laboratory for summer students have included measuring ATP levels in isolated hippocampal neurons using a FRET construct; measuring mitochondrial membrane potential; measuring Ca2+ uptake by mitochondria; immunocytochemistry to localize mitochondrial interacting proteins; use of specific therapeutic reagents to regulate mitochondrial function; measurements of synaptic plasticity in the setting of alterations in mitochondrial function; measurements of synaptic vesicle numbers and localization during synaptic plasticity.'

Javier Lloret, MBL: Nutrients and eutrophication in estuaries, ecology of estuarine plants and algae. Javier is interested in the biotic feedbacks that determine the response of marine organisms to nutrient inputs and eutrophication in coastal ecosystems. He is also interested in how large-scale external drivers, including climate change, modulate that response. Possible summer projects related to this work could be:

- **Algal carbon stable isotopes as indicators of coastal eutrophication** –When growing under nutrient-rich conditions, the bloom-forming macroalga *Ulva* displays a very marked shift in both carbon and nitrogen isotopic signatures. We plan to survey *Ulva* specimens in diferent estuaries of Cape Cod subject to different nutrient loads, and characterize their isotopic signatures.
- **Does eutrophication increase or decrease salt marsh accretion?** – Nutrient enrichment fosters changes in plant productivity, and organic matter accumulation in salt marsh soils, therefore promoting changes in marsh platform vertical accretion. We plan to measure differences in salt marsh elevation in the Great Sippewissett Marsh experimental plots, a long-term (40+ years) salt marsh nutrient enrichment experiment.
- **Coastal ecosystems are N-limited, but freshwaters are mostly P-limited: do we see a corresponding shift in ratio of DIN to phosphate in water bodies with low to high salinities?** – While phosphorus availability limits primary production in freshwater systems, nitrogen tends to be the limiting nutrient in coastal environments. We will measure inorganic nutrient concentrations and observe deviations from the Redfield stoichiometry to elucidate which nutrient limits primary production in a set of Cape Cod ponds and estuaries with different salinities.
- **Is nitrogen content a feeding cue for herbivores and detritivores? Food selection experiments with coastal invertebrates** – We will collect marsh amphipods and snails, and quantify, in laboratory conditions, if they preferentially feed on plant material collected from enriched vs. not-enriched plants from the Great Sippewissett Marsh experimental plots, and from eutrophized vs. not-eutrophized areas of Waquoit Bay.

David Mark Welch, MBL: "Evolution of DNA repair, recombination, and aging". The Mark Welch lab uses natural history and comparative genomics of rotifers, common marine and freshwater microinvertebrates, to understand novel mechanisms of DNA damage repair and the biology of aging. Undergraduates pursue independent research combining aspects of evolutionary genomics, molecular biology, biochemistry, and bioinformatics. Recent student projects have included determining the rate and extent of DNA damage repair through mutation accumulation experiments followed by Next-Gen sequencing of transcriptomes; comparative expression studies of genes involved in DNA repair; comparative analysis of miRNAs; examining the effect of oxidative damage on lifespan and fecundity; and comparing the effect of caloric restriction on lifespan and fecundity in closely related species. Future REU projects will focus on exploring and characterizing systems involved in antioxidant defense and redox maintenance in bdelloid rotifers, a novel animal model that has evolved tolerance to desiccation and ionizing radiation, two environmental insults that cause extreme amounts of oxidative damage.

Allen F. Mensinger, University of Minnesota at Duluth: “Multi-modal sensory integration in the toadfish”. The PI focuses on the neural mechanisms of behavior using the marine toadfish, Opsanus tau. He is investigating multi-modal sensory input of the auditory system and mechanosensory lateral line. Undergraduate students will be exposed to a wide range of skill sets before embarking on independent projects, including animal behavior, video imaging and analysis, microelectrode fabrication, neurophysiological data acquisition, neuroanatomy and histology. The student’s project may include: 1) Relative contribution of canal and superficial neuromast to sound localization: Students test female fish with intact or partially ablated lateral line during phonotaxis experiments. 2) Central projections of the lateral line and utricle: Students use neural tracers to label the lateral line and auditory nerves to determine if and where there is overlapping input in the brain. 3) The relative contribution of the auditory system and lateral line during sound localization. Students will record and analyze neural activity from fish with chronically implanted electrodes during sound presentation.

Jennifer R. Morgan, **MBL:** “Mechanisms of regeneration in the vertebrate central nervous system.” The lamprey is a basal vertebrate that accomplishes full functional recovery (i.e. swimming) after a complete spinal cord injury. This functional recovery is supported by rapid wound healing and repair of the lesion scar, robust axon regeneration, and synaptic reconnections. Projects in the lab are focused on understanding the molecular mechanisms that support successful spinal cord regeneration, with an emphasis on identifying evolutionarily conserved genes and pathways promoting neural regeneration in the vertebrate CNS. Student projects involve a variety of approaches, including but not limited to: bioinformatics, molecular biology, biochemistry, immunofluorescence, and behavior. Ultimately, the goal is to discover relevant genes and pathways that when manipulated could improve CNS repair and regeneration in non-regenerative models and conditions. These studies engage students in a wide range of topics ranging from molecular evolution to conserved mechanisms of cell/tissue regeneration to neural control of behavior.

Loretta Roberson, MBL: “Understanding the mechanisms of calcification in corals and their responses to environmental stressors.” Despite the importance of coral reefs to tropical, marine ecosystems, the biological components of the calcification process are poorly understood. Evidence suggests that corals regulate the movement of ions such as bicarbonate, calcium, and hydrogen to facilitate calcification and that some species are more tolerant of changes in their environment, yet the mechanisms behind these important processes and their molecular components are unknown. In particular, the details of how the symbiotic dinoflagellates (zooxanthellae) enhance calcification and their role in skeleton formation have not been identified to date. As threats such as climate change increase, understanding the mechanisms underlying coral calcification, and coral response to environmental change will be critical for the conservation of these fragile ecosystems. Interdisciplinary, multi-scale studies are therefore necessary to link molecular level changes to organismal and reef performance. For this study, students will be able to participate in and develop projects that include: population demographics of corals from Puerto Rico and Woods Hole, understanding temperature tolerance in temperate corals, the impact of environmental stressors on coral health and bleaching, changes in gene expression in response to environmental stressors, identification of genes involved in calcification, and development of techniques for microscopic imaging of live corals and algal symbionts, and use of macroalgae to improve water quality on reefs.

Joshua Rosenthal, MBL: The central dogma of biology maintains that genetic information passes faithfully from DNA to RNA to proteins; however, with the help of diverse tools, sometimes it is modified within messenger RNA. RNA editing by deamination of adenosine to inosine (A-to-I) is a process used to alter genetic information. Unlike alternative splicing, which shuffles relatively large regions of RNA, editing targets single bases. Because inosine is interpreted as guanosine during translation, this process can recode codons. A-to-I RNA editing is catalyzed by the ADAR (adenosine deaminase that acts on RNA) family of enzymes. All multicellular animals, from cnidarians to mammals, express ADARs, but the extent to which they use them to recode is generally limited. In fact, transcriptome-wide screens have only uncovered about 25 conserved recoding RNA editing sites in mammals, and several hundred in *Drosophila*. These studies have led to the general assumption that recoding by RNA editing is extremely rare. Recent studies in my lab show that cephalopods break the rules. In fact, the behaviorally sophisticated Coleoids (squid, octopus and cuttlefish) edit the majority of their messenger RNAs. This ability to alter genetic information on the fly is an intriguing innovation. We know that it is happening at unprecedented levels, and that it is used primarily in the nervous system to alter proteins directly involved in neuronal signaling. Projects in my lab focus on five basic themes: 1) what are the mechanistic underpinnings of high-level RNA editing in cephalopods; 2) how does RNA editing affect protein function and electrical signaling; 3) does RNA editing respond to environmental factors, particularly those that are being affected by human activities; 4) how do RNA editing sites evolve. Students will be exposed to genome engineering, molecular biology, synthetic biology, cell physiology, and the bioinformatics associated with large DNA sequence data sets.