

University of Guelph
College of Biological Science
Department of Molecular and Cellular Biology
COURSE OUTLINE
Metabolism in the Whole Life of Plants-BOT 4380
Winter 2016

Course Description

This course follows the developmental changes that take place in plants, and explores the molecular, biochemical, and physiological mechanisms that are responsible for development. Emphasis will be placed on the importance of modern experimental methods and critical evaluation of the data. 0.5 U. Prerequisites: BIOL*1040 or BIOL*1090 & BIOC 2580.

Teaching Team

Dr. Tariq Akhtar, Science Complex, Room 4461, Ext. 54794, takhtar@uoguelph.ca & Dr. Barry Micallef, CRSC Rm 424, Ext. 54384, bmicalle@uoguelph.ca.

Office hours are flexible, and we will be available for discussion after class or by appointment. Feel free to contact us by email; we will do our best to respond quickly.

Course Schedule

Lectures are in MCKN (MacKinnon) 116, 10:30-11:20 am, Mon/Wed/Fri, starting Monday, January 11th, 2016 and ending Friday, April 8th, 2016 (35 lectures total).

Learning Goals and Rationale

By the end of this course, students should be able to:

1. grasp both the historical development and the current state of knowledge in plant biology, and in plant metabolism in particular, including an appreciation of emerging technologies and experimental methods;
2. integrate the physiological, biochemical, and molecular mechanisms whereby autotrophic organisms, and particularly seed plants, sustain themselves in the context of the whole life cycle of the plant;
3. interpret the scientific literature and data relevant to plant biology and to plant metabolism in particular;
4. communicate effectively using scientific writing;

5. apply forms of inquiry including hypothesis development through critical analysis of relevant scientific literature and essay writing;
6. apply knowledge of plant metabolism to specific questions associated with relevant biological processes, agriculture, forestry, energy production, and medicine.

Course Resources

Required Text

Bowsher, Steer & Tobin (2008) *Plant Biochemistry*. Garland Science, Taylor & Francis Group, LLC, New York, New York. Available in the Bookstore (~\$145.00); also on library reserve.

There will also be lecture presentations and handouts posted on Courselink, and selected references from the scientific literature will be provided.

Other Sources of Information (On Library Shelves)

Bassham & Calvin (1957) *Path of Carbon in Plants*. Prentice-Hall Publishing. QK 882.B3.

Buchanan, Gruissem & Jones (2000) *Biochemistry and Molecular Biology of Plants*. American Society of Plant Physiologists. QK 861.B45 (also on library reserve).

Calvin (1962) The path of carbon in photosynthesis. *Science* 135: 879-889. QH 9 B6.B29.

Crozier, Clifford, and Ashihara (2006) *Plant Secondary Metabolites: Occurrence, Structure, and Role in the Human Diet*. Blackwell Publishing. QK 881.P55 2006.

Dennis (1997) *Plant Physiology, Biochemistry, and Molecular Biology*. Longman Publishing. QK 881.P54 1997.

Heldt (1997) *Plant Biochemistry and Molecular Biology*. Oxford University Press. QK 861 H4513 1997.

Taiz & Zeiger (2006) *Plant Physiology*. Sinauer Associates. QK 711.2 T35 2006.

Additional Useful Sources

There are several journals that provide original scientific articles dedicated to plant biology such as *Plant Physiology*, *The Plant Cell*, *The Plant Journal*, *Plant Molecular Biology*, *Plant and Cell Physiology*, *Journal of Experimental Botany*, *Plant, Cell and Environment*, etc.

Wider-audience journals such as *Science*, *Nature*, *Proceedings of the National Academy of Sciences*, *Cell*, etc. also include many original scientific articles in plant biology and related studies.

There are also several journals that publish review articles such as *Annual Reviews of Plant Physiology and Plant Molecular Biology*, *Annual Plant Reviews*, *Trends in Plant Science*, *Current Opinion in Plant Science*, *Annual Reviews of Biochemistry*, etc.

Course Content

Interactive lectures with opportunity for questions and discussion, including some discussion of scientific papers. In addition, required and supplementary readings will be posted on Courselink throughout the course. The topic for each 3-page essay will be provided in class and on Courselink. Supplementary readings from the textbook, required and supplementary readings, and scientific paper citations directed to each topic below will be indicated in the Powerpoint lectures posted on Courselink.

Lecture Topics: comprehensive treatments are given for of all the topics listed below; the list below is a general outline divided between the two lecturers in the course. It does not necessarily provide all specific topics covered.

(A) Lectures by Micallef

Module 1-Significance, Structure and Function of Autotrophic Organisms (Lectures 1-3, January 11th-15th)

Introduction to autotrophy: lithotrophic processes; definition of autotrophy; characteristics shared by all autotrophic organisms; why organisms on earth are C-based; ecological significance of autotrophy in marine and terrestrial ecosystems.

Chemolithotrophy: chemolithotrophy and chemolithoautotrophic bacteria, including energetics; ecological significance of chemolithoautotrophy; extremophiles; pathways of C fixation in chemolithoautotrophs; limitations to chemolithotrophy.

Photolithotrophy: definitions for photolithoautotrophy and photosynthesis; photosynthesis in halophytic bacteria; anoxygenic photoautotrophy; oxygenic photoautotrophy, including origin in eukaryotes; photoautotrophy and symbiosis; phylogenetics of photoautotrophic eukaryotes; photoautotrophy in the Kingdoms Chromalveolata and Plantae.

Characteristics of the clade Viridiplantae including angiosperms (see Required Reading): evolutionary trends; the angiosperm life cycle; levels of study when examining angiosperms; the body plan of angiosperms reflects their autotrophic nature; sources & sinks in plants; anatomy of autotrophic organs in terrestrial plants; parasitic angiosperms; energy-use efficiency of sunlight by terrestrial plants (see Required Reading).

Module 2-The Light Reactions in the Chloroplast (Lectures 4-7, January 18th-25th)

Photoautotrophy at the cellular to organellar levels: microscopy (see Required Reading); plant versus animal cells; plastid types and their characteristics; chloroplast structure and function; apicoplasts.

Photoautotrophy at the suborganellar to biochemical Levels: suborganellar structure and function of chloroplasts; major protein complexes in the chloroplast; chloroplasts as a solar hydrogen fuel cell; artificial photosynthesis.

Properties of light and light-absorbing pigments: basic properties of the light reactions; four crucial characteristics of chlorophyll; properties of sunlight; absorption spectrometry; specific chromophores in photoautotrophic organisms; chlorophyll species and their structure-function relationships; a pigment = a chromophore-protein

complex; metabolites derived from 5-aminolevulinate; methods used to study biochemical pathways; chlorophyll synthesis and degradation, including regulatory mechanisms; phycobilin pigments and their significance.

Photosystems and fates of absorbed light energy: characteristics of the light-harvesting apparatus; definition of a photosystem; X-ray crystallography of membrane-bound proteins; structure and function of light-harvesting complexes, including the phycobilisome antenna network; fates for excitation energy; funnelling of excitation energy to the reaction center; efficiency of a plant photosystem in utilising sunlight energy.

Electron transport and ATP synthesis: photochemistry and quantum yield; reaction center complex in purple-sulfur bacteria; function of mobile electron carriers; structure-function relationships for the major thylakoid complexes (see Required Reading); requirement for one or two photosystems; electron transport and generation of a proton gradient; coupling of the proton gradient to ATP synthesis.

Regulation of the light reactions: cyclic & non-cyclic electron transport; phosphorylation of LHC's; functional significance of the spatial arrangement of thylakoid complexes; processes to dissipate excess light energy (see Required Reading); coping with varying irradiance and light quality; improving the energy-use efficiency of sunlight.

Module 3-Photosynthetic C Metabolism (Lectures 8-11, January 27th-February 3rd)

Introduction to photosynthetic C metabolism and the Calvin-Benson cycle: elemental composition of terrestrial plants; carbon reactions of photosynthesis, including the C oxidation series; defining photosynthetic C, N & S metabolism; elucidating the 1st product of C fixation in C3 plants; elucidating the reactions of the Calvin-Benson cycle; phases and reactions of the Calvin-Benson cycle; interactions with respiratory metabolism (see Required Reading); end products of photosynthesis.

Regulation of the Calvin-Benson cycle: modulation of enzyme activity by the ionic & solute environment in the stroma; thioredoxin-ferredoxin system; properties of ribulose biphosphate carboxylase/oxygenase (Rubisco); Rubisco activase.

Photorespiration and altered photosynthetic types: definition of photorespiration; Rubisco oxygenase reaction; evolutionary kinetics of Rubisco (see Required Reading); C2 oxidative photosynthetic cycle and photorespiratory N cycle; elucidation of the photorespiratory cycle; effects of photorespiration on net C assimilation and the quantum requirement for C fixation; atmospheric CO₂, temperature and photorespiration; C4 photosynthesis; chloroplast ultrastructure in C4 plants; CAM metabolism; carboxysomes in bacteria.

End product synthesis and transport: properties of sucrose and starch; pathways of sucrose and starch synthesis, including regulation; chloroplast phosphate translocator and phosphate cycling; chloroplastic starch degradation; phloem loading and unloading; sucrose utilization in sink tissues; improving photosynthetic C metabolism.

Module 4-N & S Uptake, Assimilation and Utilization (Lectures 12-14, February 5th-February 10th)

Overview of N metabolism and N uptake: major inorganic forms of N & S; nitrogen cycle, including biochemical aspects of N₂ fixation; roles of N and S in the plant; phases

and enzymes of N uptake and assimilation; N uptake and transport, including cellular transport processes, N remobilization during senescence.

Assimilation of nitrate and ammonium to organic N: nitrate and nitrite reductase, including regulation; assimilation of ammonium by GS-GOGAT; sources of ammonium in plant cells; nitrate assimilation in roots and shoots; organic N transport compounds; interactions between C and N metabolism; N-use efficiency in plants.

S uptake and assimilation: sulfate uptake and transport; activation and reduction of sulfate; formation of cysteine and glutathione; functions for glutathione in the plant; amino acid synthesis; N & S utilization in plants.

Module 5-Reproductive Biology of Plants and Germination (Lectures 15-18, February 12th-February 26th)

Reproductive biology of plants: sporic meiosis and variations on this life cycle in Viridiplantae (see [Required Reading](#)); the 'switch' from a vegetative to floral meristem in angiosperms; role of the florigen protein in the flowering response in angiosperms; development of the male and female gametophyte; seed development and maturation.

Germination and early seedling establishment in plants: the 'switch' from seed development to seed germination; the mobilization of seed reserves, including protein, starch and fatty acid degradation; early seedling establishment, including photomorphogenesis mediated by photoreceptors.

(B) Lectures by Akhtar

Lectures 19-35 (February 29th-April 8th)

Cell walls/cell wall biosynthesis, including utilization of sucrose by sink tissues and the role of respiratory pathways.

Vitamin and cofactor biosynthesis

Plant hormone biosynthesis and physiology

Lipid metabolism: fatty acid biosynthesis in sink tissues; plant growth regulators derived from lipids.

Terpenoid metabolism: relevant primary metabolism, including carotenoids & plant growth regulators derived from the terpenoid pathways; secondary metabolism, including mevalonate and non-mevalonate pathways for terpenoid synthesis.

Nitrogen and sulfur utilization: plant growth regulators derived from N & S metabolism; phenylpropanoid compounds & their importance in plant defense responses; alkaloid compounds & their relationship to medicine; importance of N & S compounds in human nutrition.

Methods of Assessment

Form of Assessment	Weight of Assessment	Date of Exams/Due Dates for Essays	Additional Comments	Learning Outcomes Addressed
Mid-term examination	25% of final grade	Wed., Feb. 10 th , 7:00-8:30 pm (outside of class), Room TBA	Includes lecture material up to and including the Feb. 8 th lecture (13 lectures total).	1-3, 5-6
Final examination	45% of final grade	Date and Location TBA	Includes lecture material directed to the Feb. 10 th to April 8 th lectures (22 lectures in total).	1-3, 5-6
Introductory paragraph & sentences & references for the 1 st 3-page essay	2.25% of final grade	On Fri., Jan. 29 th by 4 pm as a hard copy to B. Micallef	Topic for the essay will be provided in the 1 st lecture on Mon., Jan. 11 th .	1-6
Completed 1 st 3-page essay	12.75% of final grade	By Mon., Feb. 22 nd at 4 pm as a hard copy to B. Micallef.	Completed version of the 3-page essay is due.	1-6
2 nd 3-page essay	15% of final grade	By Mon., Apr. 4 th at 4 pm as a hard copy to T. Akhtar.	Topic for the essay will be provided in the Mon., Feb. 22 nd lecture.	1-6

Additional Information on the Midterm and Final Exam

The Midterm will consist of definitions, short answer questions, and data interpretation. The Final Exam emphasizes material covered after the Midterm, but the material covered prior to the Midterm is indirectly applicable to the Final Exam. The Final Exam will consist of short to medium answer questions, and data interpretation.

Additional Information on the 3-Page Essays

Complete instructions on writing the 3-page essays, including the evaluation scheme, are provided in a separate document posted in the News Item section of Courouselink. The 1st Essay and 2nd Essay will be marked by B. Micallef and T. Akhtar, respectively. To provide writing assistance for the 1st 3-page essay, the complete introductory paragraph, the introductory sentences for the remaining paragraphs, and a minimum of 4 references for will be handed into B. Micallef for marking on Friday, January 29th. The grade provided for the introductory paragraph will be the final grade for the Introduction portion of the essay (10% of essay value), and 5% of the 55% for Research will be awarded for the introductory sentences of the remaining paragraphs

and references provided. The completed version of the 1st 3-page essay can include a revised Introduction and revised introductory sentences based on comments from B. Micallef, although these portions of the essay will not be remarked. Do consider comments and revisions provided by B. Micallef. When handing in each essay, both a hard copy and an electronic copy must be submitted to the instructor by the deadline.

Important Dates

The Midterm is on Wednesday, February 10th outside of class from 19:00-20:30 (room TBA); time conflicts should be reported to B. Micallef once the conflict is identified.

The introductory paragraph & sentences, and a minimum of 4 references for the 1st 3-page essay are due on Friday, January 29th by 4 pm to B. Micallef.

The completed 1st 3-page essay is due by Monday, February 22nd at 4 pm to B. Micallef.

The 2nd 3-page essay is due by Monday, April 4th at 4 pm to T. Akhtar.

The Winter Break is February 15th-19th, and the 40th day of classes is March 11th.

Course and University Policies

When You Cannot Meet a Course Requirement

When you find yourself unable to meet an in-course requirement because of illness or compassionate reasons, please advise the course instructor in writing, with your name, id#, and e-mail contact, and be prepared to provide supporting documentation. See the undergraduate calendar for information on regulations and procedures for Academic Consideration: [Undergraduate Calendar - Academic Consideration](#).

For the Midterm, an alternative time will be determined by B. Micallef if warranted in consultation with the student. The time selected must be prior to Wednesday, February 22nd, which is when the Midterm will be returned. B. Micallef will attempt to include all students that require a deferred Midterm in the same time period, and thus a deferred date may not be finalized immediately. Arrangements for a deferred Final Exam can potentially be made through either a course instructor or the Registrar's Office. For the Essay Assignments, any alternative submission dates for compassionate reasons must be established by the instructor marking the Essay (B. Micallef for the 1st Essay and T. Akhtar for the 2nd Essay); an alternative submission date for the 1st Essay must be no later than Friday, March 2nd, since the 1st Essay will be returned at that time.

Accessibility

The University of Guelph is committed to creating a barrier-free environment. Providing services for students is a shared responsibility among students, faculty and administrators. This relationship is based on respect of individual rights, the dignity of the individual and the University community's shared commitment to an open and supportive learning environment. Students requiring service or accommodation, whether

due to an identified, ongoing disability or a short-term disability should contact Student Accessibility Services (and Centre for Students with Disabilities) as soon as possible.

For more information, contact Student Accessibility Services at 519-824-4120 ext. 56208 or email csd@uoguelph.ca or see the website: [Centre for Students with Disabilities](#).

Academic Misconduct

The University of Guelph is committed to upholding the highest standards of academic integrity and it is the responsibility of all members of the University community – faculty, staff, and students – to be aware of what constitutes academic misconduct and to do as much as possible to prevent academic offences from occurring. University of Guelph students have the responsibility of abiding by the University's policy on academic misconduct regardless of their location of study; faculty, staff and students have the responsibility of supporting an environment that discourages misconduct. Students need to remain aware that instructors have access to and the right to use electronic and other means of detection.

Please note: Whether or not a student intended to commit academic misconduct is not relevant for a finding of guilt. Hurried or careless submission of assignments does not excuse students from responsibility for verifying the academic integrity of their work before submitting it. Students who are in any doubt as to whether an action on their part could be construed as an academic offence should consult with a faculty member or faculty advisor.

The Academic Misconduct Policy is detailed in the Undergraduate Calendar: [Undergraduate Calendar - Academic Misconduct](#).

E-mail Communication

As per university regulations, all students are required to check their <uoguelph.ca> e-mail account regularly: e-mail is the official route of communication between the University and its students.

Drop Date

The last date to drop one-semester courses, without academic penalty, is the 40th class day, which is March 11th, 2016 for the Winter 2016 semester. To confirm the actual date please see the schedule of dates in the Undergraduate Calendar. For regulations and procedures for Dropping Courses, see the Undergraduate Calendar: [Undergraduate Calendar - Dropping Courses](#).

Copies of Out-of-Class Assignments and Lecture Notes

Keep paper and/or other reliable back-up copies of all out-of-class assignments: you may be asked to resubmit work at any time. It is also advised that you keep a hard copy of all lecture notes; electronic copies of the lecture notes will not be provided to students apart from Courselink. Thus, files cannot be obtained once access to the Courselink site has expired.

Recording of Materials

Presentations that are made in relation to course work—including lectures—cannot be recorded or copied without the permission of the presenter, whether the instructor, a classmate or guest lecturer. Material recorded with permission is restricted to use for that course unless further permission is granted.

Grading

Information on dates for exams and due dates for essays are provided in **Methods of Assessment** above. For the essay assignments, a deduction will be assessed worth 10% of the essay assignment value per working day late = a deduction of 1.5% of your final grade per working day late, where a working day does not include Saturday and Sunday. For the Midterm, if a student requests a reconsideration of grade for a specific answer(s) the entire marked Midterm will be provided to the instructor, and ALL answers will be re-marked by the instructor.

Campus Resources

The Academic Calendar is the source of information about the University of Guelph's procedures, policies and regulations which apply to undergraduate, graduate and diploma programs: [Academic Calendars](#)

If you are concerned about any aspect of your academic program:

- make an appointment with a program counsellor in your degree program. [B.Sc. Academic Advising](#) or [Program Counsellors](#).

If you are struggling to succeed academically:

- There are numerous academic resources offered by the Learning Commons including, Supported Learning Groups for a variety of courses, workshops related to time management, taking multiple choice exams, and general study skills. You can also set up individualized appointments with a learning specialist. [The Learning Commons](#).

If you are struggling with personal or health issues:

- [Counselling](#) services offers individualized appointments to help students work through personal struggles that may be impacting their academic performance.
- Student Health Services is located on campus and is available to provide medical attention. [Student Health Services](#)
- For support related to stress and anxiety, besides Health Services and Counselling Services, Kathy Somers runs training workshops and one-on-one sessions related to stress management and high performance situations. [Stress Management and High Performance Centre](#).

If you have a documented disability or think you may have a disability:

- Student Accessibility Services (formerly Centre for Students with Disabilities) can provide services and support for students with a documented learning or physical disability. They can also provide information about how to be tested for a learning disability. For more information, including how to register with the centre please see: [Centre for Students with Disabilities](#).

Course Evaluation Information

- Your ratings and comments are important. Course evaluation data are used to assess and enhance the quality of teaching and student learning at the University of Guelph. Student course ratings and comments are used as an important component in the Faculty Tenure & Promotion process, and as valuable feedback to help instructors improve their teaching effectiveness and to improve the delivery of the course.
- Your responses will not affect your grade. Course evaluation data are distributed to individual instructors after final grades have been submitted to the Registrar, following the completion of each academic semester.
- Please be honest, respectful, constructive and thorough. Instructors and review committees place great value on student course ratings and read all comments provided in course evaluations. It is helpful to provide comments on the strengths of the course, in addition to the areas for improvement. Please refrain from personal comments unless they relate to teaching and learning.
- The timing and type of course evaluation for each instructor will be indicated in lecture. Since B. Micallef and T. Akhtar are in different Colleges, their course evaluations will be conducted separately.