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

INSTRUCTOR: Prof Britt Koskella
DROP-IN hours: Zoom on Mondays at 10am (https://berkeley.zoom.us/j/9670873327) or by appointment
Email: bkoskella@berkeley.edu
Webpage: http://www.naturesmicrocosm.com

CLASS TIME: Tuesdays and Thursdays, 3:30-5pm
CLASS LOCATION: Zoom (https://berkeley.zoom.us/j/98402414073)
bCourses site: INTEGBI 172 - LEC 001

DISCUSSION SECTION TIME: Fridays 1-2pm
DISCUSSION SECTION LOCATION: Zoom (https://berkeley.zoom.us/j/92406191063)
GSI: Valeria Ramirez Castaneda (vramirezc@berkeley.edu)
DROP-IN hours: Mondays 11 AM - 12 PM (https://berkeley.zoom.us/j/99734736877)

INSTRUCTOR INFORMATION

Prof Koskella has broad training in Ecology and Evolution, with a particular focus on host-pathogen interactions. Her research began as an undergraduate student examining the genetics of a fungal 'smut' pathogen that sterilizes flowers, then continued during her PhD where she used a snail-trematode interaction to test for the importance of host-parasite coevolution in driving diversity, and most recently has been focused on how bacteriophage viruses influence their bacterial hosts, and what effects this might have on the eukaryotic hosts in which these bacteria live. **Prof Koskella 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 synchronous class sessions per week and one hour of discussion section focused on developing case studies for our online, collaborative 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 a paper 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 30 minute interactive lecture about the upcoming assigned reading, a 30 minute individual assignment, and then either an in-class exercise/quiz or discussion (30 minutes).
The final project is a two-part assessment: the first involves a poster presentation on the evidence of coevolution from a species interaction of your choice, and the second is a written case study of this system. 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 a published one…. yet. **Over the course of the semester you and I are going to continue collaboratively 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 independently 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 publicly available online textbook to which each of you (should you wish) will be named as contributors**.

ASSESSMENT: (% of Final Grade, Due date)

Midterm (15%): Multiple choice (40%), short answer (60%)
Poster (on species interaction of your choice; 20%)
Participation (10%, throughout term)
Role as discussion leader (in groups; 10%, once per term)
Textbook coevolution case study (25%)
Final exam (20%, Finals week): Multiple choice (35%), short answer (50%), one essay (15%)

ABSENCES

These are unprecedented times, and I will make sure that you can succeed despite any unforeseen circumstances you encounter. **All students can miss up to 6 synchronous class sessions** without penalty, no need to contact me. The classes will be recorded and posted the same day, and students unable to attend class can still receive the participation points by watching the recording and submitting the individual assignment of the day (ideally within a week of the absence).

COURSE SCHEDULE

Each week (Tuesday) I will offer a short lecture* and exercise that will introduce you to the reading 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)!

> * *My lectures were designed to be 45 minutes, and sometimes rain to the hour. However, with the Zoom format, I will stick to strictly 30 minutes and cover any additional content with a video-recorded lecture on Kaltura.*

1/19/21	Introduction to Coevolution
1/21/21	Lecture 1: The types of coevolutionary interactions; **Discussion 1** on Janzen paper (instructor lead, but be prepared with thoughts/questions on reading)
Friday:	How to lead an active discussion. How to develop discussion questions. How not to dominate the conversation, but rather lead it.
Reading:	Janzen, D. H. (1980). *When is it coevolution*. Evolution, 34(3), 611-612. *Textbook chapter 1: Introduction to Coevolution*
1/26/21	Lecture 2: Competition; Exercise 2: Finding your own niche space.
1/28/21	Lecture 3: Character displacement; **Discussion 2**: Grant & Grant (student lead; group 2).
Friday:	How to read a scientific paper.
Reading:	Grant, P. R., & Grant, B. R. (2006). *Evolution of character displacement in Darwin's finches*. science, 313(5784), 224-226. *Textbook chapter 2: Competition and ecological character displacement*
Optional:	Stuart, Y. E., & Losos, J. B. (2013). *Ecological character displacement: glass half full or half empty?* Trends in ecology & evolution, 28(7), 402-408.
2/2/21	Lecture 4: Host-pathogen interactions; Exercise 3: Modelling coevolution
2/4/21	Lecture 5: Evolution of virulence; **Discussion 3**: Lively & Dybdahl (student lead; group 3).
Friday:	How to identify coevolutionary case studies. How to do a literature review.
Readings:	Lively, C. M., & Dybdahl, M. F. (2000). *Parasite adaptation to locally common host genotypes*. Nature, 405(6787), 679-681. *Textbook chapter 3: Host-parasite coevolution*

Optional: 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.

2/9/21 Lecture 6: Plant-pollinator interactions; Exercise 4: Attracting the right pollinator

2/11/21 Lecture 7: Chemical ecology underlying species interactions; **Discussion 4**: Hu et al. (student lead; group 4).

Friday: Narrowing down case study options. Identifying overlap and ensuring coverage.

Readings: 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.

Textbook chapter 4: Plant-pollinator coevolution and mutualism

Optional: 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.

2/16/21 Lecture 8: Predator-prey interactions; Exercise 5: Cyclical dynamics of predators and prey; how they happen and why they matter.

2/18/21 Lecture 9: Experimental coevolution; **Discussion 5**: Brodie & Brodie (student lead; group 5).

Friday: Mini-presentation (2-3 minutes) on identified case study.

Readings: Brodie III, E. D., & Brodie Jr, E. D. (1999). *Predator-prey arms races: asymmetrical selection on predators and prey may be reduced when prey are dangerous*. Bioscience, 49(7), 557-568.

Textbook chapter 5: Predator-prey and plant-herbivore interactions

Optional: Nair, R. R., Vasse, M., Wielgoss, S., Sun, L., Yuen-Tsu, N. Y., & Velicer, G. J. (2019). *Bacterial predator-prey coevolution accelerates genome evolution and selects on virulence-associated prey defences*. Nature communications, 10(1), 1-10.

2/23/21 Lecture 10: Herbivory; Exercise 6: Trade-offs in defense

2/25/21 Lecture 11: Diffuse Coevolution; **Discussion 6**: Agrawal et al. (student lead; group 6).

Friday: Review session

Readings: 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.

Textbook chapter 5 (continued): Predator-prey and plant-herbivore interactions

Optional: Iwao, K., & Rausher, M. D. (1997). *Evolution of plant resistance to multiple herbivores: quantifying diffuse coevolution*. American Naturalist, 316-335

3/2/21 MIDTERM EXAM

3/4/21 Lecture 12: Coevolving (?) with your microbiome

3/9/21 Lecture 14: Mimicry; Exercise 7: Chasing another species through trait space

3/11/21 Lecture 15: Coevolution within communities; **Discussion 7**: Kapan (student lead; group 7).

Friday: Check-in on case studies. Peer sharing about progress and hurdles. (It's not too late to change!)

Readings: Kapan, D. D. (2001). *Three-butterfly system provides a field test of Müllerian mimicry*. Nature, 409(6818), 338-340.
Textbook chapters 6 and 7: Mimicry and Coevolution within Communities

Optional: 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.

3/16/21 Lecture 16: Mutualisms; Exercise 8: The prisoner's dilemma

3/18/21 Lecture 17: How to prevent a cheat; **Discussion 8**: Ellers et al. (student lead; group 8).

Friday: How to present a scientific poster.

Readings: Ellers, 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.
Textbook chapter 4 (revisit): Plant-pollinator coevolution and mutualism

Optional: 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.

3/23/21 SPRING BREAK

3/25/21 SPRING BREAK

3/30/21 Lecture 18: The Geographic Mosaic Theory; Exercise 9: Interpreting variation across space

4/1/21 Lecture 19: Generation and maintenance of diversity; **Discussion 9**: Anderson & Johnson (student lead; group 9).

Friday: Poster help session.

Readings: Anderson, B., & Johnson, S. D. (2008). *The geographical mosaic of coevolution in a plant–pollinator mutualism*. Evolution, 62(1), 220-225.
Textbook chapter 8: The Geographic Mosaic of Coevolution

Optional: Hembry, D. H., Yoder, J. B., & Goodman, K. R. (2014). *Coevolution and the diversification of life*. The American Naturalist, 184(4), 425-438.

4/6/21 POSTER SESSION

4/8/21 Lecture 20: Time shift experiments; Exercise 10: Predicting results from a time shift experiment.

Readings: Brockhurst, M. A., & Koskella, B. (2013). *Experimental coevolution of species interactions.* Trends in ecology & evolution, 28(6), 367-375.

4/13/21	Lecture 21: Cospeciation and diversification; Exercise 11: Comparing phylogenies
4/15/21	Lecture 22: Temporal and spatial scales of coevolution; **Discussion 10**: Yao et al. (student lead; group 10).
Friday:	Writing case studies (Peer review #1)
Readings:	Yao, F., Shi, B., Wang, X., Pan, D., Bai, M., Yan, J., ... & Sun, H. (2020). *Rapid divergent coevolution of Sinopotamon freshwater crab genitalia facilitates a burst of species diversification*. Integrative zoology, 15(3), 174-186. *Textbook chapter 9: Temporal and spatial scales of coevolution*
Optional:	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.
4/20/21	Lecture 23: Ecosystem stability; Exercise 12: Applied coevolution
4/22/21	Lecture 24: Coevolution in agriculture; **Discussion 11**: Estes et al. (student lead; group 11).
Friday:	Writing case studies (Peer review #2)
Readings:	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*. Science, 333(6040), 301-306. *Textbook chapter 10: Applied coevolution*
Optional:	Buckling, A., & Rainey, P. B. (2002). *The role of parasites in sympatric and allopatric host diversification*. Nature, 420(6915), 496-499.
4/27/21	Lecture 25: Coevolution in medicine; Exercise 13: Exam review session
4/29/21	Lecture 26: Where the coevolution field is heading; **Discussion 12**: Chan et al. (student lead; group 12).
Friday:	Review session
Readings:	Chan, B. K., Sistrom, M., Wertz, J. E., Kortright, K. E., Narayan, D., & Turner, P. E. (2016). *Phage selection restores antibiotic sensitivity in MDR Pseudomonas aeruginosa.* Scientific reports, 6, 26717.
Optional:	Jørgensen, P. S., Folke, C., Henriksson, P. J., Malmros, K., Troell, M., & Zorzet, A. (2020). Coevolutionary Governance of Antibiotic and Pesticide Resistance. Trends in Ecology & Evolution.
5/4/21	RRR WEEK
5/6/21	RRR WEEK
5/14/21	FINAL EXAM (7:00-10:00pm)* *May be revised upon whole class agreement