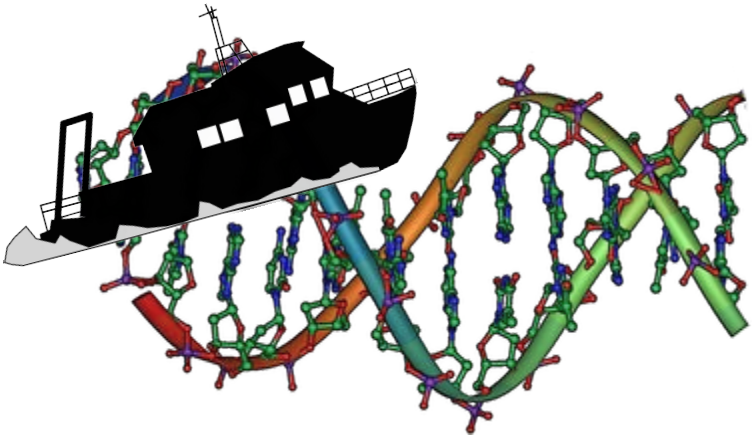
Marine Genomics



CAS BI 550 (4 credits)
Spring 2023
Tue/Thu: 12:30-3:15
Location: Biology Research Building B25 (“The BUMP Lab”)

Instructors	**John R. Finnerty**	**Joanna Lee (teaching fellow)**
Office	BRB 425	BRB 317
Office Hours	By appointment	By appointment
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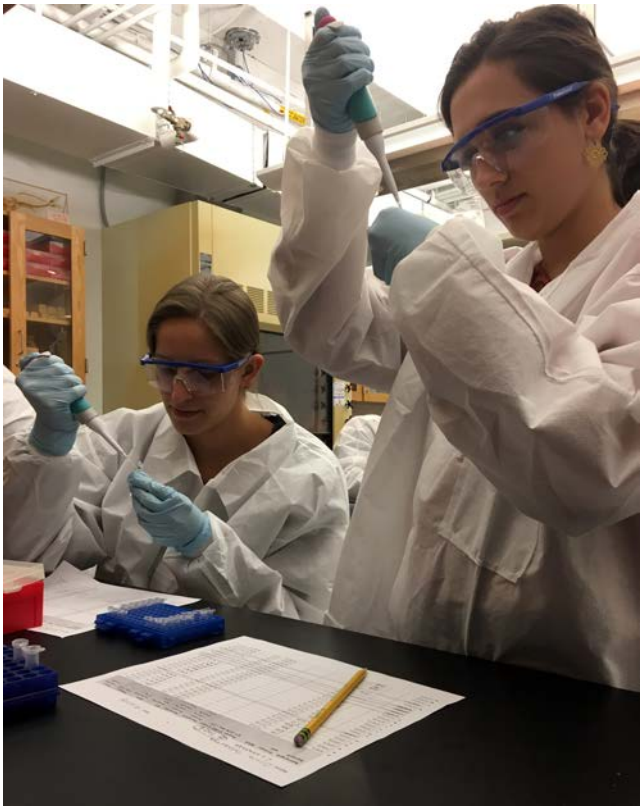
Course Description: Marine Genomics involves the application of genomic techniques to investigate the phenotype of marine organisms and the function of marine ecosystems. For example, (1) “metagenomic” approaches help reconstruct the microbial communities that drive nutrient cycling in marine ecosystems, (2) “transcriptomic” approaches are increasingly being utilized to understand how marine organisms respond to environmental stress at the level of gene expression, and (3) “population genomic” approaches are being used to investigate the microevolution of animal populations. The theoretical portion of this course will cover the evolution of genomes, the architecture of gene networks, the complexity of gene regulation, the connection between genotype and phenotype, and the basics of population genetics. In the computational portion of the course, you will“mine” the genomes and transcriptomes of marine animals to gain insights into their molecular evolution. In the laboratory portion of the course, you will apply metagenomic and population genomic techniques to the DNA of marine organisms. Our focal animals will be corals and sea anemones.



Topics and techniques we will cover in BI550:
Fundamentals of genome organization // molecular evolution // molecular phylogenetics // mechanisms governing gene expression and function // DNA isolation from animal tissues // amplification of DNA using the polymerase chain reaction // analysis of DNA using electrophoresis and spectrophotometry // DNA barcoding & metabarcoding // population genomics // epigenomics // differential gene expression analysis // gene annotation // navigation and utilization of online molecular databases // bioinformatic analysis of DNA and proteins // development of scientific graphs and figures // scientific presentation //

Course Resources:
Slideshows of lecture presentations, lab protocols, bioinformatics protocols, and past student presentations are available through the BU Marine Program Media Library: https://bumarine.smugmug.com/COURSES/Marine-Genomics. Handouts for lecture, lab, bioinformatics exercises, and literature discussions, as well as a copy of all assigned readings can be obtained through a course folder on Google Drive: https://drive.google.com/drive/folders/13BRJs-e5-I0-Ue0BV377PsmhK2HV-IuI

Assignments and Grading
During the course, you will be involved in lab-based and computational research. The computational project, which will be accomplished with your small group, will serve as the basis for your final oral research report. Each group will also host a "journal club" where you will lead the class in discussing a paper from the scientific literature that is relevant to your computational project. The lab research will be performed with another small group. Your goal is to generate reliable data from precious field-collected samples, and to carefully document your methods and results. You will be graded on the research output (experiments, data, lab notebook entries). In both the lab and computational research, discussion and collaboration among students is encouraged, but I will also be looking for signs of individual effort, scientific logic, and creativity.

Computational project and final report: 50%	**Laboratory Research:** 40%
Journal Club: 5%	**Final Exam:** 5%

Support to Help You Succeed in This Course:

1. This course will be challenging because you will be performing original research, and you will be using computational or laboratory methods you haven't used before. For this reason, everyone in the class will struggle. Please ask questions when you do not understand something, whether that happens during lecture, journal club, or in the course of your computational or lab research. If you need help outside of the scheduled course meetings, please make an appointment with either John or Joanna.
2. Accommodations for Students with Documented Disabilities: If you are a student with a disability or believe you might have a disability that requires accommodations, please contact Disability and Access Services at (617) 353-3658 or access@bu.edu to coordinate any reasonable accommodation requests.

Academic Requirements Satisfied by the Course

1. **For Biology majors**, BI550 counts as an upper-level lab course and an upper-level elective.
2. **For Biology majors concentrating in Cell Biology, Molecular Biology and Genetics**, BI550 counts as a CMG elective.
3. **For Marine Science majors**, BI550 counts as a Marine Breadth Course.
4. **For the HUB**, BI550 supplies a HUB credit in **Teamwork/Collaboration**
    - While conducting laboratory and bioinformatic research in this course, students will collaborate with peers in small research teams under the mentorship of the instructors. These student-led groups will jointly formulate and execute research plans, conduct data analyses, and compose and deliver scientific presentations.

Community of Learning: Class and University Policies

1. **Attendance & Absences.** Attendance at all scheduled class activities is mandatory unless you have been previously excused. Your final grade will be penalized 2.5% for each unexcused absence.
2. **Assignment Completion & Late Work**. Late assignments will be penalized 5% per day late.
3. **Individual Contributions to Group Assignments.** Each member of a research team is expected to contribute substantively and equitably to the group's research and presentation. For the computational project and final presentation, the contributions of individual team members should be clearly stated.
4. **Academic Conduct Statement. Data integrity is essential to the scientific process.** It is each student's responsibility to know and understand the provisions of the Academic Conduct Code at Boston University. The Code is available online at https://www.bu.edu/academics/policies/academic-conduct-code/. Cases of suspected misconduct will be referred to the Dean of the College. If the Dean's office comes to the conclusion that cheating or plagiarism have occurred, a grade of zero will be awarded for the assignment in question.
5. **Collegiality and respect for diversity.** Treat everyone you encounter during the class (classmates, teaching fellows, instructors, staff, bystanders, etc.) with the courtesy due to professional colleagues. Refrain from intemperate language or conduct. Follow BU's policy prohibiting discrimination.* Embrace and respect the diversity of backgrounds, experiences, personalities, and perspectives that everyone brings to the course. Do your share of the work. Express your scientific views, but don't dominate the conversation. Listen as much as you talk. In the lab, keep an eye out for your colleagues' safety. Arrive on time for all course activities.
   *Boston University prohibits discrimination against any individual on the basis of race, color, religion, sex, age, national origin, physical or mental disability, sexual orientation, gender identity, genetic information, military service, pregnancy or pregnancy-related condition, or because of marital, parental, or veteran status.

SCHEDULE OF COURSE ACTIVITIES

Thursday, January 19
COURSE INTRODUCTION
(pre-course) FINAL EXAM
LECTURE 1
- Genomics as a Way to Characterize Marine Biodiversity

READINGS: Lecture 1 handout;
OTHER RESOURCES: Lecture 1 slideshow;

Tuesday, January 24
LECTURE 2
- The Phylum Cnidaria — Corals, Sea Anemones, Jellyfishes, Hydras & Relatives

LECTURE 3
- Cndarian Model Systems Used in the Course

BIOINFORMATICS SESSION 1
- Overview of Molecular Evolution Projects; Selection of Projects

READINGS: Lecture 2 handout; Lecture 3 handout; Bioinformatics handout 1;
OTHER RESOURCES: Lecture 2 slideshow; Lecture 3 slideshow; Bioinformatics Session 1 slideshow;

BACKGROUND READINGS BY PROJECT:
- *PROJECT Cell Adhesion;*
- *PROJECT Eyesight;*
- *PROJECT Heat Shock;*
- *PROJECT Oxidative Stress;*
- *PROJECT Sex Determination;*
- *PROJECT TNFR*

Thursday, January 26
LECTURE 4
- Architecture of the Genome

BIOINFORMATICS SESSION 2
- BLAST searches of the NCBI Protein Database

READINGS: Lecture 4 handout, Bioinformatics Session 2 handout;
ADDITIONAL RESOURCES: Lecture 4 slideshow, Bioinformatics Session 2 slideshow;

Tuesday, January 31
LECTURE 5
- Evolution of DNA Sequencing

BIOINFORMATICS SESSION 3
- Work with your small groups to compile the dataset you will use for phylogenetic and molecular evolutionary analyses.

READINGS: Lecture 5 handout,
ADDITIONAL RESOURCES: Lecture 5 slideshow,

Background Reading:

- Shendure J, Ji H. (2008) Next-generation DNA sequencing. *Nature Biotechnology* **26**, 1135 - 1145.
- Maxam AM, Gilbert W (1977) A new method for sequencing DNA. *PNAS* **74** (2): 560–4.
- Sanger F, Nicklen S, Coulson AR (1977). DNA sequencing with chain-terminating inhibitors. *Proc. Natl. Acad. Sci. U.S.A.* **74** (12): 5463–7.
- Luckey JA, et al. (1990) High speed DNA sequencing by capillary electrophoresis. *Nucleic Acids Research*. **18**, 4417-4421.

Thursday, February 2

LECTURE 6

- Gene Expression and Gene Function

JOURNAL CLUB 1

- van Dijk et al., (2018) The Third Revolution in Sequencing Technology. *Trends in Genetics*. 34: 666-681

LABORATORY RESEARCH PLANNING SESSION 1

- Introduction to laboratory research projects and formation of research teams
- PROTOCOL: Pipetting Basics
- PROTOCOL: DNA Isolation

READINGS:

- Lecture 6 handout,
- van Dijk et al., (2018)
- Laboratory Research Planning Session handout
- Protocol—Pipetting Basics handout
- Protocol—DNA Isolation handout

ADDITIONAL RESOURCES:

- Lecture 6 slideshow,
- Protocol—Pipetting Basics slideshow
- Protocol—DNA Isolation slideshow

Tuesday, February 7

LABORATORY RESEARCH SESSION 1

- DNA Isolation

Thursday, February 8

LABORATORY RESEARCH SESSION 2

- DNA Isolation
- Spectrophotometric analysis of DNA purity and concentration

READINGS:

- Protocol—Spectrophotometric Analysis of DNA handout

ADDITIONAL RESOURCES:

- Protocol—Spectrophotometric Analysis of DNA handout slideshow

Tuesday, February 14

"LAB MEETING"

- Review of results from DNA Extraction

MOLECULAR EVOLUTION RESEARCH SESSION

- PROTOCOL: Detection of conserved protein motifs using MEME

READINGS:
- Protocol—Motif Detection handout

ADDITIONAL RESOURCES:
- Protocol—Motif Detection slideshow
- Sample MEME input data

Thursday, February 16

JOURNAL CLUB 2
- Hebert et al., (2003) Biological Identifications Through DNA Barcodes. Proc Roy Soc. 270:313-321

REVIEW OF PROTOCOL
- PCR

LABORATORY RESEARCH SESSION 3
- DNA Barcoding

READINGS:
- Hebert et al., (2003) Biological Identifications Through DNA Barcodes. Proc Roy Soc. 270:313-321
- Protocol—PCR handout

ADDITIONAL RESOURCES:
- Protocol—PCR slideshow

Tuesday, February 21

NO CLASS — Substitute Monday Schedule

Thursday, February 23

REVIEW OF PROTOCOL
- Electrophoresis

LABORATORY RESEARCH SESSION 4
- Electrophoretic analysis of DNA barcoding experiments

READINGS:
- Protocol—Electrophoresis HANDOUT
- Step-by-Step Protocol—Electrophoresis

ADDITIONAL RESOURCES:
- Protocol—PCR SLIDESHOW

Tuesday, February 28
JOURNAL CLUB 3
- Camp et al. (2020) Corals exhibit distinct patterns of microbial reorganisation to thrive in an extreme inshore environment. Coral Reefs 39: 701-716.
- Scavo Lord et al. (in prep) Microbiome varies by species and environment in two widespread Caribbean corals (*Porites astreoides* and *Siderastrea siderea*) from mangrove and lagoon habitats [a collaboration of students from BI550 (2021) and BI569 (2019 & 2021)]

LAB MEETING / Review the Barcoding Results
MOLECULAR EVOLUTION RESEARCH SESSION
- Group meetings with John & Jordan

READINGS:
- Camp et al. (2020)
- Scavo Lord et al. (2022; in prep)

Thursday, March 2
REVIEW OF PROTOCOL
- 16S-based Bacterial Metagenomics

LABORATORY RESEARCH SESSION 5
- 16S-based bacterial metagenomics

READINGS:
- Protocol—16S-based Bacterial Metagenomics HANDOUT

March 4 — March 12 SPRING BREAK

Tuesday, March 14
LABORATORY RESEARCH SESSION 6
- 16S-based bacterial metagenomics

Thursday, March 16
EXAMPLE PRESENTATION
MOLECULAR EVOLUTION PROJECTS
- Convene with your groups and work on your project.
- Each group will meet individually with John and Jordan.

READINGS:
- Example Presentation Version 01

Tuesday, March 21
LABORATORY RESEARCH SESSION 7
- Optimize metabarcoding protocol: 16S ribosomal DNA PCRs

MOLECULAR EVOLUTION PROJECTS
- Use MAST to scan transcripts from coral transcriptomes for previously identified motifs.

READINGS:
- Bioinformatics Protocol — Motif Scanning Using MAST (handout)

OTHER RESOURCES:
- Bioinformatics Protocol — Motif Scanning Using MAST (slideshow)

Thursday, March 23
Lecture 7. Molecular Evolution and the Development of Population Genomics Markers
MOLECULAR EVOLUTION PROJECTS
- Convene with your group. Meet with John and Jordan.

READINGS:
- Lecture 7 handout.
- Original References:
  - Origin of RFLP Approach: Potter et al. (1975) Proc Natl Acad Sci USA
  - Origin of AFLP Approach: Vos et al. (1995) Nucl Acids Res
  - Origin of RAPD Approach: Williams et al. (1990) Nucl Acids Res
  - Origin of Microsatellite Approach: Weber & May (1989) Am J Human Genetics
  - Origin of 2bRAD Approach: Wang et al (2012) Nat Methods

OTHER RESOURCES:

- Lecture 7 slideshow

Tuesday, March 28
LABORATORY & COMPUTATIONAL RESEARCH

Thursday, March 30
LABORATORY & COMPUTATIONAL RESEARCH

Tuesday, April 4
LABORATORY & COMPUTATIONAL RESEARCH

Thursday, April 6
LABORATORY & COMPUTATIONAL RESEARCH

Tuesday, April 11
LABORATORY & COMPUTATIONAL RESEARCH

Thursday, April 13
LABORATORY & COMPUTATIONAL RESEARCH

Tuesday, April 18
LABORATORY & COMPUTATIONAL RESEARCH

Thursday, April 20
LABORATORY & COMPUTATIONAL RESEARCH

Tuesday, April 25
DATA ANALYSIS & TALK PREPARATION

Thursday, April 27
DATA ANALYSIS & TALK PREPARATION

Tuesday, April 25
CLASS PRESENTATIONS ON MOLECULAR EVOLUTION RESEARCH PROJECTS