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

Lectures: Tuesdays and Thursdays, 9 – 10:20am (H hour), Smith-Buonanno Hall rm 207

Laboratory: Labs will be held on Thursdays in the Environmental Science Center (greenhouses). One or two lab sections will be available (TBD)

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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/seminar course, where classes will consist of both chalkboard lectures by the professor as well as discussions of articles from the primary literature. **In addition, BIO 1500 is designed to be a hands-on course, and lectures are viewed mostly as supplements to the semester-long greenhouse project that will provide 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, but will be chosen by the professor based on outstanding questions in the current literature. See page 6 for an overview of Spring 2011 projects. 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: All 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 students need it.

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. After the first two weeks of class we will switch to a format consisting of lectures interspersed with occasional discussion sessions. These discussion 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 at the beginning of the class period. Response papers handed in after class will not be accepted. The first paragraph should be a concise summary of the paper, and the second paragraph should be your 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 you 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. We will return them with comments intended to specifically improve the clarity and succinctness of your prose, with the intention that you will use these comments to improve the quality of your writing throughout the semester. This course is currently being evaluated as a (W) writing-intensive course.

Labs: There is a weekly lab that will mostly consist of continued work on a group project. Students will be split into teams of 3-5, and will work together to collect data for whichever project they sign up for: comparative physiology of C3/C4 grasses; drought-induced CAM photosynthesis in a C4 plant; anatomical and ecological preconditions for the evolution of CAM and C4 photosynthesis. There will be a poster session at the end of the semester where the groups present their findings to the broader EEB community at Brown.

Student evaluation: Course grading will consist of four components: two in-class midterm exams (20% each), a take-home final exam (20%), a group project (20%), and class participation (10%). Group project grades will be based 50% on lab participation and 50% on the poster presentation.

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 MyCourses.

Bio 1500 Course Schedule

27 Jan. Introduction to the course and the lab; organizational meeting

1 Feb. A review of plant anatomy: looking inside the leaf, stem, and root

Sadava chap.4

3 Feb. Photosynthesis, the basics

Raven chap. 7, pp. 115-130

8 Feb. 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.

10 Feb. Photosynthesis, CO_2, and the evolution of CAM and C4 pathways

Sage 2004. The evolution of C4 photosynthesis. New Phytologist 161: 341-370.

Dodd et al. 2002. Crassulacean Acid Metabolism: plastic, fantastic. Journal of Experimental Botany 53: 569-580.

Lab: get to know your plants; form project groups; introduction to equipment

15 Feb. Plant Photosynthesis and Plasticity Discussion (response papers due at start of class):

Sage and McKown. 2006. Is C4 photosynthesis less phenotypically plastic than C3 photosynthesis? Journal of Experimental Botany 57: 303-317.

Dudley and Schmitt 1996. Testing the adaptive plasticity hypothesis: density-dependent selection on manipulated stem length in Impatiens capensis. American Naturalist 147: 445-465.

17 Feb. Portulacineae, Molluginaceae, CAM, and C4- TA Matt leads- Prof E out of town

Lab: group projects

22 Feb. holiday- no class

24 Feb. Plant water potential and the soil-plant-atmosphere-continuum

Lambers pp. 154-172

Lab: group projects

1 Mar. MIDTERM EXAM (covering 1 feb through 24 feb)

3 Mar. 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.

Lab: group projects

8 Mar. Plant Hydraulics Discussion (response papers due at start of class):

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.

10 Mar. 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.

Lab: group projects

15 Mar. Drought adaptation discussion (response papers due at start of class):

Chapotin, Razanameharizaka, Holbrook. 2006. Baobab trees in Madagascar use stored water to flush new leaves but not to support stomatal opening before the rainy season. New Phytologist 169: 549-559.

Jacobsen et al. 2008. Comparative community physiology: nonconvergence in water relations among three semi-arid shrub communities. New Phytologist 180: 100-113.

17 Mar. Nutrient limitations to plant growth

Aerts and Chapin. 2000. The mineral nutrition of wild plants revisited: a re-evaluation of processes and patterns. Advances in Ecological Research 30: 1-67.

Lab: group projects

22 Mar. Plants and nutrients discussion (response papers due at start of class):

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

Gorska et al. 2008. Nitrate control of root hydraulic properties in plants: translating local information to whole plant response. Plant Physiology 148: 1159-1167.

24 Mar. Plants and temperature

Lambers pp 210-220

Korner and Larcher. 1988. Plant life in cold climates. Symp Soc Exp Biol 42: 25-57.

Lab: group projects

29 Mar. Spring break
31 Mar. Spring break

5 Apr. Plants and temperature discussion (response papers due at start of class):

Blodner et al. 2005. Freezing tolerance in two Norway spruce progenies is physiologically correlated with drought tolerance. Journal of Plant Physiology 162: 549-558.

Helliker and Richter. 2008. Subtropical to boreal convergence of tree-leaf temperatures. Nature 454: 511-514.

7 Apr. Plant phenology and life history: linking development and environmental cues

Fenner. 1998. The phenology of growth and reproduction in plants. Perspectives in Plant Ecology, Evolution, and Systematics 1: 78-91.

Primack. 1987. Relationships among flowers, fruits, and seeds. Annual Review of Ecology and Systematics 18: 409-430.

Lab: group projects

12 Apr. Plant phenology discussion (response papers due at start of class):

Borchert et al. 2005. Photoperiodic induction of synchronous flowering near the Equator. Nature 433: 627-629.

Lechowicz 1984. Why do temperate deciduous trees leaf out at different times? Adaptation and ecology of forest communities. American Naturalist 124: 821-842.

14 Apr. MIDTERM EXAM (covering 8 mar through 12 april)

Lab: data analysis

19 Apr. 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.

21 Apr. Scaling up to ecosystems discussion (response papers due at start of class)

Diaz et al. 2004. The plant traits that drive ecosystems: Evidence from three continents. Journal of Vegetation Science 15: 295-304.

Cadotte et al. 2009. Using phylogenetic, functional and trait diversity to understand patterns of plant community productivity. Plos One 4: e5695.

Lab: group project class presentations/critique

26 Apr. Ecological patterns and adaptation discussion (response papers due at start of class):

Ackerly 2004. Adaptation, niche conservatism, and convergence: comparative studies of leaf evolution in the chaparral. American Naturalist 163: 654-671.

Crisp et al. 2009. Phylogenetic biome conservatism on a global scale. Nature 458: 754-756.

28 Apr. Ecological traits, phylogeny, and community assembly

Cavender-Bares et al. 2009. The merging of community ecology and phylogenetic biology. Ecology Letters 12: 693-715.

Lab: poster session with the EEB department!!

3 May TAKE-HOME FINAL DUE, 5 PM

OVERVIEW OF LAB GROUP PROJECTS

Each limited to 5 students- sign up during first week of lectures. All projects this year revolve around the ecology and evolution of C4 and CAM photosynthetic pathways.

1. Name That Photosynthetic Pathway

Grasses with C4 photosynthesis are fundamentally important to global ecology and ecosystem function; they are responsible for ~ 25% of terrestrial primary productivity, and C4 grasslands cover ~20% of the land surface. In the past the functional repercussions of the C4 pathway in grasses have been assessed by comparing their physiological characteristics with those of very distantly related C3 grasses; recent work has shown that these studies may have been misleading, as many perceived C3/C4 differences break down when looking at more closely related C3/C4 species pairs. In this experiment, you will be responsible for characterizing various aspects of plant function in an assortment of ~20 C3 and C4 grass species (unlabeled), and inferring their photosynthetic pathway via their physiological performance. How correct will you be?? Additionally, you will collect data to test the accuracy of C3 and C4 functional type parameterization for global vegetation models.

2. The Unique Photosynthetic Properties of *Portulaca oleracea*, a Worldwide Weed

Portulaca is an extremely unusual lineage of plants. Most members exhibit C4 photosynthesis, although they are slightly to extremely succulent and sit squarely within a large clade of other succulent plants that utilize the CAM photosynthetic pathway. Interestingly, several species of *Portulaca* can switch from C4 to CAM photosynthesis in response to drought stress, making them the ***only known*** plant species to exhibit ***both*** C4 and CAM pathways. In this project you will attempt to induce a CAM response in *Portulaca oleracea*, using a set of seed collected from various locations in Afghanistan, Saudi Arabia, and Syria. What level of drought was required to induce CAM? What happens upon re-watering? Do plants from different populations respond differently? You will also be instrumental in collecting tissue for future molecular work that will characterize the different isoforms of PEP Carboxylase expressed in C4 and CAM pathways.

3. Reconstructing Developmental Enablers of CAM and C4 evolution

CAM and C4 photosynthetic pathways have much in common: they employ a shared biochemical pathway that enables the concentration of CO_2 inside plant cells, they are both considered to be adaptations to stressful environments, and they are both arguably among the most convergent of complex traits, having each evolved multiple times in various plant lineages. Historically, however, they have largely been investigated as separate and unrelated adaptations, which has led us to mostly focus on the differences between CAM and C4 plants, rather than their similarities. The Portulacineae and relatives (Caryophyllales), contain multiple origins of both CAM and C4 pathways in a relatively small group of ~ 2200 species. You will collect data on vein spacing, quantitative measures of tissue succulence, ecological habitat, and life history in C3, CAM, and C4 lineages in the Portulacineae and Molluginaceae to begin to reconstruct the various steps in the evolution of both syndromes, and to identify any potential ‘no turning back’ scenarios, where a certain assemblage of precursor traits strongly favors the evolution of one syndrome over the other.