BIO 1500: Plant Physiological Ecology (previously known as Plant Ecology)

Lectures: Mondays and Wednesdays, 10:30 – 11:50am, Walter Hall Conference Room

Laboratory: Labs will be held in the Environmental Science Center (greenhouses). We will meet there during class time in the latter half of the course, and also occasionally at other times. Please hold Tuesdays 1-3 as available time for project discussions and additional lab activities.

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Teaching assistants: Samuel Church
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Course Overview

This is an advanced botany course, preferably for students that have taken either BIO43 or BIO44 in addition to BIO20; otherwise permission must be obtained from the instructor. A keen interest in plants is a must.

Aims and objectives: The primary aim of BIO 1500 is to examine the role of the environment in shaping the anatomical, physiological, and ecological diversity of vascular plants. Lectures will provide an overview of plant-environment interactions, focusing on anatomical and physiological adaptations of leaves, stems, and roots to different habitats. A comparative, phylogenetic approach will be emphasized. This is a hybrid lecture/lab course, where the first half of the course will consist of chalkboard lectures by the professor and the second half will be an intensive period of data collection and analysis, providing students with first-hand experience in measuring and interpreting plant functional traits. Students will work on a set of group projects that are designed to test long-standing assumptions about the evolution and adaptive nature of certain plant traits. Projects will differ from year to year, and although the general theme will be chosen by the professor, students are expected to play a large role in experimental design and focus. Students will leave the class with a solid foundation both in plant functional ecology and in applying a phylogenetic comparative approach to studies of organismal biology. Furthermore, they will gather first hand experience in data collection, experimental design, data analysis, and the presentation of a scientific study.

Reading assignments: Most of the reading assignments for the course are in-depth research or review articles from the primary literature. Students who enroll in this course should already be comfortable with reading scientific journal articles. Several textbooks will be on reserve at the Science Library- these can provide additional background information as needed.

Lectures and preparing for discussion: Lectures will be primarily informal chalkboard talks and very occasional slide shows. Discussion and questioning in lectures is especially encouraged and is an explicit component of student performance evaluations. It is hoped that the lecture section of this course develops into more of a dialogue back and forth between professor and students. These sessions should be really fun, **but only if everyone reads the assignment before class.** This is an absolute requirement of this course. To encourage this, students must write short response papers (2 paragraphs long) to be submitted to the Canvas course site **before** the class period. Response papers turned in after class will not be accepted. The first paragraph should be a concise summary of the paper, and the second paragraph should be the student's own personal critique of the study- this can include not only an evaluation of what was accomplished in the paper, but what else it might inspire to do next. Your opinion must be justified- if you loved the paper, you must explain why. If you found the study to be flawed, what should they have done instead? These response papers will be evaluated for content, as well as writing style.

Labs: I will provide two general topics that the projects should address. She'll also provide some initial ideas, and inform on the basic resources available to complete the project. Over the first half of class, students will meet with the professor and TAs in 2-3 small groups to co-design the projects. The last weeks of the course will be devoted full time to carrying out the experiment, analyzing the data, preparing research posters of the projects for an end of semester poster session with the EEB department, and writing up the results in the format of a scientific publication. Please see pp. 6-7 for a sketch of the topics the lab projects will cover this semester.

Writing: this is a designated WRIT course, which means that you will be evaluated specifically on your effectiveness as a scientific writer, and will also receive constructive feedback directly on your writing within the discipline. This will happen via both your response papers as well as your final paper assignment, for which you must produce multiple drafts that will be peer-reviewed by your colleagues.

Student evaluation: Course grading will consist of four components: two in-class midterm exams (20% each), a final paper presenting the lab project (30%), a group poster presentation (15%) and a course participation grade (15%).

Recommended supplemental texts:

Plant Physiological Ecology; Lambers, Chapin and Pons
Plant Physiology 4th edition; Taiz/Zeigler
Biology of Plants 7th edition; Raven

These texts are on reserve at the Science Library.

Required reading is listed below, and available on Canvas.

Bio 1500 Course Schedule

4 Sept. Introduction to the course and the lab; organizational meeting

9 Sept. A review of plant anatomy: looking inside the leaf, stem, and root

Sadava chap.4

11 Sept. Photosynthesis, the basics

Raven chap. 7, pp. 115-130

16 Sept. Photosynthesis and adaptation to light

Lambers pp. 25-42

Jordan et al. 2005. Solar radiation as a factor in the evolution of scleromorphic leaf anatomy in Proteaceae. American Journal of Botany 92: 789-796.

Valladares and Niinemets. 2008. Shade tolerance, a key plant feature of complex nature and consequences. Ann. Rev. Ecol. Evol. Syst. 39: 237-257.

Response paper due before class: either Jordan or Vallardes.

18 Sept. Photosynthesis, CO_2, and the evolution of CAM and C4 pathways

Keeley and Rundel. 2003. The evolution of CAM and C4 carbon-concentration mechanisms. International Journal of Plant Sciences 164: S55-S77

Edwards and Obgurn. 2012. Angiosperm responses to a low CO2 world: Cam and C4 photosynthesis as parallel evolutionary trajectories. International Journal of Plant Sciences 173: 724-733.

Response paper due before class: Keeley or Edwards

Lab: first lab meeting: get to know your lab groups, initiate development of project

23 Sept. Plant water potential and the soil-plant-atmosphere-continuum

Lambers pp. 154-172

25 Sept. Xylem and phloem long distance transport; design and function

Lambers pp. 140-153

Pitterman 2010. The evolution of water transport in plants: an integrated approach. Geobiology 8: 112-139.

Response paper due before class: Pitterman 2010.

Lab: project discussions

30 Sept. Water stress, succulence, and the avoidance-tolerance continuum

Ogburn and Edwards. 2010. The ecological water-use strategies of succulent plants. Advances in Botanical Research 55: 179-255.

2 Oct. MIDTERM EXAM (covering 9 Sept through 30 Sept)

Lab: project discussions

7 Oct. Nutrient use strategies

Chapin 1980. The mineral nutrition of wild plants. Annual Review of Ecology and Systematics 11: 233-260.

9 Oct. Nutrients and the leaf economic spectrum

Wright et al. 2004. The worldwide leaf economics spectrum. Nature 428: 821- 827.

Lloyd et al. 2013. Photosynthetically relevant foliar traits correlating better on a mass vs an area basis: of ecophysiological relevance or just a case of mathematical imperatives and statistical quicksand? New Phytologist 199: 311-321

Edwards et al, in review. Leaf lifespan and the leaf economic spectrum in the context of whole plant architecture. Journal of Ecology

Response paper due before class: reconcile Wright et al. and Lloyd et al.

Lab: project initiation

14 Oct. holiday- no class

16 Oct. Plants and temperature

Lambers pp 210-220

Preston and Sandve 2013. Adaptation to seasonality and the winter freeze. Frontiers in Plant Science 4: 167.

Lab: group projects

21 Oct. Plants on the defense

Agrawal and Fishbein. 2006. Plant defense syndromes. Ecology 87: S132-S149.

Frost et al. 2008. Plant defense priming against herbivores: getting ready for a different battle. Plant Physiology 146: 818-824.

Response paper due before class: either Agrawal or Frost.

23 Oct. Thinking 'whole plant' part 1: water relations, growth, and photosynthesis

Brodribb, Feild, and Jordan. 2007. Leaf maximum photosynthetic rate and venation are linked by hydraulics. Plant Physiology 144: 1890-1898.

Koch et al. 2004. The limits to tree height. Nature 428: 851- 854.

Response paper due before class: either Brodribb or Koch.

28 Oct. Thinking 'whole plant' part 2: understanding plant phenology

Hanninen and Tanino. 2011. Tree seasonality in a warming climate. Trends in Plant Science 16: 412-416.

Cook et al. 2012. Divergent responses to spring and winter warming drive community level flowering trends. PNAS 109: 9000-9005.

Response paper due before class: either Hanninen or Cook.

Lab: group projects

30 Oct. Thinking 'whole plant' part 3: wrestling with alternative designs and 'niche conservatism'

Marks and Lechowicz 2006. Alternative designs and the evolution of functional diversity. American Naturalist 167: 55-66.

Crisp et al 2009. Phylogenetic biome conservatism on a global scale. Nature 754-756.

Response paper due before class: please reconcile these papers.

4 Nov. MIDTERM exam (covering 7 Oct thru 30 Oct)

Lab: group projects

6 Nov. **group projects**

11 Nov. **group projects**

13 Nov. **group projects**

18 Nov. **group projects**

20 Nov. **group projects- data collection should be wrapped up**

25 Nov. **group projects- data analysis**

27 Nov. **Thanksgiving holiday**

2 Dec. **group projects- final data analysis**

4 Dec. **group project class presentations/critique**

1st draft of paper due; share for peer review.

9 Dec. **poster session with the EEB department!!**

11 Dec. FINAL DRAFT OF PAPER DUE, 5 PM

OVERVIEW OF LAB GROUP PROJECTS

Please sign up during second week of lectures- the number of students working in each area must be generally balanced, so if you have a strong opinion about what you want to do at the outset it is best to sign up as soon as possible. Projects this year revolve around two main themes: the evolutionary connections between CAM and C4 photosynthesis, and time-lapse studies of plant growth.

1. Did C4 photosynthesis evolve in a CAM plant??

CAM and C4 photosynthesis, though biochemically related, were always thought to be incompatible and also very distinct ecological adapations. The Portulacineae is a lineage of 2,200 species, and many are known CAM plants. Interestingly, *Portulaca* (including purslane- common sidewalk weed and maybe coolest plant on earth) is a mostly C4 lineage embedded within this group, and can also perform some drought-induced CAM. How did this happen??!! We have new evidence in the lab supporting the hypothesis that a rudimentary CAM system was ancestral in *Portulaca,* and a C4 syndrome evolved within a CAM context. You'll explore this possibility by working with *Portulaca cryptopetala*, and amazing 'intermediate' c3/c4 species (with a photorespiratory CO2 pump, see below). Can this species also perform drought-induced CAM? You will also explore various new metrics to detect CAM-cycling, an important intermediate type of CAM metabolism.

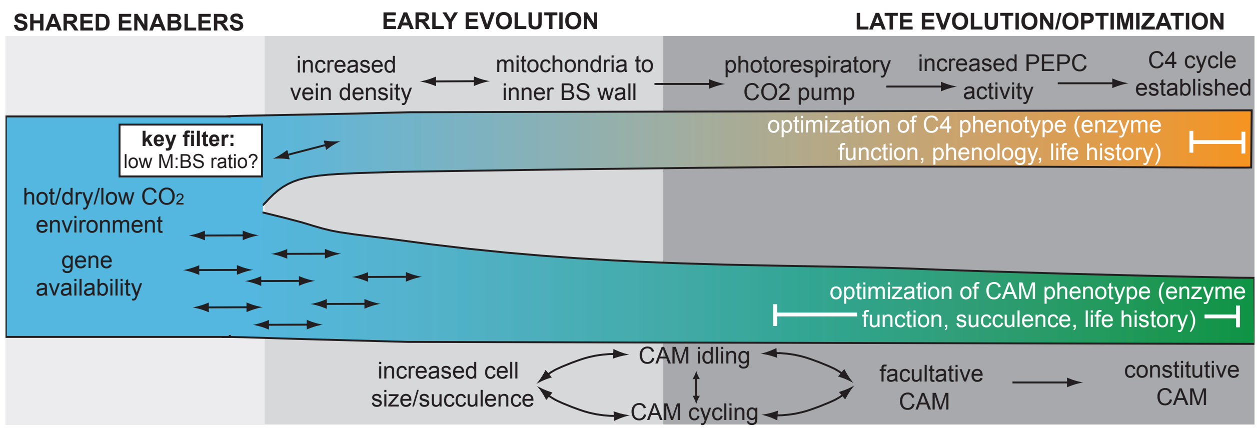

Figure 1. Postulated evolutionary trajectories of C4 and CAM photosynthetic syndromes, updated from Sage 2002. The C4 trajectory is inferred with evidence from Molluginaceae, *Flaveria*, *Heliotropium*, and grasses. The CAM trajectory is essentially hypothetical. Early points along the trajectory are more easily reversed, as indicated by the double arrows. Late evolutionary stages of both trajectories are largely irreversible, though each step represents an evolutionarily stable phenotype, and the CAM syndrome may maintain reversibility much longer throughout the trajectory. C4 and CAM syndromes become increasingly inaccessible to each other as evolution progresses. The preconditions for each pathway are largely shared, though the C4 trajectory may be accessible only to a subset of taxa that present one or more key 'filtering traits'. M:BS ratio= mesophyll: bundle sheath ratio.

2. Biological insight via time lapse photography

Many important aspects of plant function and behavior occurs over a long time period that can be missed by non-continuous observation. How does a leaf unfold? How do vines attach themselves to substrates? How does a fruit develop? How does a leaf senesce? All of these events can be monitored thru time lapse photography. Most android phones have free time-lapse apps, making this technology available to nearly all of us. You will make your own timelapse movie to study an important phenological event in a plant. As a group we will try to build one or several waterproof, solar-powered time-lapse stations that we could deploy in the field. Sky is the limit on what to monitor! The only constraint is that your movie must be useable data that was collected to test a particular hypothesis about how plants develop, grow, and die.