Syllabus

HM
hannah.mcmillan@duke.edu
hamcmillan.com
linkedin.com/in/hamcmillan

BIOMI 3000 | Plant health, the plant microbiome, and the changing climate

MWF 10:10-11:00am
334 Morrison Hall
Fall 2025
JUMP TO COURSE SCHEDULE

Pre-requisites:
BIOMI 2900 or consent of the instructor

Hannah McMillan
(she/her/hers – why pronouns matter)
hannah.mcmillan@duke.edu

School of Integrative Plant Science
Plant Pathology and Plant-Microbe Biology
Office Hours: Tues. 9-11am or by appointment

Course Overview

Although you may not see them, microbes are integral to all areas of life. Collectively known as the plant microbiome, the microbes that colonize aboveground and belowground plant tissue perform critical roles in ecosystem function and plant health. But how will these microbial services and plant-microbe interactions change in a warming climate? Understanding three-way interactions between plants, microbiota, and the environment is critical for our ability to design new agricultural treatments and ensure food security in a changing climate.

Throughout this course, students will use current literature to examine major questions and recent advances in microbiome science with a specific focus on three-way interactions between plants, microbiota, and the environment. We will focus primarily on bacterial microbiome members to gain an understanding of basic methods to study microbial communities and their functions across plant niches and species, with brief forays into fungal microbiomes to broaden student understanding.

Students are expected to enter this course having taken General Microbiology but are not expected to have a detailed knowledge of microbial community dynamics or microbiome analysis methods. With that in mind, we will start building knowledge early using papers from the current literature to learn basic principles of microbiome structure, ecological services provided by microbiome communities, molecular interactions between microbes and between microbes and plants, as well as experimental approaches to analyze microbiomes. Throughout the class meetings and assignments, students will examine how microbiome structure, function, and interactions may change in altered environmental conditions. As students acquire a working knowledge, our weekly paper discussions will shift to focus more closely on fundamental questions in the field, experimental results, and future directions for study. By the end of the course, students will have the opportunity to demonstrate their knowledge by identifying a question in the field and designing an experiment to solve one of the great mysteries of three-way interactions in a changing climate!

Course Objectives

Through full participation in this course, students will be able to:

1. Describe the basic structure of microbiome communities in plants across different plant niches, species, and in various environmental conditions
2. Discuss implications of altered microbiome community composition on plant health
3. Summarize main questions from current literature and critically evaluate scientific results
4. Formulate scientific questions and design experiments to test hypotheses in microbiome sciences
5. Evaluate potential impacts of environmental change on microbiome applications in agriculture and develop strategies for communicating these implications to the general public

Readings

All of the readings for this class will be recently published journal articles from the plant microbiome literature. These articles will be available on the course site with additional links to relevant background reading in the form of scientific reviews and opinion pieces.

There is one optional text for this course:
Plant Microbiome: Stress Response (Microorganisms for Sustainability, 5) by by Dilfuza Egamberdieva (Editor), Parvaiz Ahmad (Editor). 2019. Springer.
ISBN# 978-9811354151. *Subject to change upon review of microbiome textbooks.

This textbook may be helpful to reinforce basic principles of microbiome structure and function in a changing climate and supplement the knowledgebase we will build using the current literature. A firm foundation in these underlying principles is critical for novel discovery.

Assignments and Evaluations

All work will be assessed on a 10-point scale. For example, 90-100 results in an A, 80-90 a B, and so on. Please note that no late work will be accepted except under extenuating circumstances and with documentation in accordance with Cornell policies.

Final grades will be calculated using the following percentages:

Weekly Assignments	10%
Participation	10%
Written Assignments	15%
Final Design Project	15%
Midterm 1	15%
Midterm 2	15%
Final Exam	20%

Weekly Assignments

Each week, students will complete a brief assignment based on the readings assigned for that week. These assignments are due by 11:59PM the day before the indicated class meeting (see proposed schedule) and will be graded for completion. To begin the semester, assignments will ask students to outline the experimental techniques used in the reading. As we continue to build a working knowledge of microbiome studies, students will be asked to identify the main findings in scientific figures as well as describe the techniques used to achieve the results. By the end of the course, students will develop future directions, pose environmental considerations and considerations for plant health, and propose potential experiments. Students should be prepared to discuss the readings and assignments at the start of the class period.

Participation

During class meetings, students will participate in individual and group activities, using information from the readings and working with their peers to grapple with new concepts and challenge current scientific findings. Examples of in-class activities include analyzing scientific figures, discussing ethical concerns, and designing experiments. The purpose of these activities is to learn how to read scientific papers and analyze data and results with the help of peers and the instructor. Practicing these skills in class will prepare students for out-of-class assignments, exams, and design projects. Students are expected to come to class prepared and ready to participate actively in all activities.

Written Assignments

Throughout the course, students will submit for feedback short written assignments designed to help students fully explore potential project topics and gradually build the final project. We will dedicate time in class before each due date for questions and peer review. Each assignment will constitute 3.75% of the final grade in the course. Students should refer to the final design project rubric for guidance on what to include in each written assignment as well as formatting requirements. The written assignments will be as follows:

1. Proposed Topic and Annotated Bibliography

   The proposed topic should be an interesting, unanswered question in plant microbiome sciences. Importantly, the topic may be in an area not covered throughout the course. Bibliographies should consist of no fewer than twenty peer-reviewed articles with the relevance of each noted in a brief sentence or two.

2. Introduction and Background

   Using the references compiled in the first written assignment, students will compose a brief introduction to provide context and rationale for their scientific question and proposed experiments. This section should not exceed half a page and must include at least two tentative scientific aims that address the overarching question. The proposed aims may exceed the half page limit.

3. Research Proposal

   In this assignment, students will fully develop their proposed aims by including specific techniques and experiments to address each hypothesis. Collectively, the aims and

experiments must serve to shed light on the overarching question and central hypothesis. This section will be submitted along with a revised introduction and background. Together, these should not exceed 1.5 pages.

4. Abstract and Broader Impacts
   Students will use these sections to give a brief overview of the research proposal as well as place the scientific questions in a larger context. Additionally, these sections should explicitly state the significance of the proposed work. Students will submit this assignment along with revised versions of the preceding written assignments. Collectively, the document should not exceed 2 pages.

Final Design Project

The final project will be submitted for evaluation in the form of a National Science Foundation Graduate Research Fellowship. Written assignments are designed to generate the final design project over the course of the semester, allowing students to receive ample peer and instructor feedback on each component before the final submission. Final projects will be graded according to the rubric posted on the course website and found at the end of this syllabus.

Midterm and Final Exams

There will be two midterm exams and one cumulative final. Practice questions and exam questions from previous years are available on the course website. In general, exam questions will challenge students to interpret real scientific results and propose follow-up experiments to advance scientific understanding. For both midterms, students may submit a regrade request if they feel a mistake has been made in the grading; however, submission for a regrade may result in a lower grade than the original if the instructor finds additional mistakes or flaws in logic that were unaccounted for in the initial evaluation.

Attendance and Late Work Policies

Attendance is expected in all class meetings. More than 3 unexcused absences will result in one letter grade reduction from the final grade for the course. Please note that no late work will be accepted except under extenuating circumstances and with documentation in accordance with Cornell policies. The following circumstances constitute excused absences and exceptions to the late work policy:

1. Significant illness
2. Personal instances of distress or emergency
3. Religious observance
4. Varsity athletic participation
5. Required court or legal appearances

For more detailed policies, please consult this Cornell policy.

Disability Statement

Student learning increases within diverse classroom environments. This class welcomes students from all backgrounds, identities, and abilities. Students who need accommodations to create a more productive learning environment are encouraged to contact Student Disability Services at 607-254-4545 or sds_cu@cornell.edu before the start of the semester or early in the semester.

Title IX, Harassment, and Diversity

Cornell University and this classroom are committed to encouraging and sustaining a learning and living community that is free from harassment, violence, and prohibited discrimination. In that regard and consistent with federal law (e.g., Title IX of the Education Amendments of 1972 and the Violence Against Women Act), Cornell has developed this comprehensive Sexual Misconduct and Harassment Policy, applicable to all students (undergraduate, graduate, and professional, or any student enrolled in any Duke program).

The Sexual Misconduct and Harassment Policy prohibits all forms of sex/gender-based harassment, sexual/gender violence, sexual exploitation, relationship violence (domestic violence and dating violence), and stalking. Collectively, these terms are referred to in this policy as "Sexual Misconduct." They are defined below under "Prohibited Conduct." Non-sex/gender-based harassment is also a violation of university policy, as described under the university's policy.

Cornell and this classroom aspire to create a community built on collaboration, innovation, creativity, and belonging. Our collective success depends on the robust exchange of ideas—an exchange that is best when the rich diversity of our perspectives, backgrounds, and experiences flourishes. To achieve this exchange, it is essential that all members of the community feel secure and welcome, that the contributions of all individuals are respected, and that all voices are heard. All members of our community have a responsibility to uphold these values. More information on resources at Cornell can be found on the Office of Diversity and Inclusion website.

Academic Integrity

Cornell University is a community dedicated to scholarship, leadership, and service and to the principles of honesty, fairness, respect, and accountability. Citizens of this community commit to reflect upon and uphold these principles in all academic and non-academic endeavors, and to protect and promote a culture of integrity. Students are expected to uphold the Cornell Code of Academic Integrity:

1. A student shall in no way misrepresent his or her work.
2. A student shall in no way fraudulently or unfairly advance his or her academic position.
3. A student shall refuse to be a party to another student's failure to maintain academic integrity.
4. A student shall maintain the integrity of the classroom environment, and not engage in unauthorized sharing of materials beyond the course environment or record classroom lectures and discussions without the prior written permission of instructors.
5. A student shall not in any other manner violate the principle of academic integrity.

Proposed Schedule

Assignments are due by 11:59PM on the course website the day before the class meeting unless otherwise noted. Full descriptions of each assignment are available on the course website. No late work will be accepted without proper documentation or extenuating circumstances. Students are expected to complete the assigned readings prior to the class meeting.

Week	Class	Readings	Assignments
Overview: Microbiome Structure and Function			
1	8-25-25	Course Overview	Introduce Yourself on the course website
	8-27-25	Review: The Plant Microbiome Rout 2014 Plant-microbiome interactions: from community assembly to plant health Trivedi 2020	Bring signed copy of the syllabus to class
	8-29-25	Review: The importance of the microbiome of the plant holobiont Vandenkoornhuyse 2015 Harnessing the plant microbiome for sustainable crop production Compant 2025	Weekly Assignment 1: Outline basic principles of microbiome composition, assembly, and function from the reading
Overview: Principles and Implications of Climate Change			
2	9-1-25	Labor Day – No Class	
	9-3-25	Review: A review of the global climate change impacts, adaptation, and sustainable mitigation measures Abbass 2022 A review on climate change impacts, models, and its consequences on different sectors: a systematic approach Rawat 2023	
	9-5-25	Review: Plant-microbiome interactions under a changing world: responses, consequences and perspectives Trivedi 2022	Weekly Assignment 2: Outline projections from current climate change models and their implications for plant-microbiome interactions from the reading

		Impact of global change on the plant microbiome Hacquard 2022	
Experimental Methods in Microbiome Analysis			
3	9-8-25	Review: A bioinformatics guide to plant microbiome analysis Lucaciu 2019, through section "Microbiome Sequences Inside Plant Genome Assemblies"	FDP: Bring draft of written assignment 1 to class for peer review
	9-10-25	Review: A bioinformatics guide to plant microbiome analysis Lucaciu 2019, all sections within "Community-Based Analysis by Amplicon Sequencing"	
	9-12-25	Review: A bioinformatics guide to plant microbiome analysis Lucaciu 2019, all sections within "Additional Omics Strategies and Their Integration With Microbiome Data" and "Conclusions"	Weekly Assignment 3: Create a flow-chart of sample collection, processing, and analysis for amplicon sequencing and shotgun metagenomics
4	9-15-25	Intro to Microbiome Analysis with Galaxy Selected walk-through tutorials: https://training.galaxyproject.org/training-material/topics/microbiome/	
	9-17-25	Intro to Microbiome Analysis with Galaxy 16S microbial analysis with mothur: https://training.galaxyproject.org/training-material/topics/microbiome/ Identifying mycorrhizal fungi from ITS2 sequencing using LotuS2: https://training.galaxyproject.org/training-material/topics/microbiome/	
	9-19-25	Intro to Microbiome Analysis with Galaxy Taxonomic profiling and visualization of metagenomic data: https://training.galaxyproject.org/training-material/topics/microbiome/	Weekly Assignment 4: Outline limitations of current sequencing and omics technologies in characterizing microbiome communities
Phyllosphere Microbiomes: Colonization, Assembly, and Functions			
5	9-22-25	Review: Microbial life in the phyllosphere	Written assignment 1: Proposed FDP Topic and Annotated Bibliography

		Vorholt 2012	
	9-24-25		
	9-26-25	Midterm 1	
6	9-29-25	Intro: selected publication	Weekly Assignment 5: Propose experiments to address the claims from the reading
	10-1-25	Results and Methods: selected publication	
	10-3-25	Discussion: selected publication	FDP: Bring draft of written assignment 2 to class for peer review
7	10-6-25	Intro: selected publication	Weekly Assignment 6: Propose experiments to address the claims from the reading
	10-8-25	Results and Methods: selected publication	
	10-10-25	Discussion: selected publication	Written assignment 2: FDP Intro and Background
8	10-13-25	Fall Break	
	10-15-25	Intro: selected publication	Weekly Assignment 7: Propose experiments to address the claims from the reading
	10-17-25	Results, Methods and Discussion: selected publication	FDP: Bring draft of written assignment 3 to class for peer review
Rhizosphere Microbiomes: Colonization, Assembly, and Functions			
9	10-20-25	Review: Rhizosphere Microbiome: The Emerging Barrier in Plant-Pathogen Interactions Li 2021	
	10-22-25	Intro: selected publication	Weekly Assignment 8: Propose experiments to address the claims from the reading and suggest one follow-up experiment
	10-24-25	Results, Methods, and Discussion: selected publication	Written Assignment 3: FDP Research Proposal
10	10-27-25	Intro: selected publication	Weekly Assignment 9: Propose experiments to address the claims from the reading and suggest one follow-up experiment
	10-29-25	Results and Methods: selected publication	
	10-31-25	Discussion: selected publication	FDP: Bring draft of written assignment 4 to class for peer review
11	11-3-25	Intro: selected publication	Weekly Assignment 10: Propose experiments to address the claims from the reading and suggest one follow-up experiment

	11-5-25	Results and Methods: selected publication	
	11-7-25	Discussion: selected publication	Written Assignment 4: FDP Abstract and Broader Impacts
Microbiome Applications to Improve Food Security			
12	11-10-25	Review: A review of the global climate change impacts, adaptation, and sustainable mitigation measures Abbass 2022 The Impact of Population Growth on Natural Resources and Farmers' Capacity to Adapt to Climate Change in Low-Income Countries Maja and Ayano 2021	
	11-12-25		
	11-14-25	Midterm 2	
13	11-17-25	Review: Towards sustainable agriculture: rhizosphere microbiome engineering Bano 2021	
	11-19-25	Review: Plant–microbiome interactions for sustainable agriculture: a review Gupta 2021	
	11-21-25	Review: Current, faltering, and future strategies for advancing microbiome-assisted sustainable agriculture and environmental resilience Kabir 2024	Weekly Assignment 11: Summarize current impacts of climate change on low-income countries
14	11-24-25		FDP: Bring draft of the final design project to class for peer review
	11-26-25	Thanksgiving Break	
	11-28-25	Thanksgiving Break	
15	12-1-25	Review: Customized plant microbiome engineering for food security Batool 2024	
	12-3-25	Review: Microbiome-based solutions to address new and existing threats to food security, nutrition, health and agrifood systems' sustainability Callens 2022	
	12-5-25	Review: Microbiome rescue: directing resilience of	Weekly Assignment 12: Propose one use for microbiome engineering to

		environmental microbial communities Shade 2023	improve food security; describe experiments to test efficacy
16	12-8-25	LDOC	Final Design Project Due
	12-10-25	Study Period	
	12-12-25	Final Exams	
17	12-15-25	Final Exams	
	12-17-25	Final Exams	
	12-19-25	Final Exams	

Final Design Project Rubric

CATEGORY	Very Good	Good	Fair	Needs Improvement
Abstract	Abstract is concise, informative, and clearly indicates the relevant details of the proposed study.	Abstract is relevant and of required size, offering details about the proposed study	Abstract lacks relevance or fails to offer appropriate details about the proposed study or is too lengthy.	Abstract is missing or inappropriate given the problem, research questions, and method.
Introduction and Background	Articulates clear, reasonable, and succinct research questions, and questions are fresh, interesting and significant.	Research questions are stated clearly and are connected to the research topic.	Elements are poorly formed, ambiguous, or not logically connected to the description of the problem, purpose or research methods.	Research question(s), definitions, assumptions and limitations were omitted or inappropriate given the context, purpose or methods of the study.
Research Proposal	The purpose, questions, and design are mutually supportive and coherent. Appropriate and important limitations and assumptions have been clearly stated.	The research design has been identified and described in sufficiently detailed terms. Some limitations and assumptions have been identified.	The research design is confusing or incomplete given the research questions. Important limitations and assumptions have not been identified.	The research design is erroneous given the hypothesis or has not been identified and or described using standard terminology. Limitations and assumptions are omitted.
Broader Impacts	Includes interdisciplinary implications; benefits to society; engages diverse groups; partnerships; measurable outcomes.	Includes current outreach & teaching efforts; pubs & presentations; future plans well reasoned.	Lacks specifics; too loosely connected to scope of work; promises too much.	Failed to address; includes assertions or assumptions; no past/current efforts.
Organization	The narrative has the appropriate length and the ideas are presented in a clear structural and logic manner identifying reasonable well the reasons and means to achieve the goal of the proposal	Proposal format has been followed mostly. The narrative presents the ideas in an almost structural and logical manner.	The content and length of the proposal are inadequate (i.e. there is some logic in the narrative part, but the ideas lack clear focus and structural argumentation).	The length of the narrative exceeds the suggested limit as indicated in the solicitation. The ideas are presented in a random manner with no focus.