SIO 123, Microbial Environmental Systems Biology

Environmental systems biology is the study of the genomic basis for patterns of microbial diversity and adaptation in relation to habitat. This course introduces the microbial genome as a unit of study and surveys introductory principles in microbial genomics and bioinformatics that underlay a range of contemporary research in diverse marine habitats, such as the deep sea and polar regions, as well as studies of biomedical importance including the human microbiome**.** Three hours of lecture and one hour of recitation. ***Prerequisites****:* BILD 1 or 2, or ESYS 101, or equivalent coursework in cell biology, biochemistry, or genetics, or consent of instructor.

Grading

1) 25% class participation
2) 15% final exam
3) 30% 2 (2-3 page papers) (pick any 2 topics below)
4) 30% 1 (4-6 page paper)

Key Dates

Short Papers (2-3 pages)
1) Friday October 7 (group 1), Friday October 14 (group 2), Friday October 21 (group 3)
2) Friday October 28 (group 1), November 4 (group 2), Friday November 11 (group 3)
Longer Paper (4-6 pages) paper due, Friday December 2 (proposed topic due Friday October 31)

Friday Presentations and Short Papers **(*Short papers can be on 2 of any of the 9 Friday topics and associated papers)*. Complete course reading list (PDFs) are organized by topic on TED.**

1. **Biogeography Distribution Ecology**
2. **Sar11 (or heterotrophic bacterioplankton)**
3. **Prochlorococcos (or photosynthetic microbes)**
4. **Metagenomics**
5. **Single Cell Genomics**
6. **Metatranscriptomics**
7. **Proteomics**
8. **Nitrogen Cycle Related and Metabolomics**
9. **Phytoplankton Bacteria Networks Linkages**

Week 1 (Friday September 19)

F: Marine Environmental Systems Biology Introduction

Week 2 (September 26)

M: Darwin-Pasteur-Koch (Natural Selection, Microbiology)
W: Woese-Venter II (rRNA diversity, evolution and bacterial genomics)
F: Reading/Presentation **(group A)**: Biogeography Distribution Ecology

Week 3 (Monday October 3)

M: Microbial Oceanography (concepts and background)

W: Ecological Genomics (Prochlorococcus)

F: Reading Presentation **(group B)**: Sar11 (heterotrophic bacterioplankton) ***short paper due*(group 1)**

Week 4 (Monday October 10)

M: Ecological Genomics (SAR11)

W: Metagenomics

F: Reading/Presentation **(group C)**: Prochlorococcus (microalgae) ***short paper due*(group 2)**

Week 5 (Monday October 17)

M: Metagenomics (GOS)

W: Ecological Genomics (TARA Oceans)

F: Reading/Presentation **(group D)**: Metagenomics ***short paper due*(group 3)**

Week 6 (Monday October 24)

M: Ecological Genomics (TARA Oceans Cont'D)

W: Eukaryotes

F: Reading /Presentation **(group E)**: Single Cell Genomics***short paper due*(group 1)**

Week 7 (Monday October 31)

M: Functional Genomics

W: Proteomics

F: Reading/Presentation **(group F)**: Metatranscriptomics***short paper due*(group 2)**

Week 8 (Monday November 7)

M: Metabolomics, Genomics and Nitrogen Biogeochemistry

W: Genomics and Nitrogen Biogeochemistry

F: (Veterans Day Holiday) ***short paper due*(group 3)**

Week 9 (Monday November 14)

M: Networks and Linkages

W: Networks and Linkages

F: Reading/Presentation **(group G)**: Proteomics

Week 10 (Monday November 21)

M: Systems biology and functional genomics in diatoms

W: Systems biology and functional genomics in diatoms cont'd

F: Happy Thanksgiving!!

Week 11 (Monday November 28)

M: Environmental Genomics of Southern Ocean Microbes

W: Deep Sea/Hydrothermal Vent Environmental Genomics

F: Reading/Presentation **(group H)**: Nitrogen Cycle Related and Metabolomics or Phytoplankton Bacteria Networks and Linkages ***4-6 page paper due***

SIO123 Reading List

Biogeography, Distribution, Ecology

Needham, David M and Jed A. Fuhrman. (2016). Pronounced daily succession of phytoplankton, archaea and bacteria following a spring bloom. *Nature Microbiology*. DOI: 10.1038/NMICROBIOL.2016.5

de Vargas, C., et al. (2015). Eukaryotic plankton diversity in the sunlit ocean. Science **348**(6237).

Ghiglione JF, Galand PE, Pommier T, Pedros-Alio C, Maas EW, Bakker K, Bertilson S, Kirchmanj DL, Lovejoy C, Yager PL et al. 2012. Pole-to-pole biogeography of surface and deep marine bacterial communities. *Proceedings of the National Academy of Sciences of the United States of America* **109**(43): 17633-17638.

Hanson CA, Fuhrman JA, Horner-Devine MC, Martiny JB. 2012. Beyond biogeographic patterns: processes shaping the microbial landscape. *Nature reviews Microbiology* **10**(7): 497-506.

Ladau J, Sharpton TJ, Finucane MM, Jospin G, Kembel SW, O'Dwyer J, Koeppel AF, Green JL, Pollard KS. 2013. Global marine bacterial diversity peaks at high latitudes in winter. *The ISME journal* **7**(9): 1669-1677.

Wilkins D, van Sebille E, Rintoul SR, Lauro FM, Cavicchioli R. 2013. Advection shapes Southern Ocean microbial assemblages independent of distance and environment effects. *Nature communications* **4**: 2457.

SAR11 (heterotrophic bacteria)

Carini P, Steindler L, Beszteri S, Giovannoni SJ. 2013. Nutrient requirements for growth of the extreme oligotroph 'Candidatus Pelagibacter ubique' HTCC1062 on a defined medium. *The ISME journal* **7**(3): 592-602.

Carlson CA, Morris R, Parsons R, Treusch AH, Giovannoni SJ, Vergin K. 2009. Seasonal dynamics of SAR11 populations in the euphotic and mesopelagic zones of the northwestern Sargasso Sea. *The ISME journal* **3**(3): 283-295.

Giovannoni SJ, Cameron Thrash J, Temperton B. 2014. Implications of streamlining theory for microbial ecology. *The ISME journal* **8**(8): 1553-1565.

Grote J, Thrash JC, Huggett MJ, Landry ZC, Carini P, Giovannoni SJ, Rappe MS. 2012. Streamlining and core genome conservation among highly divergent members of the SAR11 clade. *mBio* **3**(5).

Tripp HJ. 2013. The unique metabolism of SAR11 aquatic bacteria. *Journal of microbiology (Seoul, Korea)* **51**(2): 147-153.

Rappé MS. 2013. Stabilizing the foundation of the house that 'omics builds: the evolving value of cultured isolates to marine microbiology. *Current opinion in microbiology* **16**(5): 618-624.

Vergin KL, Beszteri B, Monier A, Thrash JC, Temperton B, Treusch AH, Kilpert F, Worden AZ, Giovannoni SJ. 2013. High-resolution SAR11 ecotype dynamics at the Bermuda Atlantic Time-series Study site by phylogenetic placement of pyrosequences. *The ISME journal* **7**(7): 1322-1332.

Prochlorococcos (and photosynthetic microbes)

Hernández-Prieto, M. A., et al. (2014). Towards a systems-level understanding of gene regulatory, protein interaction, and metabolic networks in cyanobacteria. Frontiers in Genetics **5**.

Malmstrom RR, Rodrigue S, Huang KH, Kelly L, Kern SE, Thompson A, Roggensack S, Berube PM, Henn MR, Chisholm SW. 2013. Ecology of uncultured Prochlorococcus clades revealed through single-cell genomics and biogeographic analysis. *The ISME journal* **7**(1): 184-198.

Kashtan N, Roggensack SE, Rodrigue S, Thompson JW, Biller SJ, Coe A, Ding H, Marttinen P, Malmstrom RR, Stocker R et al. 2014. Single-cell genomics reveals hundreds of coexisting subpopulations in wild Prochlorococcus. *Science (New York, NY)* **344**(6182): 416-420.

Thompson LR, Zeng Q, Kelly L, Huang KH, Singer AU, Stubbe J, Chisholm SW. 2011. Phage auxiliary metabolic genes and the redirection of cyanobacterial host carbon metabolism. *Proceedings of the National Academy of Sciences of the United States of America* **108**(39): E757-764.

Metagenomics

Sunagawa, S., et al. (2015). Structure and function of the global ocean microbiome. Science **348**(6237).

Brum, J. R., et al. (2015). "Patterns and ecological drivers of ocean viral communities." Science **348**(6237).

Sheik CS, Jain S, Dick GJ. 2014. Metabolic flexibility of enigmatic SAR324 revealed through metagenomics and metatranscriptomics. *Environmental microbiology* **16**(1): 304-317

Yooseph S, Nealson KH, Rusch DB, McCrow JP, Dupont CL, Kim M, Johnson J, Montgomery R, Ferriera S, Beeson K et al. 2010. Genomic and functional adaptation in surface ocean planktonic prokaryotes. *Nature* **468**(7320): 60-66.

Single Cell Genomics

Stepanauskas R. 2012. Single cell genomics: an individual look at microbes. *Current opinion in microbiology* **15**(5): 613-620.

Swan BK, Martinez-Garcia M, Preston CM, Sczyrba A, Woyke T, Lamy D, Reinthaler T, Poulton NJ, Masland ED, Gomez ML et al. 2011. Potential for chemolithoautotrophy among ubiquitous bacteria lineages in the dark ocean. *Science (New York, NY)* **333**(6047): 1296-1300.

Swan BK, Tupper B, Sczyrba A, Lauro FM, Martinez-Garcia M, Gonzalez JM, Luo H, Wright JJ, Landry ZC, Hanson NW et al. 2013. Prevalent genome streamlining and latitudinal divergence of planktonic bacteria in the surface ocean. *Proceedings of the National Academy of Sciences of the United States of America* **110**(28): 11463-11468.

Yoon HS, Price DC, Stepanauskas R, Rajah VD, Sieracki ME, Wilson WH, Yang EC, Duffy S, Bhattacharya D. 2011. Single-cell genomics reveals organismal interactions in uncultivated marine protists. *Science (New York, NY)* **332**(6030): 714-717.

Metatranscriptomics

Krouk, G., et al. (2013). "Gene regulatory networks in plants: learning causality from time and perturbation." Genome Biology **14**(6): 123-123.

Alexander, H., et al. (2015). Metatranscriptome analyses indicate resource partitioning between diatoms in the field. Proceedings of the National Academy of Sciences **112**(17): E2182-E2190.

Bertrand, E. M., et al. (2015). Phytoplankton–bacterial interactions mediate micronutrient colimitation at the coastal Antarctic sea ice edge. Proceedings of the National Academy of Sciences **112**(32): 9938-9943.

Proteomics

Bertrand EM, Allen AE, Dupont CL, Norden-Krichmar TM, Bai J, Valas RE, Saito MA. 2012. Influence of cobalamin scarcity on diatom molecular physiology and identification of a cobalamin acquisition protein. *Proceedings of the National Academy of Sciences of the United States of America* **109**(26): E1762-1771.

Nunn BL, Faux JF, Hippmann AA, Maldonado MT, Harvey HR, Goodlett DR, Boyd PW, Strzepek RF. 2013. Diatom proteomics reveals unique acclimation strategies to mitigate Fe limitation. *PloS one* **8**(10): e75653.

Rosenwasser S, Graff van Creveld S, Schatz D, Malitsky S, Tzfadia O, Aharoni A, Levin Y, Gabashvili A, Feldmesser E, Vardi A. 2014. Mapping the diatom redox-sensitive proteome provides insight into response to nitrogen stress in the marine environment. *Proceedings of the National Academy of Sciences of the United States of America* **111**(7): 2740-2745.

Saito MA, Bertrand EM, Dutkiewicz S, Bulygin VV, Moran DM, Monteiro FM, Follows MJ, Valois FW, Waterbury JB. 2011. Iron conservation by reduction of metalloenzyme inventories in the marine diazotroph Crocosphaera watsonii. *Proceedings of the National Academy of Sciences of the United States of America* **108**(6): 2184-2189.

Saito MA, McIlvin MR, Moran DM, Goepfert TJ, DiTullio GR, Post AF, Lamborg CH. 2014. Multiple nutrient stresses at intersecting Pacific Ocean biomes detected by protein biomarkers. *Science (New York, NY)* **345**(6201): 1173-1177.

Nitrogen Cycle and Metabolomics

Bombar D, Heller P, Sanchez-Baracaldo P, Carter BJ, Zehr JP. 2014. Comparative genomics reveals surprising divergence of two closely related strains of uncultivated UCYN-A cyanobacteria. *The ISME journal* 10.1038/ismej.2014.167.

Thompson A, Carter BJ, Turk-Kubo K, Malfatti F, Azam F, Zehr JP. 2014. Genetic diversity of the unicellular nitrogen-fixing cyanobacteria UCYN-A and its prymnesiophyte host. *Environmental microbiology* 10.1111/1462-2920.12490.

Thompson AW, Foster RA, Krupke A, Carter BJ, Musat N, Vaulot D, Kuypers MM, Zehr JP. 2012. Unicellular cyanobacterium symbiotic with a single-celled eukaryotic alga. *Science (New York, NY)* **337**(6101): 1546-1550.

Tripp HJ, Bench SR, Turk KA, Foster RA, Desany BA, Niazi F, Affourtit JP, Zehr JP. 2010. Metabolic streamlining in an open-ocean nitrogen-fixing cyanobacterium. *Nature* **464**(7285): 90-94.

Hilton JA, Foster RA, Tripp HJ, Carter BJ, Zehr JP, Villareal TA. 2013. Genomic deletions disrupt nitrogen metabolism pathways of a cyanobacterial diatom symbiont. *Nature communications* **4**: 1767.

Phytoplankton, Bacteria, Networks, Linkages

Amin SA, Parker MS, Armbrust EV. 2012. Interactions between diatoms and bacteria. *Microbiology and molecular biology reviews : MMBR* **76**(3): 667-684.

Buchan A, LeCleir GR, Gulvik CA, Gonzalez JM. 2014. Master recyclers: features and functions of bacteria associated with phytoplankton blooms. *Nature reviews Microbiology* **12**(10): 686-698.

Sher D, Thompson JW, Kashtan N, Croal L, Chisholm SW. 2011. Response of Prochlorococcus ecotypes to co-culture with diverse marine bacteria. *The ISME journal* **5**(7): 1125-1132.

Steele JA, Countway PD, Xia L, Vigil PD, Beman JM, Kim DY, Chow CE, Sachdeva R, Jones AC, Schwalbach MS et al. 2011. Marine bacterial, archaeal and protistan association networks reveal ecological linkages. *The ISME journal* **5**(9): 1414-1425.

Teeling H, Fuchs BM, Becher D, Klockow C, Gardebrecht A, Bennke CM, Kassabgy M, Huang S, Mann AJ, Waldmann J et al. 2012. Substrate-controlled succession of marine bacterioplankton populations induced by a phytoplankton bloom. *Science (New York, NY)* **336**(6081): 608-611.