

INTEGBI 172 - Coevolution: from genes to ecosystems (4 units)

INSTRUCTOR: TBD

GSI: to be determined

INSTRUCTOR INFORMATION

The instructor **believes in the need for increased diversity in science, and works to foster a classroom and research environment in which all opinions and ideas are valued**, and where each student feels empowered to offer new insight to a rapidly developing field.

COURSE FORMAT

Two 1.5-hour lectures per week and one hour of discussion section focused on developing case studies for textbook.

We will begin with pairwise species interactions, and build up slowly to community-level interactions and ecosystem stability. Each week you will be assigned two papers to read in preparation for discussion. You will also work in groups to research and lead a discussion for one of the weeks (to be assigned at the first class). Classes will consist of a 45 minute interactive lecture about the upcoming assigned reading, and then either an in-class exercise/quiz or discussion (45 minutes). The topic on which you lead discussion will also be the focus of your case study for the textbook. The final project involves a poster presentation on the evidence of coevolution from a species interaction of your choice. Be creative and have fun!

PREREQUISITES

Bio 1A and Bio 1B or equivalent required, Genetics or Evolution course suggested.

FULL COURSE DESCRIPTION AND AIMS

The biological world is shaped by interactions among species. These inter-specific interactions, such as between predators and prey, plants and pollinators, or hosts and pathogens, have led to an impressive array of adaptations, helping to explain the incredible organismal and genetic diversity on Earth. Our understanding of coevolution (the responses to reciprocal selection acting on two interacting populations) has been greatly facilitated in the last few years by conceptual advancements, new methods allowing direct tests of theory, next generation sequencing technology, and the advance of 'omics' approaches. But interest in this topic has also increased in light of increasing evidence that human health and happiness is dependent on interactions with other organisms, including the vast array of microbial species that live in and on us (our microbiota).

The aim of this course is to explore the multitude of ways in which one unit of selection (whether it be a gene, cell, subpopulation, population, or community) reciprocally influences the evolution of other units

of selection. **Among the questions we will explore are:** Why do pathogens cause harm to their hosts? How does selection shape elaborate traits associated with plants and pollinators? Why do the phenotypes of sexes across many species differ so dramatically? How much of the diversity we observe on earth is the result of coevolutionary interactions? Why do some predators specialize on prey while others do not? What mechanisms ensure mutualistic interactions remain beneficial to all involved? How is the microbiome formed and how is it influencing the evolution of eukaryotes? And what role might coevolution play in maintaining the stability of an ecosystem? **Not all species interactions lead to and/or are shaped by coevolution, and it requires both a firm knowledge base and ability to think critically about ecology and evolution to discern when coevolution is likely to be occurring.** The development of this understanding is of particular relevance in light of recent human-mediated environmental change, the emergence of new diseases, and the myriad of ways in which humans are engineering organisms in nature. In order to predict the impacts of these changes at the population, community, and ecosystem levels we need to understand the influence of coevolution across scales. **By the end of the course, you should be able to make such informed predictions and understand how to go about testing them in the future.**

INTENDED LEARNING OUTCOME

- Infer patterns of species interactions by comparing phylogenies, critically examining scientific evidence, and synthesize conclusions from multiple studies.
- Demonstrate a detailed understanding of the traits underlying species interactions and how these traits might evolve through time.
- Formulate and defend hypotheses on how evolution and coevolution might lead to diversification within and among populations, and even lead to new species.
- Apply simple models to untangle the complex nature of ecological interactions.
- Identify practical methods for the study of coevolutionary interactions.
- Interpret relevant information from the primary literature on the evolution and ecology of species interactions.
- Participate in group discussions.
- Work with others to develop and propose an experiment you could use to test basic coevolutionary theory.
- Lead group discussion on a particular paper topic.
- Write a case study written for a general audience describing a specific coevolutionary interaction.
- Present a scientific poster on the evidence for coevolution between a pair of species.

TEXTBOOK

There isn't one.... yet. **Over the course of the semester you and I are going to collaboratively begin writing the first online, freely accessible textbook on coevolution.** One of the key goals of this course is to develop your ability to think critically about coevolution and use the theory to help determine whether a particular interaction is likely to be coevolving. As such, you will work both independently and in groups to choose case studies that best illustrate a given concept and to write these up in a text book format (i.e. accessible to those new to coevolution). This project will form a large part of your final grade, will be presented in the form of a poster to your classmates, and will allow you to think deeply about the coevolutionary process. **These case studies will be revised and collaboratively edited over the course of the semester with the end product being a publically available online textbook to which each of you (should you wish) will be named as contributors.**

ASSESSMENT: (% of Final Grade, Due date)

Midterm (15%, 3/2/17): Multiple choice (40%), short answer (60%)

Poster (on species interaction of your choice; 20%, 4/6/17)

Participation in weekly discussion (10%, throughout term)

Role as discussion leader (in groups; 10%, once per term)

Textbook coevolution case study (25%, due before 4/27/17)

Final exam (20%, Finals week): Multiple choice (35%), short answer (50%), one essay (15%)

ABSENCES

Each student can miss up to 3 class sessions without penalty, no need to contact me. If these absences are not used, students can drop the lowest 1 to 3 (depending on absences taken) scores they have on exercises/quizzes/participation.

COURSE SCHEDULE

Each week (Tuesday) I will offer a lecture and exercise that will introduce you to the readings we will discuss (Thursday). The readings are all primary literature from peer-reviewed science journals, and you should therefore expect to be confused and to not understand everything. **Learning to read the literature is a skill that takes time to develop** (as is writing it! And some of the authors you will read are still learning how to communicate their science effectively), so be patient with yourself and give yourself enough time to read the papers. Focus first on the big picture and key results; do you understand the main message from the paper? Can you explain why it's interesting? Then re-read the paper and try to get a bit more from it; where are your points of confusion? What do you find to be most interesting about the paper? If you go through this process each week, you will have no problem taking part in class discussions. Asking for clarification on points of confusion are just as useful of a contribution as sharing your ideas about what makes the paper strong (or weak)!

- 1/17/17 Introduction to Coevolution, Exercise 1: What is coevolution to you?
1/19/17 Lecture 1: The types of coevolutionary interactions; Discussion 1 (instructor lead):
Janzen, D. H. (1980). When is it coevolution. *Evolution*, 34(3), 611-612.
- 1/24/16 Lecture 2: Competition; Exercise 2: Finding your own niche space.
1/26/17 Lecture 3: Character displacement; Discussion 2: Grant, P. R., & Grant, B. R. (2006).
Evolution of character displacement in Darwin's finches. *science*, 313(5784), 224-226 /
Stuart, Y. E., & Losos, J. B. (2013). Ecological character displacement: glass half full or
half empty?. *Trends in ecology & evolution*, 28(7), 402-408.
- 1/31/17 Lecture 4: Host-pathogen interactions; Exercise 3: Modelling coevolution
2/2/17 Lecture 5: Evolution of virulence; Discussion 3: Lively, C. M., & Dybdahl, M. F. (2000).
Parasite adaptation to locally common host genotypes. *Nature*, 405(6787), 679-681 /
Scanlan, P. D., Hall, A. R., Blackshields, G., Friman, V. P., Davis, M. R., Goldberg, J. B., &
Buckling, A. (2015). Coevolution with bacteriophages drives genome-wide host
evolution and constrains the acquisition of abiotic-beneficial mutations. *Molecular
biology and evolution*, 32(6), 1425-1435.
- 2/7/17 Lecture 6: Plant-pollinator interactions; Exercise 4: Attracting the right pollinator
2/9/17 Lecture 7: Chemical ecology underlying species interactions; Discussion 4: Hu, S.,
Dilcher, D. L., Jarzen, D. M., & Taylor, D. W. (2008). Early steps of angiosperm-pollinator
coevolution. *Proceedings of the National Academy of Sciences*, 105(1), 240-245 /
Schiestl, F. P., & Dötterl, S. (2012). The evolution of floral scent and olfactory
preferences in pollinators: Coevolution or pre-existing bias? *Evolution*, 66(7), 2042-
2055.
- 2/14/17 Lecture 8: Mimicry; Exercise 5: Chasing another species through trait space
2/16/17 Lecture 9: Coevolution within communities; Discussion 5: Kapan, D. D. (2001). Three-
butterfly system provides a field test of Müllerian mimicry. *Nature*, 409(6818), 338-340 /
Langmore, N. E., Stevens, M., Maurer, G., Heinsohn, R., Hall, M. L., Peters, A., & Kilner, R.
M. (2011). Visual mimicry of host nestlings by cuckoos. *Proceedings of the Royal Society
of London B: Biological Sciences*, 278(1717), 2455-2463.
- 2/21/17 Lecture 10: Predator-prey interactions; Exercise 6: Cyclical dynamics of predators and
prey; how they happen and why they matter.

- 2/23/17 Lecture 11: Experimental coevolution; Discussion 6: Koskella, B., & Lively, C. M. (2009). Evidence for negative frequency-dependent selection during experimental coevolution of a freshwater snail and a sterilizing trematode. *Evolution*, 63(9), 2213-2221 / Brockhurst, M. A., & Koskella, B. (2013). Experimental coevolution of species interactions. *Trends in ecology & evolution*, 28(6), 367-375.
- 2/28/17 Lecture 12: Coevolving with your microbiome; Exam review session
3/2/17 MIDTERM EXAM
- 3/7/17 Lecture 14: Herbivory; Exercise 7: Trade-offs in defense
3/9/17 Lecture 15: Diffuse Coevolution; Discussion 7: Iwao, K., & Rausher, M. D. (1997). Evolution of plant resistance to multiple herbivores: quantifying diffuse coevolution. *American Naturalist*, 316-335 / Agrawal, A. A., Hastings, A. P., Johnson, M. T., Maron, J. L., & Salminen, J. P. (2012). Insect herbivores drive real-time ecological and evolutionary change in plant populations. *Science*, 338(6103), 113-116.
- 3/14/17 Lecture 16: Mutualisms; Exercise 8: The prisoner's dilemma
3/16/17 Lecture 17: How to prevent a cheat; Discussion 8: Currie, C. R., Wong, B., Stuart, A. E., Schultz, T. R., Rehner, S. A., Mueller, U. G., ... & Straus, N. A. (2003). Ancient tripartite coevolution in the attine ant-microbe symbiosis. *Science*, 299(5605), 386-388 / Eilers, J., Toby Kiers, E., Currie, C. R., McDonald, B. R., & Visser, B. (2012). Ecological interactions drive evolutionary loss of traits. *Ecology letters*, 15(10), 1071-1082.
- 3/21/17 Lecture 18: The Geographic Mosaic Theory; Exercise 9: Interpreting variation across space
3/23/17 Lecture 19: Generation and maintenance of diversity; Discussion 9: Anderson, B., & Johnson, S. D. (2008). The geographical mosaic of coevolution in a plant-pollinator mutualism. *Evolution*, 62(1), 220-225 / Hembry, D. H., Yoder, J. B., & Goodman, K. R. (2014). Coevolution and the diversification of life. *The American Naturalist*, 184(4), 425-438.
- 3/28/17 SPRING BREAK
3/30/17 SPRING BREAK
- 4/4/17 Lecture 20: Time shift experiments; Exercise 10: Predicting results from a time shift experiment.
4/6/17 POSTER SESSION
- 4/11/17 Lecture 21: Temporal and spatial scales of coevolution; Discussion 10: Gaba, S., & Ebert, D. (2009). Time-shift experiments as a tool to study antagonistic coevolution. *Trends in Ecology & Evolution*, 24(4), 226-232 / Betts, A., Kaltz, O., & Hochberg, M. E. (2014). Contrasted coevolutionary dynamics between a bacterial pathogen and its bacteriophages. *Proceedings of the National Academy of Sciences*, 111(30), 11109-11114.
- 4/13/17 Lecture 22: Cospeciation and diversification; Exercise 11: Comparing phylogenies
- 4/18/17 Lecture 23: Ecosystem stability; Discussion 11: Buckling, A., & Rainey, P. B. (2002). The role of parasites in sympatric and allopatric host diversification. *Nature*, 420(6915), 496-

4/20/17	499 / Estes, J. A., Terborgh, J., Brashares, J. S., Power, M. E., Berger, J., Bond, W. J., ... & Marquis, R. J. (2011). Trophic downgrading of planet Earth. <i>science</i> , 333(6040), 301-306. Lecture 24: Coevolution in agriculture; Exercise 12: Designing evolution-proof treatments
4/25/17	Lecture 25: Coevolution in medicine; Discussion 12: Brown, J. K. (2015). Durable resistance of crops to disease: a Darwinian perspective. <i>Annual review of phytopathology</i> , 53, 513-539 / Anisimova, M. (2015). Darwin and Fisher meet at biotech: on the potential of computational molecular evolution in industry. <i>BMC evolutionary biology</i> , 15(1), 1.
4/27/17	Lecture 26: Where the coevolution field is heading; Exam review session
5/2/17	RRR WEEK
5/4/17	RRR WEEK
5/8-5/12	FINAL EXAM