

12.739 - Marine Microbiology and Biogeochemistry Fall, 2017

Instructors:

Amy Apprill, WHOI MC&G, Office: Fye 116, aapprill@whoi.edu, x2649
Stefan Sievert, WHOI Biology, Office: Watson 207, ssievert@whoi.edu, x2305

Course TA: Jen Karolewski
Office: Clark 403, x4819

Course Meetings:

Tuesdays & Thursdays, 2:30 – 4:00 pm
Clark 331, with MIT video link 54-823

Course Website: <https://stellar.mit.edu/S/course/12/fa17/12.739/>

Recitation: Weekly, TBD

Course Overview:

This course is an integration of the fields of microbiology and biogeochemistry, and is centered on interchange between organisms and geochemical processes in the oceans. The course is broken into modules that first lay the theoretical framework to familiarize students with the subjects and the major tools and techniques in the field, followed by specific and general linkages between these topics. The course concludes with a synthesis module in which students will examine ocean microbial biogeochemistry data, create a specific project on the data and present their findings.

Student Learning Objectives:

- 1) Define the major types of microorganisms present in the ocean, the features that distinguish each type, and the factors and processes controlling microbial abundances and growth in the oceans.
- 2) Understand the fundamental biogeochemical cycles in the ocean, and recognize how general and specific microorganisms influence these cycles.
- 3) Explain how the above features vary within different ocean biomes and how they might be impacted by global change.
- 4) Demonstrate an appreciation for the technologies and methodologies that have advanced the study of microbial biogeochemistry.

Prerequisites:

No formal prerequisites exist. However, the course is most suitable for students who have completed their first year of coursework, and have a general introduction to the field of oceanography (completion of Biological Oceanography or Marine Chemistry).

Course Format:

Students will be responsible for 1-2 readings prior to each lecture. Students are encouraged to ask questions and participate in the lecture. Each week, the course will

allow for ~30 minutes of student-led journal club on articles related to the lecture material. Journal readings will be assigned prior to each meeting (as part of the assigned readings), and students are responsible for reading the articles and participating in a group discussion of the material.

Homework:

There are no formal homework assignments. However, students are responsible for leading paper discussions (2 each) as well as general class participation.

Exams:

Students will be formally tested on the material presented in modules I and II (lectures and journal readings) with two in-class examinations.

Student Synthesis and Teaching Presentation:

Students will be responsible for synthesizing and teaching the material for Module III, 'Microbiomes and Biogeochemistry of Marine Ecosystems'. At the beginning of the course, each student will choose an ocean biome and asked to utilize course and literature resources to synthesize an understanding of how microorganisms play a role in the biogeochemical cycles of that biome. Students will prepare a 5-page written report of this material, presented as a review-type manuscript. Additionally, students will prepare a 10-minute teaching lecture on the material for the course. Please discuss your chosen ocean biome with the course instructors prior to **Thursday, October 19**. Possible biomes include but are not limited to: oligotrophic oceans, coastal upwelling zones, oxygen minimum zones, estuaries, sediments, hydrothermal vents and cold seeps, seafloor, polar oceans, and coral reefs. The written report is due **Thursday, November 21**. Oral presentations will occur over **November 28 – December 14**.

Grading:

Participation and leading paper discussions (20%)

Examinations (40%)

Written synthesis review (20%)

Teaching presentation (20%)

Course Material:

As there is no comprehensive textbook for this course, we will utilize a combination of different resources to form the readings for this course. Course readings will be available on the course Stellar site (<https://stellar.mit.edu/S/course/12/fa17/12.739/>). If you would like to purchase a textbook for the course, we will draw a number of readings from the following two books:

1. Processes in Microbial Ecology by David L. Kirchman, 2012, Oxford University Press.
2. Microbial Ecology of the Oceans, edited by David L. Kirchman, 2008. John Wiley & Sons Press.

Lecture Schedule:

Module I: Marine microbial diversity, cellular function and physiology, key players and functional analyses

Sept. 12 (Tues, Aprill & Sievert): Course introduction, Foundations of microbial oceanography, Overview of marine biogeochemistry

Readings:

- *Sea of Microbes magazine*, Foundations of Microbial Oceanography (Ch. 1) & The Microbial Loop (Ch. 2)

Sept. 14 (Thurs, Sievert): Basic cellular construction & physiology of prokaryotes and eukaryotes and Thermodynamics and microbial metabolism

Readings:

- *Kirchman 3rd* Elements, biochemical, and structure of microbes
- *Canfield et al* Thermodynamics and microbial metabolism

Sept. 19 (Tues, Aprill): Approaches to study microbial diversity and functions

Reading:

- *Kirchman 3rd*, Ch. 9: Community structure of microbes in natural environments

Discussion papers:

Sogin, M.L., Morrison, H.G., Huber, J.A., Welch, D.M., Huse, S.M., Neal, P.R., et al. Microbial diversity in the deep sea and the underexplored "rare biosphere". PNAS. 2006; 103(32):12115-20.

Gibbons, S.M., Caporaso, J.G., Pirrung, M., Field, D., Knight, R. and Gilbert, J.A., 2013. Evidence for a persistent microbial seed bank throughout the global ocean. *Proceedings of the National Academy of Sciences*, 110(12), pp.4651-4655.

Sept. 21 (Thurs Aprill): Photosynthetic bacteria & phytoplankton

Reading:

- *Kirchman 3rd*, Ch. 4: Microbial primary production and phototrophy

Sept. 26 (Tues, Sievert): Hetero- and autotrophic bacteria & archaea

Readings:

- *Kirchman 2nd* Bacterial and archaeal community structure and its patterns

Discussion papers:

SW Chisholm, RJ Olson, ER Zettler, R Goericke, J Waterbury, and N Welschmeyer. A novel free-living prochlorophyte abundant in the oceanic euphotic zone. *Nature* 1988, 334(6180): 340-343.

Könneke, M. et al. Isolation of an autotrophic ammonia-oxidizing marine archaeon. *Nature* 2005, 437: 543-546

Sept. 28 (Thurs, Sievert): Viruses and Protists

Readings:

- *Kirchman 2nd* Ch 12: Marine viruses: community dynamics, diversity, and impact on microbial processes
- *Kirchman 2nd* Ch 11 Protistan grazing on marine bacterioplankton

Oct. 3 (Tues, Apprill): Metagenomics

Readings:

- *Kirchman 2nd*, Ch4: Genomics and metagenomics of marine prokaryotes

Discussion papers:

Shi, Y., Tyson, G.W., Eppley, J.M. and DeLong, E.F., 2011. Integrated metatranscriptomic and metagenomic analyses of stratified microbial assemblages in the open ocean. *The ISME journal*, 5(6), p.999.

Dupont, C.L. et al. 2012. Genomic insights to SAR86, an abundant and uncultivated marine bacterial lineage. 6: 1186-1199.

Oct. 5 (Thurs, Elizabeth Kujawinski): Metabolomics

Readings: TBA

Oct. 10 (Tues): HOLIDAY - NO CLASS

Oct. 12 (Thurs, Mak Saito): Proteomics and Metaproteomics

Readings: TBA

Oct. 17 (Tues, Sievert): Linking identity with function: Isotopes and visualization of microorganisms and their cellular properties and products

Readings:

- *Madsen* Generating and interpreting information in environmental microbiology: Methods and their limitations

Module II: Microbial roles in the major marine biogeochemical cycles

Oct. 19: (Thurs, Apprill): Microbial food webs I (Photic zone; includes DOM)

Readings:

- *Kirchman 2nd*, Ch 2: Understanding roles of microbes in marine pelagic food webs: A brief history
- *Kirchman 2nd*, Ch 10: Resource control of bacterial dynamics in the sea

Oct. 24: Exam I (administered by Jen)

Oct. 26 (Thurs, Babbin): Nitrogen I

Readings:

- *Kirchman 3rd* The nitrogen cycle

Oct. 31 (Tues, Karolewski) Nitrogen II

Discussion paper:

Thompson, A.W., Foster, R.A., Krupke, A., Carter, B.J., Musat, N., Vaultot, D. et al. (2012) Unicellular Cyanobacterium Symbiotic with a Single-Celled Eukaryotic Alga. *Science* **337**: 1546-1550.

Nov. 2 (Thurs, Sievert): Microbial food webs II (Aphotic zone & sediments, includes symbiosis)

Readings:

- Herndl et al., 2008. Regulation of aquatic microbial processes: the 'microbial loop' of the sunlit surface waters and the dark ocean dissected. *Aquatic Microbial Ecology*, 53: 59-68

Discussion papers:

Pomeroy, L.R. 1974. The Ocean's Food Web, A changing Paradigm. *Bioscience* 24: 499-504.

Teeling et al. 2012. Substrate-Controlled Succession of Marine Bacterioplankton Populations Induced by a Phytoplankton Bloom, *Science* 366: 608-611

Nov. 7 (Tues, Sievert): Sulfur

Readings:

- *Sievert et al* The sulfur cycle
- *Canfield et al* The sulfur cycle

Nov. 9 (Thurs, Sievert): Phosphorous, oxygen, metals, silicon

Readings:

- *Dyhrman et al* Microbes and marine phosphorus cycle
- *Canfield et al* The silicon cycle
- *Canfield et al* The iron and manganese cycle

Discussion paper:

Milucka et al., 2012. Zero-valent sulphur is a key intermediate in marine methane oxidation. *Nature* 491: 541-546

Nov. 14 (Tues): **EXAM II**

Module III: 'Microbiomes and Biogeochemistry of Marine Ecosystems'

Nov. 16 (Thurs): Guest lecture by Mick Follows (tbd)

Nov. 21 (Tues, Sievert): Biomes 1 (vents)

Nov. 23 (Thurs): **HOLIDAY – NO CLASS**

Nov. 28 (Tues, Apprill): Biomes 2 (Marine animal microbiomes)

Nov. 30 (Thurs):

Dec. 5 (Tues):

Dec. 7 (Thurs):

Dec. 12 (Tues):

Dec. 14 (Thurs):