Plant Pathology/Botany/Entomology 505

Plant-Microbe Interactions: Molecular and Ecological Aspects

Meets: 9:55–10:40 MWF in A228 Russell Labs

Instructors:	Phone	email Address	Office	Office Hours
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Course Overview: Microbes and plants have developed intriguing strategies to encourage, resist or profit from their coexistence. This course is focused on the molecular mechanisms of plant-microbe interactions, drawing on the disciplines of genetics, biochemistry, molecular biology and cell biology. Several of the mutualistic or antagonistic interactions that we study illustrate broader principles and contribute to our fundamental understanding of biological processes. These interactions have a strong impact on agricultural ecosystems, and as such are also of applied importance.

Establishment of a relationship between a plant and a microbe may involve colonization, infection, nodulation, or systemic spread of a microbe in or on a plant. In the microbe, our focus will be on the mechanisms of host detection, colonization, virulence, and maintenance of the infection. We'll also consider microbial strategies to alter host physiology and morphology. We will explore ways to adapt microbial pathogens as powerful tools for scientific research. In the plant, our focus will be on the genes, gene products and biochemical events that control plant-microbe interactions, especially plant perception of microbial signals and associated defense mechanisms. Signal transduction pathways are a key element of plant-microbe interactions, and these will be studied. The tripartite interaction between pathogen, insect vector and host plant will also be covered. Finally, we'll discuss genetic modification of plants and microbes to improve agriculture.

Course goals: 1. To give students a sound and current understanding of the genetics and biochemistry of plant-microbe interactions, firmly anchored in a biological context.

2. To develop students' ability to read, abstract, and analyze original research literature.

Course Readings: The assigned readings will be distributed electronically on the "Learn@UW" course page, or rarely, as hard copies. Some background readings will be on reserve in the Plant Pathology Reading Room (583 Russell Labs).

Course Format: Mixed lecture and discussion on Mondays and Wednesdays; Fridays will be devoted to in-depth discussion of an original paper from the current literature.

Course Grading:

Class participation	10
Leading discussion/seminar write-up*	5
Discussion worksheets	25
Midterm Exam	30
Final Exam	30
Total	**100 points**

*****Graduate students will lead a Friday paper discussion. Undergraduate students will attend a seminar from a provided list and write a 1-page summary analysis.

Course Expectations

Participation (10 points): Students are expected to attend class regularly, read the assigned readings before the corresponding class session, and contribute substantially to class discussions. Please note that a significant part of your grade is based on your class participation, which consists of attendance, unannounced in-class writing exercises, and - most importantly - regular, informed, and meaningful contributions to class discussion. You are unlikely to earn an A or an AB in this course if you do not participate actively and effectively in class on a regular basis.

Leading a Paper Discussion (graduate students only) (5 points): Because one of the primary course goals is to help you understand the process of building new biological knowledge through experiments, we will work extensively from the primary research literature in this field. Before class on Fridays, all students will read a relevant journal article and all students other than the discussion leader will write comments on a Discussion Worksheet. Each Friday, a student will lead a class discussion of the paper. From 9:55 to 10:25 the discussion leader will present a very brief background introduction and then lead a class discussion of the most important data/figures/findings in the paper. Beginning no later than 10:25, we will then shift to a broader discussion of the implications of the work, and discuss future experiments that might most effectively advance our understanding in this area. Before leading discussion, the discussion leader should prepare by reading some additional background material. Discussion leaders are also **required** to meet with one of the instructors in advance to plan the discussion. Specific suggestions on leading discussions will be distributed. The student leading the discussion doesn't complete a worksheet.

Outside seminar attendance and write-up (undergraduate students only) (5 points). Undergraduate students who are not leading a discussion are required to attend a relevant plant-microbe or plant-insect research seminar on campus, chosen from a provided list from the Plant Pathology Departmental seminar series (Tuesdays at 3:30-4:30 in 150 Russell Labs) and other relevant public seminars. If you have a conflict with this time, a list of acceptable alternative seminars will be provided. You should submit a seminar worksheet about this seminar ***within 1 week of the seminar***. Late papers will not be accepted.

Discussion worksheets (25 points): Whenever there is a paper discussion, each student will be required to complete and turn in a typed worksheet on the assigned paper. This sheet is intended to encourage active, analytical reading of the paper and to prepare you for thoughtful participation in the discussion. A printed copy of your completed worksheet is due in class on the day the paper in question is discussed. Late worksheets will not be accepted. If your printer is not working, e-mail a copy of your worksheet to the instructor prior to class.

Exams: (30 points each) There will be written mid-term and final examinations**.** Exams are take-home and open-book: the questions will emphasize synthesis and analysis, not memorization. Sample exams from the previous year will be supplied as study aids.

Due date policy: You are expected to submit your written assignments by the due date. We will not accept late discussion worksheets or exams without advance permission.

Technique and Background Assistance: Many of the original research papers we will read assume familiarity with common molecular genetics research techniques, and we recognize that many students do not yet have such familiarity. Techniques will be reviewed briefly in class. If you are not fully conversant with the technique in question and would like further review, please ask! We can provide greater depth of coverage or, if we do not adequately explain the technique in class, we will be happy to go over the necessary material after class or in office meetings. The same goes for conceptual material. Our office doors, telephones and e-mail are open and we welcome student visits. If we are busy when you come by, let us know you are there and we will arrange to meet in a few minutes or at a later available time. If we are absent, leave a message. We are here to help you learn and we enthusiastically welcome your questions.

Academic Honesty:
You should be familiar with the University's standards for academic honesty as described on the Dean of Students Office web page http://students.wisc.edu/doso/acadintegrity.html and items accessible through that web page. Note as an instructive example UWS 14.03:
(1) Academic misconduct is an act in which a student:
(a) Seeks to claim credit for the work or efforts of another without authorization or citation;
(b) Uses unauthorized materials or fabricated data in any academic exercise;
(c) Forges or falsifies academic documents or records;
(d) Intentionally impedes or damages the academic work of others;
(e) Engages in conduct aimed at making false representation of a student's academic performance; or
(f) Assists other students in any of these acts.

In this course you are **encouraged** to discuss course material with each other, but **you must work alone when completing written assignments and exams**. Also, be alert to avoid plagiarism through the unattributed copying and use of sentences written by other persons. You should frequently consult scientific articles, books, reviews, commentaries and class notes, but **you must cite** in your papers and exams any sources that you rely on extensively or quote directly.

How Will PP505 Grades Be Determined?

Rubric for Participation Grade

	Exemplary 9-10 points	*Satisfactory* 5-8 points	*Limited/Unsatisfactory* 0-4 points
Attendance and In-Class Discussion	Never missed a class; always on time. Consistently active in discussions while leaving ample opportunities for others to also comment. Stimulated/sustained further group discussion by building on instructor or peer ideas, including building a focused argument around a specific issue, asking a new related question, or advancing a well-supported insight or oppositional hypothesis.	Missed only one class during the semester and notified the professor in advance. Contributed sometimes to ongoing class discussions, as evidenced by affirming statements, responses to instructor questions, asking related questions, or advancing a reasonably supported insight or oppositional hypothesis.	Missed more than one class with prior notice, or any classes without prior notice, or consistently late for class. Did not participate much in class discussions

Rubric for Discussion worksheet grading. (First and third sections of worksheets are graded; second section is only checked for presence of topical questions)

	Exceeds Expectations 3 points	*Meets Expectations* 2 points	*Doesn't Meet Expectations* 1 point	*No Worksheet* 0 points
Understanding	Went beyond understanding the reading content to integrate it with broader course themes and material learned outside this classroom.	Demonstrated comprehension of the assigned paper's hypotheses, experiments, and results.	Errors or misconceptions about the reading.	
Communication Quality	Very clear, not unnecessarily long or wordy.	Complete, grammatically correct sentences. Typed. Met length expectations	Grammar and spelling errors, or, very brief or excessively wordy, or, shallow coverage.	
Research Creativity	Exciting and/or original ideas for new research, of a quality found in fundable competitive grant proposals.	Logical, biologically relevant question(s). Proposed experiment(s) that plausibly test the new hypothesis.	Proposed work would result in only minor additional progress, or does not seem to successfully test relevant questions.	

PP505 Course Learning Objectives

Skills

1. Become comfortable reading & critically assessing research papers from the peer-reviewed science literature.

2. Become conversant in our current understanding of molecular plant-microbe interactions.

3. Refine your skill at presenting ideas at a professional level, in both oral and written form.

4. Develop ability to lead productive discussion, a key teaching skill

Concepts

1. Plants have evolved to co-exist with an enormous number and variety of microbes; some of these relationships are well-characterized but most are not.

2. Evolutionary selection pressure tends to discourage all-or-none strategies by hosts or by pathogens. Thus, most virulence factors and defense strategies are quantitative, additive, and functionally redundant.

3. Many pathogens carry a common set of tools (mechanisms) that allow them to enter and multiply in plants and survive host defenses.

4. Host-pathogen specificities are determined by discreet molecular interactions among microbes, vectors, and plants.

5. Many specific pathogen virulence mechanisms suppress specific host disease resistance mechanisms; study of virulence mechanisms can reveal previously unknown host defense mechanisms.

5. Plant-associated microbes are capable of rapid population increases and genetic change, adapting them to changing environments and changes in host resistance.

6. Plants have multiple forms and types of disease resistance. Plant disease resistance is active and interactive.

7. Plant disease resistance mechanisms are conserved, and there are parallels between plant-microbe and animal-microbe interactions.

8. The biology of host-pathogen interactions can itself provide useful tools for understanding these interactions.

Plant Pathology/Botany/Entomology 505 Schedule of Topics and Readings

Wk	Date	Inst	Topic	Readings
1	Jan 21 (W)	CA	Introduction to plant-microbe interactions: importance, variety, and two examples (*Metarhizium* and *Agrobacterium*) Course logistics.	Lucas 1998. Plant Pathology Ch. 1 & 2 *(Plant pathology fundamentals)* Behie 2012. Endophytic insect-parasitic fungi translocate nitrogen directly from insects to plants. *Science* 336:1576.
	Jan 23 (F)	CA	Plants as microbial habitat; overview of plant defense mechanisms	Chrispeels 2003. Plants, Genes, & Crop Biotechnology Ch. 8. Plant Growth & Development *(Botany fundamentals)*
2	Jan 26 (M)	CA	Introduction to cellular plant pathogens and the diseases they cause; How to make mutants and measure virulence.	Microbe of the Week (MOTW): *Xylella fastidiosa* Lucas 1998. Plant Pathology Ch. 8 Microbial Pathogenicity
	Jan 28 (W)	CA	Common problems, common tools in cellular pathogens (CWDE, toxins, hormones)	
	Jan 30 (F)	CA	**Student-led Paper Discussion**	Killiny 2013. Exopolysaccharide of *Xylella fastidiosa* is essential for biofilm formation, plant virulence, and vector transmission. *MPMI* 26:1044.
3	Feb 2 (M)	CA	Avoiding defenses: Microbial effectors	MOTW: Aster Yellows Phytoplasma Win 2012. Effector biology of plant-associated organisms: Concepts and perspectives. *CSH Symposia on Quant Biol*
	Feb 4 (W)	CA	Connecting virulence & resistance: The R gene/effector paradigm	Jones & Dangl 2006. The plant immune system. *Nature* 444:323-9.
	Feb 6 (F)	CA	**Student-led Paper Discussion**	MacLean 2014 Phytoplasma effector SAP54 hijacks plant reproduction by degrading MADS-box proteins and promotes insect colonization in a RAD23 *PLoS Biol* manner.
4	Feb 9 (M)	CA	Hide & Seek: PAMPs and MAMPs	MOTW: *Pseudomonas syringae pv. syringae* Pel 2013. Microbial recognition and evasion of host immunity. *J. Exp Bot*
	Feb 11 (W)	CA	TAL Effectors	Doyle 2013. TAL effectors: highly adaptable phytobacterial virulence factors and readily engineered DNA-targeting proteins. *Trends in Cell Biology* 23:390
	Feb 13 (F)	CA	**Student-led Paper Discussion**	Clarke 2013. Allelic variation in two distinct *Pseudomonas syringae* flagellin epitopes modulates the strength of plant immune responses

				but not bacterial motility. *New Phytologist*
5	Feb 16 (M)	CA	The Good Guys: Rhizobia	MOTW: *Sinorhizobium meloloti* Murray 2011. Invasion by invitation: rhizobial infection in legumes. *MPMI* 24:631.
	Feb 18 (W)	CA	The Good Guys: Mycorrhizae	Parniske 2008. Arbuscular mycorrhiza: the mother of plant root endosymbiosis. *Nature Rev Microbiol* 6:763. Delaux 2013. Evolution of the plant–microbe symbiotic 'toolkit'. *Trends Plant Sci* 18:298
	Feb 20 (F)	CA	**Student-led Paper Discussion**	Fellbaum 2014 Fungal nutrient allocation in common mycorrhizal networks is regulated by the carbon source strength of individual host plants. *New Phytologist*
6	Feb 23 (M)	CA	*Menage a mille*? Complex microbial populations associated with plants	MOTW: The Phytobiome Verholt 2014 Complexities of microbial life on leaf surfaces. *Microbe* Kemen 2014 Microbe–microbe interactions determine oomycete and fungal host colonization. *Curr Opin Plant Biol*
	Feb 24 (Tues)		Dr. Boris Vinatzer seminar 3:30-4:30. 150 Russell Labs	"Investigating the geographic and evolutionary origins of *Pseudomonas syringae* crop pathogens"
	Feb 25 (W)	CA	***Guest lecture by Dr. Boris Vinatzer, Virginia Tech University***	
	Feb 27 (F)	CA	**Student-led Paper Discussion**	Roberts 2013 Loline alkaloid production by fungal endophytes of *Fescue* sp select for epiphytic bacterial microflora. *ISME Journal*
7	Mar 2 (M)	MK	Surface sensing & penetration	MOTW: *Magnaporthe oryzae* Molecular mechanisms of mechanosensing and their roles in fungal contact sensing. 2008. *Nature Rev Microbiology* 6:667-673.
	Mar 4 (W)	MK	Signal transduction & biotrophic invasion strategies	Xu 2000. MAP kinases in fungal pathogens. *Fungal Genet Biol* 31: 137-152
	Mar 6 (F)	MK	**Student-led Paper Discussion**	Djamei 2011. Metabolic priming by a secreted fungal effector. *Nature* 478, 395–398
8	Mar 9 (M)	MK	Fungal effectors: What we (don't) know	MOTW: *Cladosporium fulvum* Giraldo 2013. Filamentous plant pathogen effectors in action. Nature Rev Microbiol 11,:800 Stergiopolis 2009. Fungal Effector Proteins. Ann Rev Phytopathol. 47: 233 -263
	Mar 11 (W)	MK	Gene 4 gene: Harold Flor and beyond	deJonge 2011. How filamentous pathogens co-opt plants: the ins and outs of fungal effectors. Curr Opin Plant Biol 14: 1–7

	Mar 13 (F)	MK	**Student-led Paper Discussion**	deJonge 2010. Conserved fungal LysM effector Ecp6 prevents chitin-triggered immunity in plants. Science 329: 953–955.
	Mar 14 (Sat)	***Take-home Midterm Exam 10 AM-2 PM***		
9	Mar 16 (M)	AB	Nematodes	Kyndt et al. 2013. Nematode feeding sites: unique organs in plant roots. Planta 238:807-818
	Mar 18 (W)	AB	***Guest lecture by Dr. Tarek Hewezi, University of Tennessee***	Mitchum et al. 2013. Nematode effector proteins: an emerging paradigm of parasitism. New Phytologist 199:879-894 (read sections I-IV and VI-end; skim section V)
	Mar 20 (F)	AB	**Student-led Paper Discussion**	Hamamouch et al. 2013. The interaction of the novel 30C02 cyst nematode effector protein with a plant β-1,3-endoglucanase may suppress host defence to promote parasitism. *J Exp Bot* 63:3683-3696
10	Mar 23 (M)	AR	What are viruses?	Rybicki. 2015 A Top Ten list for economically important plant viruses. *Arch. Vir*. 160: 17-20
	Mar 25 (W)	AR	Cellular remodeling during plant viral infection	Weber and Bujarski. 2015. Multiple functions of capsid proteins in (+) stranded RNA viruses during plant-virus interactions. 195:140-149
	Mar 27 (F)	AR	**Student-led Paper Discussion**	He W. et al. 2015. Differential profiles of direct and indirect modification of vector feeding behaviour by a plant virus. *Sci Rep*. 5 7682
Mar 28 - Apr 5			***No class – spring break***	
11	Apr 6 (M)	AR	Plant virus movement	Vuorinen 2011. Why do viruses need phloem for systemic invasion of plants? *Plant Science* 181:355.
	Apr 8 (W)	AR	Plant defense responses against viruses	Pallas & Garcia 2011. How do plant viruses induce disease? Interactions and interference with host components. *J Gen Virol* 92:2691-2705
	Apr 10 (F)	AR	**Student-led Paper Discussion**	Goic et al. (2013). RNA-mediated interference and reverse transcription control the persistence of RNA viruses in the insect model *Drosophila. Nature Immunology.*
12	Apr 13 (M)	AR	RNAi and suppressors of silencing	Burgyan & Havelda 2011. Viral suppressor of RNA silencing. *Trends Plant Sci.* 16265.
	Apr 15	AR	Plant virus transmission	Fereres. 2015. Insect vectors as drivers of plant

	(W)			virus emergence. *Current Opin Virol* 10:42-46
	April 17 (F)	AR	**Student-led Paper Discussion**	Weiberg. et al. 2013. Fungal Small RNA Suppress Plant Immunity by Hijacking Host RNA Interference Pathways. *Science* 342:6154:118-123
13	April 20 (M)	AB	Molecular Basis of Plant Disease Resistance	*Note: You should review the reading from Feb. 4:* Jones & Dangl 2006. The plant immune system. *Nature* 444:323-9. *And read this new assignment:* Hammond-Kosack, K. and Jones, J. 2000. "Responses to Plant Pathogens" Chapter 21 in: Buchanan, B. B., Gruissem, W. and Jones, R. L., eds. Biochemistry & Molecular Biology of Plants. Read pp. 1131-1147.
	April 22 (W)	AB	R Gene Products: Structure and Evolution	Takken 2012. How to build a pathogen detector: structural basis of NB-LRR function, *Curr Opin Plant Biol* 15: 375-384
	April 24 (F)	AB	**Student-led Paper Discussion**	Harris 2014. Stepwise artificial evolution of a plant disease resistance gene. *PNAS* doi/10.1073/pnas.1311134110
14	Apr 27 (M)	AB	Defense Signal Transduction	More use of: Hammond-Kosack and Jones 2000. pp. 1131-1147 (see April 13), and, Handouts
	Apr 29 (W)	AB	Effector-Based Plant Breeding	Vleeshouwers and Oliver 2014. Effectors as Tools in Disease Resistance Breeding against Biotrophic, Hemibiotrophic, and Necrotrophic Plant Pathogens. *MPMI* 27:196-206
	May 1 (F)	AB	**Student-led Paper Discussion**	To be determined
15	May 4 (M)	AB	Biotechnology for Plant Disease Control	Collinge, D. et al. 2010. Engineering pathogen resistance in crop plants: Current trends and future prospects. *Annu. Rev. Phytopathol*. 48:269-291.
	May 6 (W)	AB	Biotechnology for Plant Disease Control, part II	Abstracts-Handouts
	May 8 (F)	AB	**Student-led Paper Discussion**	To be determined
	May 15	***Take-home Final Exam***		

The class **Final Exam** will be an open-book take-home test mostly focused on the second half of the semester. This exam will be similar in format and length to the first exam, with a due date corresponding to the final exam time, which is 5:05 P.M. on Friday May 15. If you have a conflicting exam, please contact one of the instructors. The above schedule of topics and readings will be supplemented and revised during the semester.