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BIOB 524.01: Physiological Plant Ecology

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BIOB 524 - PHYSIOLOGICAL PLANT ECOLOGY - FALL 2020

Instructor: Dr. Anna Sala; NS Annex 101
Email: anna.sala@umontana.edu
Days and Time: Tuesdays and Thursdays 2:00- 3:20 p.m.
Meeting Room: LA 307
Office Hours: By appointment

Learning outcomes:

1. Appreciation of the complexity of plant function and design
2. Appreciation of the multiple, interacting mechanisms by which plant cope with their biological and physical environment
3. Ability to critically evaluate scientific data
4. Ability to critically evaluate papers in the primary literature
5. Ability to write in scientific format
6. Appreciation of how basic principles of physiology may inform students' individual research.

Reference Texts:
We will not follow a textbook. Instead, we will read papers from the literature. I will provide a list of general reference textbooks.

Reading Materials:
Digital copies of selected papers will be distributed via email or Moodle

Course Format:
This course is not a plant ecology class. Rather, we will emphasize on the physiological mechanisms by which plants interact with their environment. These processes ultimately take place in cells, with consequences on tissues and whole plants. The course is not meant to be a comprehensive, content-filled 'walk' through the entire field of Plant Physiological Ecology. Instead, we will cover several broad topics centered on one or a few questions. For each topic, we will alternate background overviews and discussions of papers. First, I will provide a brief overview of the topic (students may be assigned to read review papers ahead of time). Then, we will have a student-driven discussion of papers from the primary literature (conceptual syntheses, reviews, or original research). ***Student participation is critical in this class.***

Critiques: Students will also write short syntheses/ reviews of a total of 10 papers identified as 'critique' in the syllabus (there are more than 10 'critique' papers, so you can chose from the list). See details below. I will not accept more than one synthesis/review per week. So choose ahead which papers you are most interested and space them out throughout the semester.

Critiques are due prior to the discussions.

The list of topics is tentative. We may modify it based on student's interests. Also, I prefer to emphasize depth over breath. This means that the syllabus is only tentative. I will try to give updates as we go, but if you miss class it is ultimately your responsibility to know what we

covered and if there are any upcoming assignments. It also means that we are often not able to cover all topics outlined. This is fine as long as you are aware of the issues not covered, and the relevance they may have for your work.

Students will also write a literature review with a well-defined goal (see guidelines below). At the end of the semester each student will prepare a short oral presentation of what they have learned from their review.

Please submit your written assignments as hard copies.

Pre-requisites:
Plant Physiology is fundamental. This means some background of cellular and molecular processes. If you are rusty, please review the basics of water relations, photosynthesis, mineral nutrition and growth and development.

What to expect:
This is a graduate course that requires a graduate student attitude: you are here because you are interested to learn, not because you are asked to or you need the credits. Therefore, what you learn from this course ultimately depends on what you want to learn. You are no longer in the passive, listener end. Rather, student participation and motivation is fundamental. Therefore, class preparation and attendance is critical. Inquisitive and involved students result in interactive, fun and productive classes. Therefore, class success depends as much on your contribution as on mine. Read, read, read, and ask, ask, ask, particularly, if you do not know or you do not understand something. I benefit immensely from your feedback. I particularly welcome alternative interpretations or views, intellectual challenge (I benefit from your challenge as much as I will try to challenge you).

Grade Basis:

Assignment	*Points*
Class attendance and participation	50
One Page handouts of discussed papers	30
Syntheses/Reviews (10 @ 20 points each)	200
Final Literature Review	50
Class Presentation	20
TOTAL	350

Students with disabilities
The University of Montana assures equal access to instruction through collaboration between students with disabilities, instructors, and Disability Services for Students. If you think you may have a disability adversely affecting your academic performance, and you have not already registered with Disability Services, please contact Disability Services in Lommasson Center 154 or 406.243.2243. I will work with you and Disability Services to provide an appropriate modification.

Special circumstances due to COVID-19

We may have to switch to a remote setting. I will make available all the materials as needed via email or Moodle.
Mask use is required within the classroom. View UM's face covering policy.
Each student is provided with a Healthy Griz kit to clean your personal work space when you arrive for class, and before you leave the classroom.
Refill stations for cleaning supplies/hand sanitizer will be set up around campus - please learn where they are and use them.
Classrooms may have one-way entrances / exits to minimize crowding.
Please ensure social distancing.
Please, do not drink and eat in class as it requires mask removal.

Stay home and contact the Curry Health Center at (406) 243-4330 if you feel sick and/or if exhibiting COVID-19 symptoms.
If you are diagnosed with COVID-19, follow instructions for quarantine and contact your advisor so they can help you stay on track academically.

Synthesis/critique of selected papers:
You are asked to write a short synthesis/critique of 10 of the papers discussed in class. Note that there are more papers discussed than written synthesis required. However, *please read each paper prior to class discussion regardless of whether you write a synthesis or not*. I will not take more than one synthesis/critique per week (i.e. it comes to about one paper per week). Synthesis/critiques should be turned in **prior** to the discussion in class. Late papers **will not** be accepted. You are welcome to submit more than 10 syntheses, in which case I will use only the best 10 for grading purposes.

Each synthesis/critique should be typed, 12 font, adequate margins (no less than 1 inch), and no more than two pages long (please use a 1.5 line spacing so I can add notes). Please follow a bulleted format as in the abstracts of many journals (e.g. *New Phytologist; Functional Ecology*, etc.). I tend to grade generously the first syntheses/critiques submitted, but I will tighten the grading gradually. The idea is for students to practice writing well, clearly, with a logical flow, and as succinctly as possible while addressing the main points.

For original research papers, the first bullet should identify the broad conceptual/theoretical framework of the paper. Subsequent bullets should identify the specific topic of the paper, the questions/hypotheses pursued, the overall approach followed, main results and conclusions. A final bullet(s) should be your own critical evaluation of the paper (is the conceptual framework well defined?; are the hypotheses/main questions well justified and reasonable?; are the experiments and/or measurements appropriate to test the hypothesis/questions formulated?; are the methods and statistical analysis appropriate?; are the results clear and well presented?; are the results sufficient to test the hypothesis and draw the conclusions?; are there alternative hypotheses that have been ignored?; is the paper sound?; what is the potential impact of the paper to the scientific community? etc.). If you think the research is well done and has no major flaws, you might not need to raise all of these points and your own creative comments and interpretation of the results will be just as valuable (or more!) for the discussion in class.

For review papers: Summarize in your own words the conceptual framework and the main ideas. I suggest writing a bulleted outline (as if you were preparing a talk about the material in the review) where each bullet conveys a clear message (e.g. broad conceptual background; purpose of the review; main approach; main findings; proposed directions, etc.). You may want to highlight what you think are particularly relevant or innovative ideas. It may also be that you find the review problematic for whatever reason (e.g. certain topics not covered or not current enough, narrow focus, etc.). If so, add some bullets on why the review is problematic.

Literature Review
The literature review should be on a physiological topic. It is due on Tuesday of finals week. It should be typed and no more than 6 pages (1.5-spaced, 1" margins) excluding literature cited and figures.

The review should have a clear goal. Why are you reviewing a specific topic? One reason may be to summarize the current research on a given topic (i.e. a more descriptive review). Another is to provide background information as rationale for a specific hypothesis/idea you want to test (similar to the introduction of a proposal). It may be that you want to convince the scientific community of innovative approaches needed and provide case-study examples.

I suggest you browse published reviews to have a better sense of what a review entails and how to structure it ('Perspective', 'Commentaries' or similar sections in journals may also help).

First, formulate a general question to start. For instance:
What are the carbon costs of mycorrhizae for plants?

Are plants capable of refilling the xylem in vivo?
What are the physiological costs of reproduction?
How do plants cope with freezing stress?
How can physiology help restoration?

Then start browsing the literature and read the most relevant papers based on your general question. This will help to narrow down the specific goal of the review. Keep in mind that the more specific the question is, the easier it is to tackle. If you start too broad or ambitious you may get lost.

The key elements are WHAT and WHY.

- Before you start writing, have a very well defined goal of why you are doing this review. What are you reviewing? Why is it relevant?
- Based on your readings, think about potential sections following a logical flow (make a tentative outline). After working on the different sections, you may want to reorganize them (i.e. the outline may change). Envision the main concluding points.

- Start with the broad picture → Provide a clear broad conceptual/theoretical/applied framework (i.e. the broad significance of your topic)
- Narrow to the specific issue addressed. Its significance should be crystal clear.
- Summarize the key literature: what is known, what the voids are and why they matter. This is the core of the review and must be structured carefully so it flows logically.
- The review should maintain a core focus throughout, and follow a clear logic and flow
- Write simple and clear (avoid fluff and fillings and complex sentence structures)

Oral presentations

You will have ca. 15-20 minutes (depending on the number of students) to give an oral presentation of your reviewed topic. The oral presentation is a communication exercise. Your goal is to effectively communicate to your audience (in this case the rest of the class) what you reviewed, why and what you have learned. You should end with concluding remarks (take home messages) that are linked to your original rationale (close the circle).

Make a general outline to determine the main structure and flow of the talk. Revise your outline from the perspective of the listener. At the end of your talk the audience should be able to take home one or very few messages. Avoid complexity in your visuals and do not put anything in them that you will not refer to (very little text, simple diagrams). The simpler the better (fancy slides may end up being are more confusing than anything else).

Write your script word by word. Read it aloud while going through the visuals (this will help determine the correct wording and timing). If needed, memorize the text, but avoid reading your talk during the presentation. If you need to memorize the text, pretend that you have not (i.e. rehearse to talk confidently and naturally). Rehearse the talk to ensure it flows smoothly and that your timing is correct (it is extremely important to finish your talk on time and that you do not have to rush through the last slides).

Make sure to talk slowly and to explain in detail everything included in your visuals (e.g. all axes in figures, legends, etc.). Do not assume that the audience knows what you know and explain all concepts and terms used, even if they seem obvious to you. Even when dealing with complex issues simplicity and clarity result in good presentations. It is much better to present less material but clearly than rushing through lots of material.

***TENTATIVE* SCHEDULE (See separate Topic list and readings)**

WEEK	DATE	TOPIC
Week 1	20 Aug.	Introduction and current directions.
Week 2	25-27 Aug.	Functional traits. Papers 1, 2 (read), 3 (critique) Finish paper 3 critique. Photosynthesis: responses environment background
Week 3	1-3 Sep.	Photosynthesis: responses environment. Papers 4, 5 (background). Paper 6 (critique)
Week 4	8-10 Sep.	Carbon Isotopes. Papers 7, 8 (background), Carbon Isotopes: Paper 9 (critique). Photosynthetic pathways background
Week 5	15-17 Sep.	Photosynthetic pathways. Papers 10, 11 (background). Papers 12, 13 (critique). Photosynthesis & climate. Paper 14 (critique)
Week 6	22-24 Sep.	Respiration. Paper 15, 16 (critique) Carbon and growth. Papers 17, 18. Paper 19 (critique)
Week 7	29 Sep.-1 Oct.	Phloem. Papers 20, 21 (critique) Catch up
Week 8	6-8 Oct.	Tissue water relations. Paper 22 (background), 23 (critique) Whole Plant Water relations. Papers 24 (critique)
Week 9	13-15 Oct.	Stomata Paper 25 (critique). Drought Mortality. Papers 26 (background), 27, 28 (critique)
Week 10	20-22 Oct.	Mineral nutrition. Papers 29 (background), 30 (critique) Mineral nutrition. Papers 31, 32 (critique)
Week 11	27-29 Oct.	Mycorrhizae. Papers 33, 34 (background), 35 (critique) Catch up
Week 12	3 Nov. 5 Nov.	Election Day Root Ecophysiology Papers 36, 37 (critique)
Week 13	10-12 Nov.	Seedling Ecophysiology. Papers 38, 39 (critique) Plant Reproduction. Papers 40, 41 (critique)
Week 14	17 Nov. 19 Nov.	Plant Reproduction Finals week. Instruments (LiCor)

MAIN TOPICS AND READINGS

Plant Groupings *Why grouping?*

- On what basis? Functional groups or Trait-based grouping? Pros and cons.

Readings:

1. Wright IJ, Reich PB, Westoby M et al. 2004. The worldwide leaf economics spectrum. Nature 428:821-827
2. Reich PB. 2014. The world-wide 'fast–slow' plant economics spectrum: a traits manifesto. Journal of Ecology 102: 275–301.
3. Osnas JLD, Katabuchi M, Kitajima K, Wright SJ, Reich PB, Van Baele SA, Kraft NJB, Samaniego MJ, Pacala SW, Lichstein JW. 2018. Divergent drivers of leaf trait variation within species, among species, and among functional groups. PNAS 115:5480-5485. Discussion

Photosynthesis: responses to the environment

- Do plants maximize photosynthesis?
- How sensitive is photosynthesis to changes in light, nutrients, water, temperature and CO_2?

Readings:

4. Evans JR, Poorter H. 2001. Photosynthetic acclimation of plants to growth irradiance: the relative importance of specific leaf area and nitrogen partitioning in maximizing carbon gain. Plant Cell and Environment 24: 755-767.
5. Leakey ADB, Ainsworth, EA, Bernacchi CJ, et al. 2009. Elevated CO_2 effects on plant carbon, nitrogen, and water relations: six important lessons from FACE. Journal of Experimental Botany 60: 2859-2876.
6. Xu, LK; Baldocchi, DD. 2003. Seasonal trends in photosynthetic parameters and stomatal conductance of blue oak (*Quercus douglasii*) under prolonged summer drought and high temperature. Tree Physiology 23: 865-877.

Carbon Isotope Ratios

- What explains variation?

Reading:

7. Dawson, TE; Mambelli, S; Plamboeck, AH; et al. 2002. Stable isotopes in plant ecology. Annual Review of Ecology and Systematics 33: 507-559
8. Gessler A, Ferrio JP, Hommel R, et al. 2014. Stable isotopes in tree rings: towards a mechanistic understanding of isotope fractionation and mixing processes from the leaves to the wood. Tree Physiology 34: 796-818.
9. Tepley AJ, Hood SM, Keyes CR, Sala A. 2020. Forest restoration treatments in a ponderosa pine forest enhance physiological activity and growth under climatic stress. Ecological Applications. doi: 10.1002/EAP. 2188

Photosynthetic pathways and climate change

- Do we expect shifts between C3 and C4 species with climate change?

Readings:

10. Sage RF, Sage TL, Kocacinar T.2012. Photorespiration and the Evolution of C4 Photosynthesis. Annu. Rev. Plant Biol. 63:19–47
11. Winter K. 2019. Ecophysiology of constitutive and facultative CAM photosynthesis. Journal of Experimental Botany 70: 6495–6508.

12. Winter K, Sage RF, Edwards EJ, Virgo A, Holtum JAM. 2019. Facultative crassulacean acid metabolism in a C3–C4 intermediate. Journal of Experimental Botany 70: 6571–6579.
13. Reich, Peter B.; Hobbie, Sarah E.; Lee, Tali D.; et al. 2018. Unexpected reversal of C-3 versus C-4 grass response to elevated CO_2 during a 20-year field experiment. Science 360: 317-320.
14. Wittmer MIHO, Auerswald K, Bai Y, Schäufele R, Schnyder H. 2010. Changes in the abundance of C3/C4 species of Inner Mongolia grassland: evidence from isotopic composition of soil and vegetation. Global Change Biology 16: 605–616.

Respiration

- How sensitive is respiration to light, temperature and moisture?
- Does respiration acclimate to climate conditions?

Reading:

15. Dusenge *ME, Duarte AG,* Way D. 2019. Plant carbon metabolism and climate change: elevated CO_2 and temperature impacts on photosynthesis, photorespiration and respiration. *New P*hytologist 221: 32–49
16. Atkin OK, Bloomfield KJ, Reich PB, et al. 2015. Global variability in leaf respiration in relation to climate, plant functional types and leaf traits. New Phytologist 206: 614-636

Carbon and growth

- Does carbon availability control growth?

Readings:

17. Körner C. 2003. Carbon limitation in trees. Journal of Ecology 91: 4–17.
18. Sala A, Woodruff DW, Meinzer FR. 2012. Carbon dynamics in trees: feast or famine? Tree Physiology 32: 764-775.
19. Smith, AM; Stitt, M. 2007. Coordination of carbon supply and plant growth. Plant Cell and Environment 30: 1126-1149

Phloem

- How much do we know and why should we care?

Readings:

20. Savage JA. 2020. It's all about timing—or is it? Exploring the potential connection between phloem physiology and whole plant phenology. Am. Jour. Bot., 107(6), 848-851
21. Fu QS, Cheng LL, Guo YD, Turgeon R. 2011. Phloem Loading Strategies and Water Relations in Trees and Herbaceous Plants. Plant Physiology 157: 1518-1527.

Water Relations

- Why does plant growth cease when water is limiting?
- Do plants face water transport efficiency vs. safety tradeoffs?
- What are the ecological implications of different drought resistance strategies?
- How does drought kill trees?

Readings:

22. Chaves MM, Maroco JP, Pereira JS. 2003. Understanding plant responses to drought –From genes to the whole plant. Functional plant Biology 30:239-264.
23. Bartlett, MK, Scoffoni C, Sack L. 2012. The determinants of leaf turgor loss point and prediction of drought tolerance of species and biomes: a global meta-analysis. Ecology Letters 15: 393-405.
24. Choat B, Jansen S, Brodribb TJ, et al. 2012. Global convergence in the vulnerability of forests to drought. Nature 491, 752–755.

25. Martin-StPaul N, Delzon S, Cochard H. 2017. Plant resistance to drought depends on timely stomatal closure. Ecology Letters 20: 1437-1447 .

Drought Mortality

- How does drought kill trees?

Readings:

26. McDowell, N., W.T. Pockman, C.D. Allen, et al. 2008. Mechanisms of plant survival and mortality during drought: why do some plants survive while others succumb to drought? New Phytol. 178:719–739.
27. Trugman AT, Anderegg LDL, Shaw JD, Anderegg WRL. 2020. Trait velocities reveal that mortality has driven widespread coordinated shifts in forest hydraulic trait composition. Proceedings of the National Academy of Sciences 117: 8532–8538.
28. Garcia-Forner N, Adams H, Sevanto S et al. 2016. Responses of two semiarid conifer tree species to reduced precipitation and warming reveal new perspectives for stomatal regulation. Plant Cell and Environment 39: 38-49.

Mineral nutrition/Mycorrhizae

- Which nutrients are most limiting for plant growth in nature? Why?
- What are important nutrient acquisition and conservation strategies in plants?
- What are their relative costs and benefits?

Readings:

29. Lambers H, Raven JA, Shaver GR, Smith SE. 2008. Plant nutrient-acquisition strategies change with soil age. Trends in Ecology and Evolution 23:95-103.
30. Sianta SA, Kay KM. 2019. Adaptation and divergence in edaphic specialists and generalists: serpentine soil endemics in the California flora occur in barer serpentine habitats with lower soil calcium levels than serpentine tolerators. Am. J. Bot. 106:690-703 .
31. Perakis SS, Pett-Ridge JC. 2019. Nitrogen-fixing red alder trees tap rock derived nutrients. PNAS 116: 5009–5014
32. Chen W, Koide R, Adams TS, DeForest JL, Chenga L, Eissenstat DM. 2016. Root morphology and mycorrhizal symbioses together shape nutrient foraging strategies of temperate trees. PNAS 113: 8741–8746

Mycorrhizal Networks

- How do plants benefit from mycorrhizae?
- Are all mycorrhizae equal?
- When are mycorrhizae no longer mutualistic?
- Do mycorrhizae improve water relations under drought?

Readings:

33. Tedersoo & Bahram. 2019. Mycorrhizal types differ in ecophysiology and alter plant nutrition and soil processes. Biological Reviews 94: 1857–1880.
34. Delavaux CS, Smith-Ramesh LM, Kuebbing SE. 2017. Beyond nutrients: a meta-analysis of the diverse effects of arbuscular mycorrhizal fungi on plants and soils. Ecology 98: 2111–2119
35. Sapes G, Demaree P, Lekberg Y, Sala A. Plant carbohydrate depletion impairs water relations and spreads via ectomycorrhizal networks.

Root Ecophysiology

36. Meier IC, Leuschner C. 2008. Genotypic variation and phenotypic plasticity in the drought response of fine roots of European beech. Tree Physiology 28: 297–309.

37. Nardini A, Casolo V, Dal Borgo A, et al. 2016. Rooting depth, water relations and non-structural carbohydrate dynamics in three woody angiosperms differentially affected by an extreme summer drought. Plant Cell and Environment 39, 618–627

Seedling Ecophysiology

38. Cavender-Bares J, Bazzaz FA. 2000. Changes in drought response strategies with ontogeny in *Quercus rubra*: Implications for scaling from seedlings to mature trees. Oecologia 124: 8–18.
39. Lazarus BE, Castanha C, Germino MJ, Kueppers LM, Moyes AB. 2018. Growth strategies and threshold responses to water deficit modulate effects of warming on tree seedlings from forest to alpine. J. Ecol. 106:571–585.

Plant Reproduction

- How costly is reproduction?
- What are the consequences of seed size?
- Do plants fine tune phenology and physiology to optimize reproduction?

Reading:

40. Rubio de Casas R, Willis CG, Pearse WD, Baskin CC, Baskin JM, Cavender-Bares J. 2017. Global biogeography of seed dormancy is determined by seasonality and seed size: a case study in the legumes. New Phytologist PD: 2017-06-01T00:00:00
41. Kudo G. et al. 2008. Linkages between phenology, pollination, photosynthesis, and plant reproduction in deciduous forest understory plants. Ecology 89: 321-331.