CAS GE/BI 525: Plant Physiological Ecology (PLANT PHYS ECOL)

Nathan G. Phillips
Department of Geography and Environment
Office: Room 441A
Stone Science Building
675 Commonwealth Avenue
617-353-2841
Nathan@bu.edu

Lecture Location/Time: CAS320/ MWF 1:00-2:00
Office Hours: MW 2:00-3:00 TH 12:00-1:00

Pre-requisites:

CH101 and PY211, and one of the following: (BI303 or BI305), or consent of instructor.

Required text:

Plant Physiological Ecology. Lambers H., Pons T. L., Chapin F. S. III. 1998. Springer – Verlag. ISBN: 0387983260, paperback, 356 p.

Supplementary text on reserve:

Plants and Microclimate: A quantitative approach to environmental plant physiology. H. J. Jones. 2nd edition. 1992. University of Cambridge Press, UK. ISBN 0 521 42524 7 paperback, 428 p.

Course Description:

Plant ecophysiology as a discipline is concerned with understanding how a plant's structure and function reflects adaptation to its unique physical and biotic environments. This course covers first principles of physiology based on biophysics and biochemistry, and applies those principles in the context of both ecosystem structure and function, and global change. To this end, the course combines textbook readings covering first principles of plant ecophysiology with seminal literature readings and recent selections from the literature focused on contemporary issues of plant physiological ecology and global change biology. The course is designed for graduate students and advanced undergraduate students with an interest in global change science, ecology, hydrology, and/or plant sciences.

Depending on students' schedules, we may schedule some Friday afternoons for short field trips to demonstrate the use of plant eco-physiological measurement instruments.

Lecture and Readings Schedule

Week 1:
Overview. The scope of eco-physiology. Time and space scales. Theoretical and experimental approaches. Relationship between eco-physiology and global change biology. *Reading: Ch. 1, Tracy and Turner 1982; Gross et al. 1989 (optional); DeLucia et al. 2001*

Weeks 2-3:
Photosynthesis and respiration. General characteristics of the photosynthetic apparatus. Photosynthetic responses to light, water, soil nutrients, temperature, air pollutants, and CO2. General characteristics of the respiratory system. Effects of environmental conditions on respiration. The role of respiration in plant carbon balance. *Reading: Ch. 2, Farquhar and Von Caemmerer 1982, Tezara et al. 1999*
**Term project 1-2 page synopsis due*

Week 4-5:
Stomatal function and its control over water and carbon exchange.
Mechanism of stomatal movements. Response of stomata to environmental factors, including humidity light, and carbon dioxide. Control of photosynthesis, transpiration, and leaf energy balance by stomata, and carbon efficiency of water use. *Reading: Ch. 3, Cowan 1977, Daley and Phillips 2006; Phillips et al. (in prep).*

Week 6-7:
Whole plant (root, stems, leaves) hydraulic structure and function
Concept of water potential and the cohesion-tension theory of sap ascent. Anatomy and function of conducting tissue in roots, stems and leaves. Membrane transport. Dysfunction of the conducting system due to drought stress and freezing. Hydraulic control over stomata and whole plant gas exchange and growth. Resistance-capacitance models of water transport. *Reading: Ch. 3, Zwieniecki et al.* 2001, *Phillips et al.* 2004, *Burgess and Dawson 2008; Phillips et al. 2008*

Week 8:
Leaf and canopy energy and water balance
Inputs and outputs of energy to leaves and canopies. Physiological effects of radiation and temperature on leaf function. Penman-Monteith formulation of leaf and canopy energy balance. Aerodynamic resistances of leaves and canopies, and the concept of aerodynamic coupling. Big leaf versus distributed models of energy flux. *Reading: Ch. 4,5, Jarvis and McNaughton 1986, Raupach and Finnegan 1988, Friedl 2001.*

Week 9:
Mineral Nutrition
Acquisition of Nutrients, nutrient mobility in soils, root traits that promote nutrient uptake, transport of nutrients within plants. Nutrient acquisition in stressed or extreme environments. Effects of nutrient deficiencies. *Reading: Ch. 6, Ingestad and Agren 1988, Phillips et al. 2001.* ***MIDTERM EXAM FRIDAY NOV 7.***

Week 10:

Plant growth, phenology, reproduction, and its control by internal and environmental factors.

Growth by addition of cells and by cell expansion. Growth in different plant organs. Definition of relative growth rate at the whole plant level. Allocation of growth resources to different organs. Environmental controls on growth. Growth strategies and adaptation. Internal and environmental controls on plant phenology. *Reading: Ch. 7, Lambers and Poorter 1992, Primack et al. 2004.*

Week 11:

Comparative eco-physiology of major plant life forms

Functional grouping of plant types, based on physiological features. Functional versus species diversity. Climographs, and mapping of plant niche space onto geographical maps. Evergreen versus deciduous species. Nitrogen symbionts. *Reading: Woodward and McKee 1991, Smith et al. 1993; Körner 1993, Bonan et al. 2002.*

Week 12-13:

Impact of plant/community age/size on whole plant and ecosystem function.

Nutritional, genetic, hydraulic, metabolic, and biomechanical controls on physiological function in aging plants and trees. Relationship between organism age, ecosystem age structure, and ecosystem mass and energy transport. *Reading: Ryan and Yoder 1997; Ryan et al. 1997, Phillips et al. 2002, Phillips et al. 2008.*
**Draft of term project due.*

Week 14-15:

Impacts of climate change on plant and ecosystem function.

Effects of elevated CO2 on photosynthesis and growth. Effects of altered mean and variance of temperature and precipitation regimes. Feedbacks of vegetation on climate. *Reading: Ch 10A, 10B. Bergh and Linder 1998; Oren et al. 2001.*

Week 16:

Scaling of plant ecophysiological processes from individuals to ecosystems

Issues involved in scaling of linear vs. non-linear processes, power laws in plant function, error propagation. *Reading: Hinckley et al. 1998, West et al. 1999*
**Term project report due.*

Supplementary Readings:

In addition to texts cited above, the following supplemental readings will be on reserve (see week by week schedule for reading assignments).

Bergh, J. & Linder, S. 1998. Effects of soil warming during spring on photosynthetic recovery in boreal Norway spruce stands. *Global Change Biology* 4: 101-110.

Bonan G.B., S. Levis, L. Kergoat, and KW Oleson 2002: Landscapes as patches of plant functional types: an integrating concept for climate and ecosystem models. *Global Biogeochemical Cycles* 16(2): 1021, doi:10.1029/2000GB001360

Burgess SSO, Dawson TE. 2008. Using branch and basal trunk sap flow measurements to estimate whole-plant water capacitance: a caution. *Plant and Soil* 305:5-13

Cowan, I.R. 1977. Stomatal behaviour and environment. *Advances in Botanical Research* 4:117-128

Daley MJ, Phillips NG. 2006. Interspecific variation in night-time transpiration and stomatal conductance in a mixed New England deciduous forest. *Tree Physiology* 26:411–419.

DeLucia E. H., J. S. Coleman, T. E. Dawson, and R. B. Jackson. 2001. Plant physiological ecology: linking the organism to scales above and below. *New Phytologist* 149:12-16.

Farquhar G.D., Von Caemmerer S. 1982. Modelling of photosynthetic response to environmental conditions. In: Lange O.L., Nobel P.S., Osmond C.B. and Ziegler H. (eds). Encyclopedia of Plant Physiology, N.S., Vol 12B., Springer-Verlag, Berlin, pp. 549-587.

Friedl M. A. 2001. Forward and inverse modeling of land surface energy balance using surface temperature measurements. *Remote sensing of Environment* 78:1-11.

Gross L. J. 1989. Plant Physiological Ecology: A Theoretician's Perspective. In: Roughgarden J., May R.M., Levin S.A. (eds.) Perspectives in Ecological Theory. Princeton University Press, Princeton, New Jersey, pp. 11-24.

Hetherington, A. M. and F. I. Woodward. 2003. The role of stomata in sensing and driving environmental change. *Nature* 424:901-908.

Hinckley T. M., D. G. Sprugel, J. R. Brooks, K. J. Brown, T. A. Martin, D. A. Roberts, W. Schaap, and D. Wang. 1998. Scaling and Integration in Trees. In: Peterson D. L., and V. Thomas Parker (eds.) Ecological Scale: Theory and Applications. Columbia University Press, New York. pp. 309-337.

Ingestad T. and Agren G. I. 1988. Nutrient uptake and allocation at steady-state nutrition. *Physiologia Plantarum* 72:450-459.

Jarvis P. J. and McNaughton K. G. 1986. Stomatal control of transpiration: scaling up from leaf to region. In: MacFadyen A. Ford E. D. (eds.) Advances in Ecological Research. Academic Press, New York 15:1-49.

Körner Ch. 1993. Scaling from species to vegetation. The usefulness of functional groups. In: Biodiversity and Ecosystem Function, E-.D. Schulze and H. A. Mooney (eds). Ecological Studies, Vol. 99, Springer-Verlag, Berlin.

Lambers H. and Poorter H. 1992. Inherent variation in growth rate between higher plants: A search for physiological causes and ecological consequences. *Advances in Ecological Research* 22:187-261.

Oren R., D. S. Ellsworth, K. H. Johnson, N. Phillips, B. E. Ewers, C. Maier, K. V. R. Schafer, H. McCarthy, G. Hendrey, S. G. McNulty and G. G. Katul. 2001. Soil fertility limits carbon sequestration by forest ecosystems in a CO2-enriched atmosphere. *Nature* 411:469-472.

Phillips N., J. Bergh, R. Oren and S. Linder 2001. Effects of nutrition and soil water availability on water use in a Norway spruce stand. *Tree Physiology* 21:851-860.

Phillips N, B. J. Bond, N. G. McDowell and M. G. Ryan. 2002. Canopy and Hydraulic conductance in young, mature, and old Douglas-fir trees. *Tree Physiology* 22:205-211.

Phillips N., M. G. Ryan, B. J. Bond, N. G. McDowell, T. M. Hinckley and J. Cermak. 2003. Reliance on stored water increases with tree size in three species in the Pacific Northwest. *Tree Physiology* 23:237-245.

Phillips N, Oren R, Licata J, Linder S. 2004. Time series diagnosis of Tree Hydraulic Characteristics. Tree Physiology 24:879–890.

Phillips N, Scholz F, Bucci S, Goldstein G, Meinzer FC. 2008. Using branch and basal trunk sap flow measurements to estimate whole-plant water capacitance: comment on Burgess and Dawson (2008). *Plant and Soil* (in press)

Phillips N, Buckley TN, Tissue DT. 2008. Capacity of old trees to respond to environmental change. *Journal of Integrative Plant Biology* (in press)

Primack R. et al. 2004. Herbarium specimens can demonstrate earlier flowering times in response to climate change. *American Journal of Botany.*

Raupach, M.R. and Finnigan, J.J. 1988. Single layer models of evaporation from plant communities are incorrect, but useful, whereas multi-layer models are correct but useless: discussion. *Australian Journal of Plant Physiolog*y. 15: 705-716.

Ryan M. G., and Yoder B. J. 1997. Hydraulic limits to tree height and tree growth. *Bioscience* 47: 235-242.

Ryan, M.G., D. Binkley, and J.H. Fownes. 1997**.** Age-related decline in forest productivity: pattern and process. *Advances in Ecological Research* 27: 213-262

Smith T. M., H. H. Shugart, F. I. Woodward, and P. J. Burton. 1993. Plant Functional Types. In: Solomon A. M. and H. H. Shugart, (eds.) Vegetation Dynamics and Global Change. Chapman and Hall, New York.pp 272-292.

Sperry, J. S., F. R. Adler, G. Campbell, and J. P. Comstock. 1998. Limitation of plant water use by rhizosphere and xylem conductance: results from a model. *Plant Cell and Environment*. 21:347-359.

Tezara W, V. J. Mitchell, S. D. Driscoll and D. W. Lawlor (1999). Water stress inhibits plant photosynthesis by decreasing coupling factor and ATP. Nature 401:914-917.

Tracy CR, Turner JS. 1982. Commentary: What is Physiological Ecology? A collection of commentaries by noted physiological ecologists (1982). Bulletin of the Ecological Society of America 63(4): 340-346.

West, G.B., Brown, J.H. & B.J. Enquist. (1999) A general model for the structure, and allometry of plant vascular systems. *Nature* 400: 664-667

Woodward F. I. And I. F. McKee. 1991. Vegetation and Climate. *Environment International* 17:535-546.

Zwieniecki M.A., P. J. Melcher and N. M. Holbrook. 2001. Hydrogel control of xylem hydraulic resistance in plants. Science 291:1059-1062.

Assignments

Problem sets will be assigned approximately every three weeks, consisting of quantitative problems and short essay questions. One midterm exam and a final exam will be given. A NSF-style Graduate Research Fellowship proposal, or Research Experience for Undergraduates (REU) application essay will also be required. Students are encouraged to develop proposal ideas relevant to their graduate research, or of exploratory interest for undergraduates. Students should consult with the instructor on proposal ideas, and submit a project synopsis during the third week of the semester. The proposal may involve direct research using instrumentation from the Biogeography Lab, or may make use of existing data sets and literature. A proposal draft is due during the 13th week of the semester, and a final proposal is due during the final week of classes. The proposal should be no more than 15 pages in length, including figures, tables, and a fully referenced bibliography. In addition a condensed proposal draft and final version, conforming to the two-page NSF Graduate Research Fellowship rule or REU specifications, will be required and due in parallel with the longer proposal. Please see www.nsf.gov/pubs/2008/nsf08593/nsf08593.htm for detailed information on NSF Graduate proposal preparation or www.nsf.gov/funding/pgm_summ.jsp?pims_id=5517&from=fund for Research Experience for Undergraduates application information.

Grading

Problem sets, 5% each = 25%
Term Project and Proposal/Application = 20%
One take home midterm exam, 25%
One in-class midterm exam, 30%

Policies

The College of Arts and Sciences policies on incomplete grades and academic conduct will be followed. For details refer to the BU undergraduate or graduate bulletins and the CAS Academic Conduct Code. All written work must be your own.