Environmental Microbiology 6155: MICROBIAL ECOLOGY & EVOLUTION

Instructors: Dr. Matt Sullivan
Office: 914 Riffe Bldg
sullivan.948@osu.edu
614-247-1616
https://u.osu.edu/viruslab/

Dr. Virginia Rich
Office: 934 Riffe Bldg
rich.270@osu.edu
614-247-1622
https://openwetware.org/wiki/SWES-MEL

Please **email us through Carmen**. Office hours are by emailed appointment. Do not leave voice mails as they may not be received.

Credit hours: 3. From the Ohio Department of Higher Education guidelines, this equates to ~3 hrs of in-class time each week, and "requires students to work at out-of-class assignments an average of two hours for every hour of formalized instruction".

Lecture time/location: F 9:30am-12:30pm, location Biological Sciences 676.

I. Course objective/goals: The course will cover, at a graduate level and focused around key primary literature, the ecology and evolution of microbes. We will explore essential methods and concepts, and ongoing 'unknowns' in the field. In this course, the term "microbial" is shorthand for prokaryotes + viruses.

We will cover the following **overarching scientific themes**:

- Microbial ecology: What are the patterns and drivers of microbial communities? How do we grapple with scale, & statistical power? What are approaches to time series analyses, and to multi-disciplinary systems datasets (including WCGNA analyses)? What 'central dogma' considerations should inform our interpretation of multi-omic experiments? What are the defining ecological characteristics, at the microbial scale, of oceans, soils, and engineered systems?
- Microbial evolution: How is selection examined in microbes, and what is known about microbial evolutionary rates and processes? How are lineages traced, and their relationships examined?
- Microbial evolution in an ecological context: How can the above concepts be applied in unified systems frameworks, such as for understanding symbioses, or the co-evolution of viruses & microbes, or microbial metabolic hand-offs & their evolution?

The course **learning objectives** for this material are:

- Develop knowledge of foundational concepts and methods in microbial ecology and evolution.
- Explore principles of sound experimental design in these fields.
- Learn how to read, summarize, and critique primary literature in these fields.
- Improve professional communication skills as a scientist: writing & presenting, peer-evaluation of writing & presenting, and leading scientific discussions.

The course learning objectives specifically support these **Microbiology PhD Program learning goals**:

- Broad Knowledge: PhD graduates of Microbiology should be able to demonstrate a broad base of knowledge in several areas.
- In-Depth Knowledge: PhD graduates of Microbiology should be able to demonstrate in-depth in an area of interest. *This course advances this goal for students continuing in these areas of study.*
- Effective Communication. PhD graduates of Microbiology should be able to effectively communicate science through oral and written presentations to both scientific and general audiences.

II. Required materials:
This class is focused around key concepts in Microbial Ecology & Evolution, fields which are continually evolving. Therefore, and as a graduate-level course, we will read primary literature rather than a text book. Readings will be posted on **Canvas. You will be expected to access this site regularly in order to prepare for class**. It is your responsibility to turn on your notifications in Canvas so you receive alerts or emails when Announcements are made or assignments are posted.

III. Grading:

30% Weekly write-ups (13 weeks)
10% Peer evaluation of weekly write-ups
40% Presentations (20% for first presentation, 20% for second)
5% Peer evaluation of presentations
10% In-class participation in discussions
5% Learning objectives write-ups

Primary literature discussions are the heart of this course. To support these discussions, there will be lectures by the professors, presentations by students, and at-home viewing and reading assignments, to introduce foundational concepts and methods.

Homework.

A. Preparation: we will read 1-3 papers each week, and some weeks we will view videos or short supplementary writing to support the weekly topic.

B. Weekly write-ups: to provide an opportunity to synthesize the information in the assigned paper(s), each week you will write a short writing assignment with the following structure:
   - 1 paragraph summarizing each of the paper(s) (i.e. 1 paragraph per paper). What was the key Q it was addressing and why is it important? What was their experimental design and approach? And what were there key findings?
   - A short list of the "muddiest points" – what questions do you have about the paper(s).
   - A short list of "axes of connection" to other research or concepts – how does this paper(s) relate to other papers or ideas covered in this course, in your own research, or in other classes, or elsewhere (including mainstream media)?

   You will turn these write-ups in on Carmen, and bring 1 printed copy to class.

Weekly Write-ups rubric:

Criteria	Rating			Points (19)
Key Qs stated & concisely contextualized	3: clearly stated goals of all assigned papers and gave quick context	1: mentioned a single goal without context	0: did not describe goals of any of the papers.	3
Experimental approach	3: clearly identified the essential experimental approach of the papers at a summary-level (ie not every step of protocols)	1: just lists some of methods or tools used, without overarching approach.	0: did not describe approach	3
Findings	3: concisely articulated the key findings of the paper	1: states a single finding	0: did not describe findings	3
Quality of writing	2: easy to read, clearly laid out	1: could follow, but there were some confusing sections.	0: poorly crafted, difficult to follow	2

Spelling and grammar	2: no spelling and grammar errors	1: one error	0: more than one error	2
Muddiest points	3: >2 questions identified clearly	1: a single question	0: none provided.	3
Axes of connection	3: >1 axis of connection clearly defined	1: a poorly defined linkage to one other topic.	0: none provided	3

C. Peer evaluation of weekly write-ups: Assessing our colleagues' work is one of the best ways of improving our own. Each week you will assess a write-up from a different peer, using the same grading rubric as the instructors, and adding 1 sentence per criteria justifying your score. These will be due the following week.

Peer evaluations rubric:

Criteria	Rating			Points (8)
Scored the rubric	1: filled in the rubric		0: did not complete	1
Concisely justified each score.	7: Justified each score in a single clear sentence.	3: Only provided justifying sentences for a subset of the scores, and/or sentences did not actual relate to evaluate of criteria.	0: did not explain scores	7

Presentation. You will give 2 presentations during the semester. Presentations will be 15-20 minutes, with open question and discussion time afterwards. (1). You will sign up to present on a topic (a method, concept, or paper) related to the syllabus and assigned readings; the list of these options will be provided on the first day of class. The goal of your presentation will be to deliver a primer on the assigned topic to your peers, these will directly feed into improved paper discussions. You are encouraged but not required to arrange a meeting with an instructor the week before your presentation to go over your slides. (2). The last day of class, we will each present on connecting the semester's material to concepts in our everyday lives (see syllabus). You may select any topic.

Presentation rubric:

Criteria				Points (60)
Content	A	B	C/D	F
Organization	Organization clear from the start, & followed	Organization presented and mostly adhered to	Organization inconsistent	Disorganized
Concept conveyance	Concepts are clearly conveyed, with succinct explanations, appropriate examples, and informative visual aids	Concepts presented but some are unclear	Concepts periodically murky; key concepts missing	No key concepts covered
Referencing	Literature & knowledge sources referenced	Knowledge mostly referenced	Some important key ideas stated as 'known facts' without attribution	No referencing
Accuracy	The information presented is correct	The information is mostly correct with only minor inaccuracies	One appreciable inaccurary	Rampant inaccuracies
Timeliness	Talk fit within allotted timeframe	Talk was <2" over	Talk <5" over	Talk >5" over
Q & A	Qs addressed with thought, some known answers, and engaged group brainstorming when answers not known	Qs addressed thoughtfully	Poor handling of Qs without known As	Qs addressed blankly
Slides				
Style	Slides uncluttered, easy to follow	Slides mostly clear	Difficult to follow, e.g. from excessive text, variable fonts, use of illegible tables	Slides impossible to follow
Source attribution	Graphics consistently attributed to their source	Graphics almost always sourced.	Some graphics sourced.	No sources
Speaking style				
Physically	Professional bearing, no nail-biting, swaying, etc	A few fidgety moments	Periodic fidgets but generally stable	Excessive fidgety movement

Verbally	(after the first 5"☺) Minimal 'ums', cogent verbiage, content matches slide content	Generally smooth delivery, a few rough spots	Periodically distracted; reads from notes	Frequently loses place; verbiage does not match slides
Rapport	Maintains eye contact, "presence" in the space, facial expressions, use of laser pointer to help guide audience	Generally engaged with audience	Spends long periods with back to audience looking at slides; spends long periods looking down or out of window, or with eyes closed	No eye contact

You will evaluate your peers' presentations using an in-class evaluation sheet based on the above rubric, and with time to write down comments about their performance. Full completion of the evaluation sheet, with comments, will earn full credit; partial completion partial credit; no completion will get zero credit.

Participation. Show up on time and prepared, and participate in class. Because these are discussions, it is OK if you dislike speaking up with answers, or feel you know less than the rest of the class - you can still participate, by bringing your pithy questions to the group.

Participation Rubric

	A	B	C/D	F
Preparation	Arrives on time fully prepared a every class session	Arrives mostly, if not fully, prepared (ongoing)	Inconsistent preparation	Rarely or never prepared
Participation	Plays an active role in discussions (ongoing)	Participates constructively in discussions (ongoing)	When prepared, participates constructively in discussions	Comments vague if given; frequently demonstrates lack of interest
Contribution to Class	Comments advance level and depth of dialogue (consistently)	Makes relevant comments based on assigned material (ongoing)	When prepared, relevant comments are based on assignments	Demonstrates a noticeable lack of interest

Courtesy of Jesse Kwiek; Adapted from The Teaching Professor, March 2005.

YOU WILL POSITIVELY AFFECT YOUR PARTICIPATION GRADE BY:

1. Becoming more active and/or making more effective comments that raise overall level of discussion.
2. Asking thoughtful questions that will enhance discussion and engage peers.
3. Listening carefully to, supporting, and engaging your peers in discussion.

YOU WILL NEGATIVELY AFFECT YOUR PARTICIPATION GRADE BY:

1. Not attending class (unexcused), or **arriving to class late**.
2. Using electronic devices (*e.g.* cell phone, iPad, computer, etc.) for personal, non-class related reasons.
3. Dominating class discussions, thereby restricting others' participation.
4. Making offensive, and/or disrespectful comments during discussions.

Learning objectives write-ups. At the beginning and end of the course you will be required to complete short writing assignments (no more than 1 page single-spaced) self-evaluating your strengths and weaknesses in each of the areas covered by the 4 course learning objectives, based on the 3 overarching themes. At the start of the course you will evaluate your knowledge coming in, describe how these knowledge and training areas fit into your longer term research and career goals, and the areas you are most excited to learn about, and identify your strategy for succeeding in the course. We will read a summary of learning styles to help frame this. At the end of the course, you will reflect on which areas you advanced your knowledge and in what ways, and what learning strategies worked for you.

Learning objectives write-ups (written for entry exercise; exit rubric will have same sections, slightly adjusted wording)

Criteria	Rating			Points (19)
Strengths & weaknesses	8: for each of the 4 learning objectives, articulated a clear self-assessment	4: only identified strengths *or* weaknesses, or only addressed a subset of objectives	0: did not self-assess.	8
Longer-term context	3: identified how the course material fits into your overall training and professional goals	1: mentioned a goal but without contextualizing course material.	0: did not describe context	3
Strategy	4: clearly articulated strategies you will use to achieve your learning goals in this course	2: identified a single strategy but did not link it to this course	0: did not describe strategy	4
Quality of writing	2: easy to read, clearly laid out	1: could follow, but there were some confusing sections.	0: poorly crafted, difficult to follow	2
Spelling and grammar	2: no spelling and grammar errors	1: one error	0: more than one error	2

IV. Course Outline

Week	Date	Topic	Readings
1	Jan 11	The microbial species concepts. What to count? The term 'population' in ecology vs. in evolution	1. OX Cordero, MF Polz. 2014 Explaining microbial genomic diversity in light of evolutionary ecology (2014). Nature Reviews In Microbiology, 12, pages 263–273 2. Shapiro BJ, Polz MF. 2014. Ordering microbial diversity into ecologically and genetically cohesive units. Trends Microbiol. 2014 May;22(5):235-47. https://www.ncbi.nlm.nih.gov/pubmed/24630527 3. Cadillo-Quiroz et al. Patterns of Gene Flow Define Species of Thermophilic Archaea.http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1001265
2	Jan 18	Microbial phylogeny & taxonomy	1. **LA Hug et al. 2016. A new view of the tree of life.** *Nature Microbiology* **1**: 16048. https://www.nature.com/articles/nmicrobiol201648 2. Parks et al. 2017. Recovery of nearly 8,000 metagenome-assembled genomes substantially expands the tree of life. *Nature Microbiology* **2**:1533–1542 https://www.nature.com/articles/s41564-017-0012-7
3	Jan 25	Diversity metrics. Richness and evenness; alpha beta and gamma diversity	1. Hughes et al. 2001. Appl Environ Microbiol. 67:4399-406. **Counting the uncountable: statistical approaches to estimating microbial diversity.** https://www.ncbi.nlm.nih.gov/pubmed/11571135 2. Martiny et al. 2006. **Microbial biogeography: putting microorganisms on the map.** Nat Rev Microbiol. 4:102-12. https://www.ncbi.nlm.nih.gov/pubmed/16415926 3. Haegeman B[1], Hamelin J, Moriarty J, Neal P, Dushoff J, Weitz JS. 2013. Robust estimation of microbial diversity in theory and in practice. ISME J. 7:1092-101. https://www.ncbi.nlm.nih.gov/pubmed/23407313
4	Feb 1	Patterns and drivers of microbial community structure; ecological statistics; multi-disciplinary datasets	1. Sunagawa, S.*, et al. 2015. Structure and function of the global ocean microbiome. *Science.* 348:1261359. (*=co-first authors) http://science.sciencemag.org/content/348/6237/1261359.full 2. S Banerjee, K Schlaeppi, MGA Heijden - 2018. Keystone taxa as drivers of microbiome structure and functioning. *Nature Reviews Microbiology*, https://www.nature.com/articles/s41579-018-0024-1 3. Evan P. Starr, Shengjing Shi, Steven J. Blazewicz, Alexander J. Probst, Donald J. Herman, Mary K. Firestone and Jillian F. Banfield. 2018. Stable isotope informed genome-resolved metagenomics reveals that Saccharibacteria utilize microbially-processed plant-derived carbon. *Microbiome.* **6**:122. https://microbiomejournal.biomedcentral.com/articles/10.1186/s40168-018-0499-z [tutorial level website = Gusta Me website -- https://mb3is.megx.net/gustame]
5	Feb 8	Scaling across time and space	1. Needham, David M., Rohan Sachdeva, Jed A. Fuhrman. 2017. Ecological dynamics and co-occurrence among marine phytoplankton, bacteria and myoviruses shows microdiversity matters. *ISMEJ*. 11: 1614-29. https://www.ncbi.nlm.nih.gov/pubmed/28398348 2. Needham, David M and Jed A. Fuhrman. 2016. Pronounced daily succession of phytoplankton, archaea and bacteria following a spring bloom. *Nature Microbiology.* 1: 16005. https://www.nature.com/articles/nmicrobiol20165
6	Feb 15	Incorporating microbes into ecological models	1. S.M. Vallina, P. Cermeno, S. Dutkiewicz, M. Loreau, J.M. Montoya. 2017. Phytoplankton functional diversity increases ecosystem productivity and stability, Ecological Modelling. 361: 184-196, https://doi.org/10.1016/j.ecolmodel.2017.06.020 2. William R. Wieder, Gordon B. Bonan & Steven D. Allison. 2013. Global soil carbon projections are improved by modelling microbial processes Nature Climate Change.3, 909–912. https://www.nature.com/articles/nclimate1951
7	Feb 22	Habitat comparisons	T.B.D. as critical new papers only just arising in this area

8	Mar 1	Population genetics and communities	1. Schloissnig et al. 2013. Genomic variation landscape of the human gut microbiome. Nature. 493: 45-50. https://www.ncbi.nlm.nih.gov/pubmed/23222524 2. T.B.D. as critical new papers only just arising in this area
9	Mar 8	Experimental evolution	1. Good, B. H., M. J. McDonald, J. E. Barrick, R. E. Lenski, and M. M. Desai. 2017. The dynamics of molecular evolution over 60,000 generations. *Nature* 551: 45-50. https://www.nature.com/articles/nature24287 2. Tenaillon et al. 2016. Tempo and mode of genome evolution in a 50,000-generation experiment. *Nature* 536:165-170. https://www.nature.com/articles/nature18959 3. Barrick, J. E. & Lenski, R. E. 2013. Genome dynamics during experimental evolution. *Nature Rev. Genet.* **14**: 827–839 https://www.nature.com/articles/nrg3564
10	Mar 15	Spring break	
11	Mar 22	Guest discussion lead by Matt Anderson: Evolution of microbial eukaryotes	T.B.D. by guest lecturer
12	Mar 29	How do viruses fit into the frameworks discussed so far?	1. Gregory et al. 2016. Genomic differentiation among wild cyanophages despite widespread horizontal gene transfer. ***BMC Genomics.*** 17: 930. https://bmcgenomics.biomedcentral.com/articles/10.1186/s12864-016-3286-x 2. Roux et al. 2016. Ecogenomics and potential biogeochemical impacts of globally abundant ocean viruses. ***Nature.*** 537: 689-693. https://www.nature.com/articles/nature19366 3. Emerson et al. 2018. Host-linked soil viral ecology along a permafrost thaw gradient. ***Nature Microbiology***. *In press.*
13	Apr 5	Metabolic hand-offs and their evolution	1. Dekas, Anne E. and Poretsky, Rachel S. and Orphan, Victoria J. (2009) *Deep-Sea Archaea Fix and Share Nitrogen in Methane-Consuming Microbial Consortia. Science*, 326: 422-426. 2. Giovannelli et al. 2017. Insight into the evolution of microbial metabolism from the deep-branching bacterium, *Thermovibrio ammonificans*. *eLife* 6:e18990. https://elifesciences.org/articles/18990
14	Apr 12	Co-evolution of hosts and symbionts/parasites	1. Thompson. 2014. Microbes in the coral holobiont: partners through evolution, development, and ecological interactions. Front Cell Infect Microbiol. 4: 176. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4286716/ 2. **Rubin-Blum M**, **Antony CP**, **Borowski C**, **Sayavedra L**, Pape T, Sahling H, Bohrmann G, Kleiner M, Redmond MC, Valentine DL, **Dubilier N** (2017). Short-chain alkanes fuel mussel and sponge *Cycloclasticus* symbionts from deep-sea gas and oil seeps. *Nature Microbiology* 2:nmicrobiol201793.
15	Apr 19	Applying course concepts to your everyday life (e.g. cheese, wastewater treatment, agriculture, wine, antibiotic resistance, etc.)	Each person presents for 15".
	Apr 22	Last day of spring semester classes	
	Apr 25 – May 1	Final exam period; **no exam for this course**.	

Due to the dynamic nature of this class, this syllabus is subject to revision as the semester proceeds. Announcements will be made on Carmen. Students are responsible for being aware of any changes.

V. Academic integrity. It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term "academic misconduct" includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct http://studentaffairs.osu.edu/csc/

Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories (e.g., race). If you or someone you know has been sexually harassed or assaulted, you may find the appropriate resources at http://titleix.osu.edu or by contacting the Ohio State Title IX Coordinator, Kellie Brennan, at titleix@osu.edu.

VI. Communication: Students are responsible for announcements made in class, available on the course's website or sent by e-mail. Late assignments will not be accepted without prearrangement with TA or instructor. Assignment due dates will be explicitly noted and followed, including turned in at the start of class or via Canvas at an assigned time.

VII. Disability Services.

The University strives to make all learning experiences as accessible as possible. If you anticipate or experience academic barriers based on your disability (including mental health, chronic or temporary medical conditions), please let me know immediately so that we can privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion. SLDS contact information: slds@osu.edu; 614-292-3307; slds.osu.edu; 098 Baker Hall, 113 W. 12th Avenue.