Marine Microbial Ecology MEES684

The course will be taught at the Institute of Marine and Environmental Technology or the Horns Point Laboratory. The course will also be taught entirely over Zoom.

Course Instructors:

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Course Description:

This course presents a survey of marine microbial ecology, proceeding from seminal discoveries and the development of widely used molecular tools to current advances. The course will cover a suite of microorganisms, with particular emphasis on bacteria (including cyanobacteria), archaea, micro-eukaryotes, and viruses. Students will become familiar with their population dynamics, genetic diversity, ecological interactions, microscale processes, and biogeochemical cycling in marine environments. The class will involve lectures; reading and discussion of primary scientific literature and published reviews. Students will demonstrate mastery of course material by leading class discussions of primary literature, participation in class discussions, and preparing a term paper and oral presentation. A background in molecular microbiology is not required.

Class Schedule:

Classes are taught over Zoom on Tuesday and Thursday from 11:00 am to 12:30 pm Eastern Time. Typically, instructors or guest lecturers will give a lecture on Tuesday, and student presentations of the literature, followed by student-led discussions on Thursday. A detailed class schedule and paper selection will be available a week before the class.

Expected Learning Outcomes:

1. Students will become familiar with marine microorganisms, their biogeochemical activities and energetic constraints, and their ecological roles in marine environments through lectures and from reading and discussion of primary scientific literature and published reviews.

2. Students will demonstrate mastery of course material by leading class discussions of primary literature and participating in class discussions. Every opportunity will be provided for all students to actively participate in the discussion and students are strongly encouraged to comment on the strengths and weaknesses of the papers discussed in this class.

3. Students will learn how to read research articles critically and write a comprehensive review in a specific research field. At the end of class, students will share what they learn through term paper writing to classmates. Students will learn how to give a formal oral presentation. We believe that the best way to learn is to teach someone else.

Grading:

Paper presentations (20%)
Sending out reading questions to the class (10%)
Answer the reading questions (10%)
Class participation (10%)
Term paper (40%)
Final oral presentation on a term paper (10 min) (10%)

Paper Presentation (20%)

Each week, a student will present a seminar on two papers on a related topic. Dates for paper presentations will be determined in the first week of class. The presentation will include a general introduction to the topic covered, a detailed explanation of the methods employed in the paper, a detailed examination of the results described in papers, a discussion of the significance of the work, and a critique of the strengths and weaknesses of the papers. The presenting student should cover background material and additional details of methods by doing supplementary reading as necessary. They will also lead a class discussion. All students are expected to read all discussion papers and participate in class discussions on the topic.

Sending out reading questions to the class (10%)

The presenting student will be required to email the class 2-3 reading questions related to the presenting papers a week before the presentation.

Answer the reading questions (10%)

All students will be required to answer reading questions raised by presenting students and email answers to the instructors and presenter before the class.

Participation (10%)

Students will be encouraged to actively participate in class discussion, which includes raising and answering questions, sharing opinions, and commenting on the papers and/or lecture material.

Term Paper (40%)

Students are expected to write a mini-review (maximum 2500 words, excluding references) on an interesting subject in marine microbial ecology. The term paper should be written with double spacing and font size 12. The topic should be chosen by the student in discussion with a course instructor and can be adjacent to the student's thesis work, but not the identical subject.

At least 10 papers related to the topic should be carefully read and synthesized. Students should consider what is exciting and novel about the research and make clear how the papers advance our understanding of the topic. We are looking for an integrated understanding of the topic, rather than a summary of collected papers. Topics on controversial issues are encouraged. Your review should also identify what important questions still need to be answered.

There will be three steps in the development of your term paper. The topic should be identified during the first month of class, by Mar 1, 2024, in discussion with a course instructor. By Mar 15, 2024, an annotated bibliography will be submitted to the course instructor. The bibliography will present 10 key references, and a short paragraph (4-5 sentences) describing the content of the reference. The final paper is due 19 April, 2024. The term paper is mandatory, and must be completed at the scheduled time, subject to standard university guidelines. Makeup assignments as allowed by the university must be requested (in writing) within one week of the missed assignment.

The final will be graded on the following criteria:

Completion of the annotated bibliography /5

Provides a compelling overview of the topic /5

Addresses what is exciting and novel about the research and how the papers advance our understanding /5

Correct citation of papers /5

Paper is clearly structured /5

Correct use of references /5

Paper is grammatically correct /5

Paper is formatted as requested /5

Final oral presentation based on the term paper (10%)

Students are required to give an oral presentation based on their research project. The oral presentation includes a 10 minute PowerPoint presentation (plus 5 minutes for questions). Students should present background, questions, approaches, data, and summary.

The presentation will be based on the following criteria:

Slides /4
Do the slides have an appropriate amount of text on them? Are the figures clear to the audience?

Content /3
Does the presentation convey the main aspects of the report (background, questions, approach, data, and summary) in a way that is clear?

Quality /3
Does the presenter speak slowly and clearly, while remaining under the time limit?

Course Evaluation

At the end of the course, students are strongly encouraged to complete the online process facilitated by the MEES Graduate Program to provide anonymous feedback to the instructors on our course. This feedback is extremely valuable for planning and preparing for future classes. Time will be allocated at the end of the course for a general discussion led by students for improving the course in future years.

Topics and Course Schedule for Spring 2024 (at a glance)

Week	Topic	Date	Activities	Instructor
1	Course Meeting/paper selection	Tu Jan 25	Course meeting	Feng Chen & Jacob Cram
	Introduction to Microbial Ecology	Th Jan 27	Lecture Due: Sign up for a paper discussion	Feng Chen & Jacob Cram
2	Isolation of marine microbes – culture the "unculturable"	Tu Feb 1	Lecture	Feng Chen
		Th Feb 3	Paper discussion	
3	Phototrophy, heterotrophy and mixotrophy	Tu Feb 8	Lecture	Feng Chen Nayani Vidyarathna
		Th Feb 10	Paper discussion	
4	Protists, dinoflagellates, and phytoplankton	Tu Feb 15	Lecture	Allen Place ?Sarah Hu (Texas A&M)
		Th Feb 17	Paper discussion	
5	Marine viruses and their ecological role	Tu Feb 22	Lecture	Feng Chen
		Th Feb 24	Paper discussion	
6	Oxygen Minimum Zones	Tu Mar 1	Lecture Due: Select topic for final project	Clara?

		Th Mar 3	Paper discussion	Jacob Cram
7	Biogeography	Tu Mar 8 Th Mar 10	Lecture Paper discussion	Jacob Cram
8	Particulate Organic Matter and the Biological Pump	Tu Mar 15 Th Mar 17	Lecture Due Mar 15: Annotated bibliography Paper discussion	TBD
9	Spring break March 20-27			Jacob Cram
10	Microscale Processes	Tu Mar 28 Th Mar 31	Lecture Analysis Workshop Paper discussion	Jacob Cram
11	Deep Biosphere	Tu Apr 5 Th Apr 7	Flipped Lecture Analysis Workshop Paper discussion	Guest Lecture
12	Marine carbon cycling	Tu Apr 12 Th Apr 14	Lecture Paper discussion	Guest Lecture
13	Marine Nutrient cycling	Tu Apr 19 Th Apr 21	Lecture Paper discussion	Guest Lecture
14	Marine Animal Microbiomes	Tu Apr 26	Lecture	Guest Lecture
		Th Apr 28	Paper discussion Due Apr 28: Final research report	

15	Oral presentations	Tu May 3 Th May 5	Oral presentations Oral presentations	Feng Chen/Jacob Cram Feng Chen/Jacob Cram
16	Last class	Tu May 10	Course evaluation	

Topics and Reading List

Weeks 1: Introduction to marine microbial ecology

Course meeting (January 25): First class meeting, syllabus review, paper selection and assignment, a brief overview on marine microbial ecology.

Lecture (January 27 by Feng Chen and Jacob Cram): history of microbial ecology, great plate count anomaly, types of microbes; microbial loop.

Required background reading: Books: Microbial Ecology of the Oceans, ed. David Kirchman 2008 or ed. Josep Gasol and David Kirchman 2018. Chapter 1 provides a good introduction. The ebook by Gasol and Kirchman 2018 can be downloaded from UMD WorldCat.

Week 2: Isolation of marine microbes – culture the "unculturable"

Lecture (Feb 8, by Feng Chen) and topics: Microbial cell counting, culture media, low growth efficiency, importance of microbial cultivation.

Required background reading: Carini P. 2019. A "cultural" renaissance: genomics breathes new life into an old craft. mSystems 4:e00092-19. https://doi.org/10.1128/mSystems.00092-19

Paper discussion (Feb 10):

(1) Rappé, M., Connon, S., Vergin, K. *et al.* 2002. Cultivation of the ubiquitous SAR11 marine bacterioplankton clade. *Nature* 418: 630–633. https://doi.org/10.1038/nature00917
(2) Jung, D., B.Y. Liu, X.P. He, J.S. Owen, L.W. Liu, Y. Yuan, W.Y. Zhang, S. He. 2021. Accessing previously uncultured marine microbial resources by a combination of alternative cultivation methods. *Microbial Biotechnology* 14:1148– 1158, doi:10.1111/1751-7915.13782

Week 3: Phototrophy, heterotrophy and mixotrophy

Lecture (Feb 15, by Feng Chen) and topic: cyanobacteria, picocyanobacteria, AAnP and proteorhodopsin-containing prokaryotes.

Required background reading:

Abby Olena 2019. Oceanic bacteria trap vast amounts of light without chlorophyll. The Scientist.

Paper discussion (Feb 17):

(1) Cruz and Neuer 2019. Heterotrophic bacteria enhance the aggregation of the marine picocyanobacteria *Prochlorococcus* and *Synechococcus.* Frontiers in Microbiology, https://doi.org/10.3389/fmicb.2019.01864

(2) Gomez-Consarnau et al. 2019. Microbial rhodopsins are major contributors to the solar energy captured in the sea. *Sci. Adv.* 5, eaaw8855.

Week 4: Protists, dinoflagellates and phytoplankton

Lecture (Feb 22, by Dr. Allen Place) and Topics: Protist grazing, phytoplankton, harmful algal blooms, picoeukaryotes

Required background reading:

Burki et al. 2020. The new tree of eukaryotes. Trends in Ecology & Evolution, https://doi.org/10.1016/j.tree.2019.08.008

Paper discussion (Feb 24):

(1) Cordier T, Angeles IB, Henry N, Lejzerowicz F, Berney C, et al. 2022. Patterns of eukaryotic diversity from the surface to the deep-ocean sediment. Sci Adv. Feb 4;8(5):eabj9309. DOI: 10.1126/sciadv.abj9309

(2) Anderson, S.I., Barton, A.D., Clayton, S. *et al.* Marine phytoplankton functional types exhibit diverse responses to thermal change. *Nat Commun* **12,** 6413 (2021). https://doi.org/10.1038/s41467-021-26651-8

Week 5: Marine viruses and their ecological role

Lecture (March 1, by Feng Chen) and Topics: virioplankton, bacteriophage, algal viruses, giant viruses

Required background reading:

Curtis Suttle, 2005. Viruses in the sea. Nature, doi:10.1038/nature04160

Discussion papers (March 3):

(1) Zhao, Y., Temperton, B., Thrash, J. *et al.* 2013. Abundant SAR11 viruses in the ocean. *Nature* 494, 357–360. https://doi.org/10.1038/nature11921

(2) Gregory et al., 2019, Marine DNA viral macro- and microdiversity from pole to pole. Cell 177, 1109–1123, https://doi.org/10.1016/j.cell.2019.03.040

Week 6: Oxygen Minimum Zones

Lecture: Large regions of the oligotrophic ocean harbor no or zero oxygen. In these regions microorganims can mediate chemical transformations such as anammox and dentitrification that are not seen elsewhere.

Required background reading: (TBD)

Paper discussion: (TBD)

Week 7: Biogeography

Lecture By Jacob Cram**:** Topics: Why are some microbes found only in certain environments. We will look at how environmental factors, along with historical factors, such as which organisms arrive in an environment in a certain order drive patterns in beta-diversity. We will touch on neutral theory.

Required background reading:

Martiny JBH, Bohannan BJM, Brown JH, Colwell RK, Fuhrman JA, Green JL, et al. Microbial biogeography: putting microorganisms on the map. Nat Rev Micro. 2006 Feb; 4(2):102–12.

In class: Work on research projects.

Paper Discussion:

(1) Fuhrman JA, Steele JA, Hewson I, Schwalbach MS, Brown MV, Green JL, et al. A latitudinal diversity gradient in planktonic marine bacteria. Proceedings of the National Academy of Sciences. 2008 May; 105(22):7774–8.

(2) Nelson CE, Carlson CA, Ewart CS, Halewood ER. Community differentiation and population enrichment of Sargasso Sea bacterioplankton in the euphotic zone of a mesoscale mode-water eddy. Environ Microbiol. 2014 Mar 1; 16(3):871–87.

Week 8: Spring break

Week 9: Particulate organic matter and the biological pump

Lecture by Jacob Cram: Topics: Marine particles, such as aggregates of dead phytoplankton and fecal pellets from zooplankton, form in surface waters. Some of these sink into or through the mesopelegic zone, effectively transporting carbon from the atmosphere into the deep ocean. We will explore how particulate-associated bacteria interact with their host particles and regulate the biological pump.

Required background reading:

Herndl GJ, Reinthaler T. Microbial control of the dark end of the biological pump. Nature Geosci. 2013 Sep; 6(9):718–24.

Azam F. Microbial Control of Oceanic Carbon Flux: The Plot Thickens. Science. 1998 May 1; 280(5364):694–6.

Simon M, Grossart H, Schweitzer B, Ploug H. Microbial ecology of organic aggregates in aquatic ecosystems. Aquat Microb Ecol. 2002 Jun 26; 28(2):175–211.

Paper Discussion:

Smith D, Simon M, Alldredge A, Azam F. Intense Hydrolytic Enzyme-Activity on Marine Aggregates and Implications for Rapid Particle Dissolution. Nature. 1992 Sep 10; 359(6391):139–42.

Mestre M, Ruiz-González C, Logares R, Duarte CM, Gasol JM, Sala MM. Sinking particles promote vertical connectivity in the ocean microbiome. PNAS. 2018 Jun 27; 201802470.

Fontanez KM, Eppley JM, Samo TJ, Karl DM, DeLong EF. Microbial community structure and function on sinking particles in the North Pacific Subtropical Gyre. Front Microbiol [Internet]. 2015 May 19 [cited 2020 Jan 28]; 6. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4436931/

Week 10: Microscale processes

Lecture by Jacob Cram. Topics: Microorganisms live in environments that are heterogeneous at microscopic scales. We will explore how planktonic bacteria take advantage of microscopic environments and are affected by microscale phenomena.

Required background reading:

Azam F, Malfatti F. Microbial structuring of marine ecosystems. Nat Rev Micro. 2007 Oct;5(10):782–91.

Stocker R. Marine Microbes See a Sea of Gradients. Science. 2012 Nov 1;338(6107):628–33.

Seymour JR, Marcos, Stocker R. Resource Patch Formation and Exploitation throughout the Marine Microbial Food Web. The American Naturalist. 2009 Jan 1;173(1):E15–29.

In class: Work on research projects.

Discussion papers:

Seymour JR, Seuront L, Doubell M, Waters RL, Mitchell JG. Microscale patchiness of virioplankton. J Mar Biol Ass. 2006 Apr;86(03):551.

Ebrahimi A, Schwartzman J, Cordero OX. Cooperation and spatial self-organization determine rate and efficiency of particulate organic matter degradation in marine bacteria. Proceedings of the National Academy of Sciences. 2019 Nov 12;116(46):23309–16.

Week 11: Modeling microbial dynamics:

Guest lecture (TBD): Much can be learned about microorganims and their role in the environment by simulating how they might behave on computers. We will explore some of the advances in microbial ecological and biogeochemical modeling.

Reading TBD

Discussion paper TBD:

Week 12: Marine carbon cycling

Microbes and ocean carbon cycling - DOM

Lecture (April 19, by TBD) and topic: Microbial loop, biological pump, microbial carbon pump, ocean carbon cycling, dissolved organic carbon, microbial degradation

Required background reading: Moran, M.A., Elizabeth B. Kujawinski, Aron Stubbins, Rob Fatland, Lihini I. Aluwihare, et al. 2016. Deciphering ocean carbon in a changing world. PNAS 113 (12) 3143-3151; https://doi.org/10.1073/pnas.1514645113

Paper discussion (April 21):

Hansen et al. 2019. Biodegradability of hydrothermally altered deep-sea dissolved organic matter, Marine Chemistry 217, https://doi.org/10.1016/j.marchem.2019.103706.

Brandon Kieft, Zhou Li, Samuel Bryson, Robert L. Hettich, Chongle Pan, Xavier Mayali, Ryan S. Mueller. Phytoplankton exudates and lysates support distinct microbial consortia with specialized metabolic and ecophysiological traits. *Proceedings of the National Academy of Sciences*, 2021; 118 (41): e2101178118 DOI: 10.1073/pnas.2101178118

Week 13: Marine Nitrogen Cycle

Lecture (April 26 by TBD) and topics: focus will be on gains of N to the marine environment; distribution of nitrogen phases in the ocean; bioenergetics of N-fixation; diversity and ecology of N-fixing bacteria, pathways and bioenergetics of chemoautotrophic nitrification

Required background reading: Sohm and Webb and Capone. 2011. Emerging Patterns of Marine Nitrogen Fixation. *Nature Reviews Microbiology* 9: 499-508

Discussion Papers:

(1) Zehr et al. 2016. Unusual marine unicellular symbiosis with the nitrogen-fixing cyanobacterium UCYN-A. *Nature Microbiol*. 2: article 16214. (10 pages) doi: 10.1038/nmicrobiol.2016.214

(2) Moisander, P.H., M. Benavides, S. Bonnet, I. Berman-Frank, A.E. White, L. Riemann. Chasing after Non-cyanobacterial Nitrogen Fixation in Marine Pelagic Environments. *Frontiers in Microbiology* 8: article 1736. doi: 10.3389/fmicrb.2017.01736

Week 14: Marine Animal Microbimes and Microbial Associations

Lecture (April 26 by TBD) and topics: Many microorganisms in the ocean live in or on marine animals for at least some portion of their life-cycle. Therefore we will explore animals as microbial environments and explore how interactions between animals and microorganisms might drive chemical cycles in the ocean.

Week 15: Oral Presentations

Week 16: Last Class