BISC 579 Ecology & Evolution of Infectious Disease (EEID) Syllabus

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Office Hours: By appt.
Lecture: 408 Shoemaker Hall; Tu, Th 2:30-3:45 pm

Course Description: In recent years there has been an unprecedented rise in the global incidence and severity of infectious diseases in human, animal, and plant populations across nearly all of the world's terrestrial, aquatic, and marine ecosystems. At the same time, the ways in which we approach the prevention and management of diseases have changed little in the past 50-100 years. It is becoming increasingly clear that the intensification of diseases around the world is, in part, due to human activities, which have brought about habitat transformation, biological invasions, environmental contamination, climate change, and ensuing losses of biodiversity. Although disease outbreaks have historically been studied in relative isolation, the ecological complexities of disease development and spread have been clearly illustrated by such famous examples as the plague, smallpox, and flu epidemics, the Irish potato blight, and more recently, the swine flu epidemic, amphibian chytridiomycosis, white nose disease of bats, Tasmanian devil facial tumor disease, bee colony collapse disease, various forest declines, SARS, Lyme disease, West Nile virus and now Zika virus.

In this course we will examine and discuss current concepts and trends in infectious disease biology, assessing our basic understanding of human and wildlife diseases and their impacts on one another. When new concepts are introduced and a broad view is needed as an introduction, we will be reading selected book chapters and review papers. We will then deepen our understanding of the concepts by reading primary literature, which will be discussed in depth during class time. Articles from the primary and secondary literature have been selected for various reasons, including everything from studies that beautifully illustrate the implementation of the concepts you are learning to studies that present major disagreements amongst researchers in terms of methodology and interpretation.

On a most basic level, this is a class based around problem solving and critical thinking. We will focus on problems related to the ecological and evolutionary processes that drive the transmission of pathogens between hosts; the impact of disease on host populations; and what causes the emergence of an infectious disease. The course content includes a theoretical framework and extensive discussion of wildlife and human diseases.

Course Goals/Learning Objectives:

- An appreciation for the complexity of disease, including the number of disciplines that are involved in a thorough understanding of any given disease (e.g., ecology, evolution,

epidemiology, clinical medicine, economics, politics, agriculture, wildlife management, public health,…).
- The ability to integrate ecological and evolutionary concepts and theory in ways that inform disease models/predictions/control.
- Basic knowledge of parasite diversity and host defensive repertoires.
- Ability to skillfully read and synthesize primary literature.
- Ability to effectively convey the natural history and current literature pertaining to an infectious disease in an oral presentation
- *Graduate students:* Ability to review the historical and current literature regarding a specific infectious disease in the context of disease ecology in a research paper format

Grades (Undergraduates): Leading discussions 25%; Participating in discussions 25%; Homework Assignments 20%; Final presentation 15%; Journals 15%

Grades (Graduates): Leading discussions 25%; Participating in discussions 25%; Homework Assignments 20%; Presentation 10%; Research Paper 10%; Journals 10%;

Grading scheme:

A	90-100%
B	80-89%
C	70-79%
D	60-69%
F	<60%

Course Readings: There is no single book, but the assigned readings are absolutely essential to success in this course. We will read a mix of book chapters, review papers, and primary literature to facilitate learning and discussion in this course. **Therefore, readings must be completed prior to coming to class. There is a lot of reading.** Putting the time in to not only read the assigned papers, but think about them as you do so is absolutely essential to the success of the course and for your ability to participate in informed analysis and debate during discussions. Assigned readings are listed in this syllabus, and pdfs of each will be posted on Blackboard at least one full week before they are due.

Journals: You are required to write about your thoughts and reflections of the week's major ideas, activities, discussion, and remaining questions or controversies that came up either in or outside of class. These journals are mainly for you to review and reinforce what you learned each week. They have the added benefit of providing feedback to the instructor about the effectiveness of the classroom activities and readings for teaching you the desired concepts and skills. Entries are to be submitted online through the course Blackboard page by 5pm each Friday (not including Spring break). A minimum of three sentences is adequate, but a longer discussion is welcome as well.

Homework: Your homework points will be awarded based on work you will hand in: 2 homework assignments and 2-3 in class activities (case studies and games) Due dates for homework assignments are given in the course schedule.

Presentation: A powerpoint presentation will be required for all class participants and all students are required to attend each presentation and ask relevant questions following the presentations. The final presentation will consist of a 15-min overview of an infectious disease not covered in detail in class or assigned readings. Presentations of each disease must be placed within the most relevant conceptual framework(s) discussed over the course of the semester and must include information regarding host and pathogen natural history as well as current research regarding the disease. Specific topics will be chosen mid-semester in consultation with me.

Research Paper: *Graduate students* enrolled in the course will also write an approximately 8-page paper associated with their presentation topic, to be turned in before 4pm on May 4th. These papers must be double-spaced and 12 point font. This paper will address some aspect of the topic that the student finds of particular interest (especially something related to their thesis or dissertation if possible). Papers must have a minimum of 10 references drawn from the primary or secondary literature (no websites and no "gray" literature unless discussed with me first). Note that references must be cited appropriately; see the citations in this syllabus for examples of appropriate citation styles.

Attendance: Be aware that attendance and discussion are a large portion of your grade. If you miss class, your final letter grade will reflect this.

****Note:** If there is a topic you would like included in the readings and discussion, please contact me.

Wk	Day	Topic	Readings	Leader
1	Tue	Syllabus, course expectations; Evolutionary thinking; What is disease ecology, and what is it good for?	1*, 2*	Balenger
1	Thu	Ecological theory and disease	3-5	Balenger
2	Tue	Fundamental theory: SIR models, R0, Frequency and density dependent transmission	6,7	Balenger
2	Thu	Fundamental theory: SIR models, R0, Frequency and density dependent transmission	8,9	Balenger
3	Tue	Diversity and natural history of parasites & pathogens	10	1
3	Thu	Host defenses - the immune system	11	2
4	Tue	Coping with infection: resistance and tolerance of parasites in Soay sheep (CASE STUDY)	12,13 + hand out	Balenger
4	Thu	Evolution of virulence: hosts, pathogens, vectors	14,15	3
5	Tue	Evolution of virulence: coevolution and generalism	16,17	4
5	Thu	Coevolution – Myxoma virus and wild rabbits	18,19	Balenger
6	Tue	Community ecology and biodiversity	20,21	5
6	Thu	Directly transmitted human pathogens	22,23	1
7	Tue	Ebola (CASE STUDY?)	24,25	Balenger
7	Thu	Livestock, wildlife pathogens	26,27	2
8		SPRING BREAK		
9	Tue	Disease control: Vaccination, Behavioral changes, culling	28,29,30	3
9	Thu	Cholera	31,32	4
10	Tue	Cholera Outbreak (CASE STUDY)	hand out	Balenger
10	Thu	*Homework due; Class discussion of cholera models*		Balenger
11	Tue	Pathogen interactions via the immune system, and parasite caused changes in host behavior	33,34	5
11	Thu	Herd immunity	35,36	1
12	Tue	Malaria I – *Class discussion of readings*	37,38	2
12	Thu	Malaria II – *Homework due; Class discussion of readings*	39,40	3
13	Tue	Seasonality, climate change and transmission dynamics	41,42,43	4
13	Thu	Evolution proofing drugs	44,45,46	5
14	Tu	Presentations		
14	Th	Presentation		
15	Tu	Presentations		
15	Th	Presentations		

Readings

*1 Stearns, S.C., Evolutionary Medicine. Pp. 1-23. (2016). *Basic introduction to evolutionary biology (from a human disease perspective). If you have taken a course in Evolution then this is not necessary.*

*2 Schmid-Hempel, P., Evolutionary Parasitology. Pp. 9-17. (2011). *Basic introduction to evolutionary biology (a broader host-parasite evolution perspective). If you have taken a course in Evolution then this is not necessary.*

3 Kilpatrick, A. M. and Altizer, S., Disease Ecology. *Nature Education Knowledge* 1 (11), 13 (2010).

4 Smith, K. F., Dobson, A. P., McKenzie, F. E., Real, L. A., Smith, D. L., and Wilson, M. L., Ecological theory to enhance infectious disease control and public health policy *Frontiers in Ecology and the Environment* 3 (1), 29 (2005).

5 Plowright, R. K., Sokolow, S. H., Gorman, M. E., Daszak, P., and Foley, J. E., Causal inference in disease ecology: investigating ecological drivers of disease emergence *Frontiers in Ecology and the Environment* 6 (8), 420 (2008).

6 Anderson, R. M. and May, R. M., A framework for discussing the population biology of infectious diseases in *Infectious diseases of humans. Dynamics and control.* (Oxford University Press, London, 1991), pp. 13.

7 Lloyd-Smith, J. O., Cross, P. C., Briggs, C. J., Daugherty, M., Getz, W. M., Latto, J., Sanchez, M. S., Smith, A. B., and Swei, A., Should we expect population thresholds for wildlife disease? *Trends in Ecology & Evolution* 20 (9), 511 (2005).

8 Anderson, R. M. and May, R. M., Population biology of infectious diseases I *Nature* 280 (5721), 361 (1979).

9 May, R. M. and Anderson, R. M., Population Biology of Infectious-Diseases II *Nature* 280 (5722), 455 (1979).

10 Schmid-Hempel, P., Evolutionary Parasitology. Pp. 18-51. (2011).

11 Schmid-Hempel, P., Evolutionary Parasitology. Pp. 52-97. (2011).

12 Schneider, D.S., and J.S. Ayres. 2008. Two ways to survive infection: what resistance and tolerance can teach us about treating infectious diseases. *Nature Reviews: Immunology* 8: 889–95.

13 Medzhitov, R., D.S. Schneider, and M.P. Soares. 2012. Disease tolerance as a defense strategy. *Science* 335: 936–41.

14 Grenfell, B. T., Pybus, O. G., Gog, J. R., Wood, J. L. N., Daly, J. M., Mumford, J. A., and Holmes, E. C., Unifying the epidemiological and evolutionary dynamics of pathogens *Science* 303(5656), 327 (2004).

15 Mackinnon, M. J., Gandon, S., and Read, A. F., Virulence evolution in response to vaccination: The case of malaria *Vaccine* 26, C42 (2008).

16 Woolhouse, M. E. J., Webster, J. P., Domingo, E., Charlesworth, B., and Levin, B. R., Biological and biomedical implications of the co-evolution of pathogens and their hosts *Nature Genetics* 32 (4), 569 (2002).

17 Brown A.P., Cornforth D.M., and Mideo N. (2012) Evolution of virulence in opportunistic pathogens: generalism, plasticity, and control. *Trends in Microbiology* 20: 336-342.

18 Kerr, P.J., Myxomatosis in Australia and Europe: A model for emerging infectious diseases. *Antiviral Research* 93, 387-415 (2012).

19 Kerr P., Isabella M. Cattadori, June Liu, Derek G. Sim, Jeff W. Dodds, Jason W. Brooks, Mary J. Kennett, Edward C. Holmes, and Andrew F. Read (2017) Next step in the ongoing arms race between myxoma virus and wild rabbits in Australia is a novel disease phenotype. *Proceedings of the National Academy of Sciences* 114 (35) 9397-9402.

20 Holdo, R. M., Sinclair, A. R. E., Dobson, A. P., Metzger, K. L., Bolker, B. M., Ritchie, M. E., and Holt, R. D., A Disease-Mediated Trophic Cascade in the Serengeti and its Implications for Ecosystem C *Plos Biology* 7 (9), e1000210 (2009).

21 Ostfeld R.S, Keesing F. and LGuidice K. (2006) Community ecology meets epidemiology. In: Disease ecology: Community structure and pathogen dynamics. Eds. S. K. Collinge and C. Ray. Pp 28-40.

22 Woolhouse, M. E. J., Dye, C., Etard, J. F., Smith, T., Charlwood, J. D., Garnett, G. P., Hagan, P., Hii, J. L. K., Ndhlovu, P. D., Quinnell, R. J., Watts, C. H., Chandiwana, S. K., and Anderson, R. M., Heterogeneities in the transmission of infectious agents: Implications for the design of control programs *Proceedings of the National Academy of Sciences* 94 (1), 338 (1997).

23 Ferguson, N. M., Cummings, D. A. T., Fraser, C., Cajka, J. C., Cooley, P. C., and Burke, D. S., Strategies for mitigating an influenza pandemic *Nature* 442 (7101), 448 (2006).

24 Aylward B, Barboza P, Bawo L, et al. Ebola Virus Disease in West Africa – The First 9 Months of the Epidemic and Forward Projections. *N Engl J Med* 2014; 371(16): 1481-95.

25 Viboud C., Broutin H., and Chowell G. (2018) Spatial-temporal transmission dynamics and control of infectious diseases: Ebola virus disease (EVD) as a case study. In: Ecology and Evolution of Infectious Diseases: Pathogen control and public health management in low income countries. Eds. B. Roche, H. Broutin, and F. Simard. Pp.43-58.

26 Hochachka WM, Dhondt AA. Density-dependent decline of host abundance resulting from a new infectious disease. *Proc Natl Acad Sci U S A* 2000; 97(10): 5303-6.

27 Dobson, A. and Meagher, M., The population dynamics of brucellosis in the Yellowstone National Park *Ecology* 77 (4), 1026 (1996).

28 Fraser, C., Riley, S., Anderson, R. M., and Ferguson, N. M., Factors that make an infectious disease outbreak controllable *Proceedings of the National Academy of Sciences of the United States of America* 101 (16), 6146 (2004).

29 Galvani, A. P., Reluga, T. C., and Chapman, G. B., Long-standing influenza vaccination policy is in accord with individual self-interest but not with the utilitarian optimum *Proceedings of the National Academy of Sciences of the United States of America* 104 (13), 5692 (2007).

30 Bielby J., Donnelly C.A., Pope L.C., Burke T. and Woodroffe R. (2014) Badger responses to small-scale culling may compromise targeted control of bovine tuberculosis. *Proceedings of the National Academy of Sciences* 111: 9193-9198.

31 Vynnycky E., and White, R.G., An Introduction to Infectious Disease Modelling. Pp. 13-37 (2010).

32 Harris, J. B., R. C. LaRocque, F. Qadri, E. T. Ryan, and S. B. Calderwood. 2012. Cholera. Lancet 379:2466-2476.

33 Schmid-Hempel, P., Evolutionary Parasitology. Pp. 187-218. (2011).

34 Hughes D.P. and Libersat F. (2018) Neuroparasitology of parasite-insect associations. *Annual Review of Entomology* 63: 471-487.

35 Metcalf, C. J. E., M. Ferrari, A. L. Graham, and B. T. Grenfell. 2015. Understanding Herd Immunity. *Trends in Immunology* 36:753-755.

36 Brisson M., et al. (2016) Population-level impact, herd immunity, and elimination after human papillomavirus vaccination: a systematic review and meta-analysis of predictions from transmission dynamic models. *The Lancet* 1: e8-17.

37 Sachs, J. and Malaney, P., The economic and social burden of malaria *Nature* 415, 680 (2002).

38 Alonso PL, Brown G, Arevalo-Herrera M, et al. A Research Agenda to Underpin Malaria Eradication. *PLoS Med* 2011; 8(1) e1000400.

39 Mordecai EA, Paaijmans KP, Johnson LR, et al. Optimal temperature for malaria transmission is dramatically lower than previously predicted. *Ecol Lett* 2013; **16**(1): 22-30.

40 Gething, P. W., D. L. Smith, A. P. Patil, A. J. Tatem, R. W. Snow, and S. I. Hay. 2010. Climate change and the global malaria recession. *Nature* 465:342-346.

41 Ostfeld, R. S., Canham, C. D., Oggenfuss, K., Winchcombe, R. J., and Keesing, F., Climate, deer, rodents, and acorns as determinants of variation in Lyme-disease risk *Plos Biology* 4 (6), 1058 (2006)

42 Rohr, J. R., Raffel, T. R., Romansic, J. M., McCallum, H., and Hudson, P. J., Evaluating the links between climate, disease spread, and amphibian declines *Proceedings of the National Academy of Sciences of the United States of America* 105 (45), 17436 (2008)

43 Gozlan R.E. and Combe M. (2018) Environmental change and pathogen transmission. In: Ecology and Evolution of Infectious Diseases: Pathogen control and public health management in low income countries. Eds. B. Roche, H. Broutin, and F. Simard. Pp.59-76.

44 Levy SB, Marshall B. Antibacterial resistance worldwide: causes, challenges and responses. *Nat Med* 2004; 10(12): S122-S9.

45 Read AF, Day T, Huijben S. The evolution of drug resistance and the curious orthodoxy of aggressive chemotherapy. *Proc Natl Acad Sci U S A* 2011; 108: 10871-7.

46 Read AF, Lynch PA, Thomas MB. How to Make Evolution-Proof Insecticides for Malaria Control. *PLoS Biol* 2009; 7(4): e1000058.

Make up work:

- If you have a documented school function (marching band, game) or research-related function (conference, workshop) that requires you to miss class you must provide documentation in advance.

Students with disabilities:

- University policy provides for reasonable accommodations to be made for students with verified disabilities on an individualized and flexible basis as specified under Section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act of 1990 (ADA).
- SDS provides classroom accommodations to all students on campus who disclose a disability, request accommodations, and who meet eligibility criteria. We do not have specialized programs for specific types of disabilities.
- It is the responsibility of any student with a disability who requests a reasonable accommodation to contact the Office of Student Disability Services (915-7128). SDS will then contact the instructor through the student by means of an Instructor Notification of Classroom Accommodations form.

Cheating:

- Is, of course, unacceptable. This absolutely includes plagiarism. Any assignment including plagiarized material will automatically be given 0 points, and extreme cases of cheating and/or plagiarizing will result in failure of the course.

Disclaimer:

The instructor retains the right to modify this syllabus during the semester. Students will be notified of modifications during class.