

**University of Guelph**  
**College of Biological Sciences**  
**Department of Molecular and Cellular Biology**  
**Metabolism in the Whole Life of Plants-BOT 4380**  
**Winter 2017**

### **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 data. 0.5 U. Prerequisites: BIOL\*1090 & BIOC\*2580.

### **Course Schedule**

Lectures are in MCKN (MacKinnon) 120, 10:30-11:20 am, Mon/Wed/Fri, starting Monday, January 9<sup>th</sup>, 2017 and ending Friday, April 7<sup>th</sup>, 2017 (36 lectures total).

### **Instructor Information**

Dr. Tariq Akhtar, Science Complex, Room 4461, Ext. 54794, [takhtar@uoguelph.ca](mailto:takhtar@uoguelph.ca) &  
Dr. Barry Micallef, CRSC Rm 424, Ext. 54384, [bmicalle@uoguelph.ca](mailto:bmicalle@uoguelph.ca).

B. Micallef will have office hours from 11:30-12:15 on MWF. We will also be available by appointment. Feel free to contact us by email; we will do our best to respond quickly. There are no GTAs in BOT 4380.

### **Course Content**

#### **Specific Learning Outcomes**

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.

### **Lecture Content and Topics**

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.

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 9<sup>th</sup>-13<sup>th</sup>)**

Introduction to autotrophy: definition of autotrophy; characteristics shared by all autotrophic organisms.

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

Phototrophy and photolithotrophy: definitions for phototrophy, photoheterotrophy and photolithoautotrophy (photosynthesis); photoheterotrophy including halophytic bacteria; anoxygenic photoautotrophy; oxygenic photoautotrophy, including origin in eukaryotes; photoautotrophy and symbiosis; phylogenetics of photoautotrophic eukaryotes;

Photoautotrophy in the Kingdoms Chromista and Plantae: evolutionary trends and characteristics of organisms in the Kingdom Chromista; evolutionary trends and characteristics of organisms in the Kingdom Plantae, including viridophytes: ecological significance of photoautotrophy in marine and terrestrial ecosystems.

#### **Module 2-The Light Reactions in the Chloroplast (Lectures 4-7, January 16<sup>th</sup>-23<sup>rd</sup>)**

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.

Photoautotrophy at the cellular to organellar levels: microscopy; 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; 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; coping with varying irradiance and light quality; improving the light reactions.

### **Module 3-Photosynthetic C Metabolism (Lectures 8-11, January 25<sup>th</sup>-February 1<sup>st</sup>)**

Introduction to photosynthetic C metabolism and the Calvin-Benson cycle: why organisms on earth are C-based; elemental composition of terrestrial plants; defining photosynthetic C, N & S metabolism; elucidating the 1<sup>st</sup> 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; 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; 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 CO<sub>2</sub>, 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 12-15, February 3<sup>rd</sup>-February 10<sup>th</sup>)**

Overview of N metabolism and N uptake: major inorganic forms of N & S; nitrogen cycle, including biochemical aspects of N<sub>2</sub> 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 16-18, February 13<sup>th</sup>-February 17<sup>th</sup>)**

Reproductive biology of plants: sporic meiosis and variations on this life cycle in Viridiplantae; 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**

### **Module 6-Introduction to Secondary Metabolism (Lectures 19-22, February 27<sup>th</sup>-March 6<sup>th</sup>)**

Understanding the interface between primary and secondary metabolism: Classification of the three main clades of 'specialized metabolites'; focus will be on alkaloid, glucosinolate, and polyamine biosynthesis and their physiological importance. Medicinal plants will be discussed.

### **Module 7-Isoprenoid Metabolism (Lectures 23-27, March 8<sup>th</sup>-March 17<sup>th</sup>)**

Isoprenoids: the largest class of secondary metabolites. Focus will be on isoprenoid synthesis from primary precursors to the physiological and ecological roles that these compounds serve. Focus will be on terpenes, sterols, carotenoids, polyprenols and isoprenoid-derived vitamins and plant hormones. Industrial applications of isoprenoids will be discussed.

### Module 8-Lipid Metabolism (Lectures 28-30, March 20<sup>th</sup>-March 24<sup>th</sup>)

Fatty acid biosynthesis and nomenclature: Assembly of phospholipids, galactolipids, triacylglycerols, and cutin/epicuticular waxes. Biophysical properties of plant lipids and the regulation their synthesis will be explored.

### Module 9-Phenolics (Lectures 31-33, March 27<sup>th</sup>-March 31<sup>st</sup>)

Biosynthesis and function of plant phenolics: Flavonoids, aromatic amino acid metabolism, plant volatiles, and cell wall assembly.

### Module 10-Vitamins, Cofactors, and Polyketides (Lectures 34-36, April 3<sup>rd</sup>-April 7<sup>th</sup>)

Co-factor biosynthesis: Emphasis will be on B-vitamins and their functional roles. Branched chain amino acid metabolism, prenylated polyketides and their industrial significance.

### Course 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. 8 <sup>th</sup> , 7:00-8:30 pm (outside of class), Location TBA	Includes lecture material up to and including the Feb. 6 <sup>th</sup> lecture (13 lectures total).	1-3, 5-6
Final examination	45% of final grade	April 22 <sup>nd</sup> , 11:30-13:30, Location TBA	Includes lecture material directed to the Feb. 8 <sup>th</sup> to April 7 <sup>th</sup> lectures (23 lectures in total).	1-3, 5-6
Introductory paragraph, Introductory sentences for each paragraph & references for the 1 <sup>st</sup> 3-page essay	2.25% of final grade	On Fri., Jan. 27 <sup>th</sup> by 4 pm as an electronic & hard copy to B. Micallef.	Topic for the 1 <sup>st</sup> 3-page essay will be provided in the 1 <sup>st</sup> lecture on Mon., Jan. 9 <sup>th</sup> .	1-6
Completed 1 <sup>st</sup> 3-page essay	12.75% of final grade	By Fri., Feb. 17 <sup>th</sup> at 4 pm as an electronic & hard copy to B. Micallef.	Topic for the 2 <sup>nd</sup> 3-page essay will be provided on Fri., Feb. 17 <sup>th</sup> .	1-6

Form of Assessment	Weight of Assessment	Date of Exams/Due Dates for Essays	Additional Comments	Learning Outcomes Addressed
Completed 2 <sup>nd</sup> 3-page essay	15% of final grade	By Mon., Apr. 3 <sup>rd</sup> at 4 pm as an electronic & hard copy to T. Akhtar.		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 Courselink. The 1<sup>st</sup> Essay and 2<sup>nd</sup> Essay will be marked by B. Micallef and T. Akhtar, respectively. To provide writing assistance for the 1<sup>st</sup> 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 27<sup>th</sup>. 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% total for Research will be awarded to the introductory sentences of the remaining paragraphs and references provided. The completed version of the 1<sup>st</sup> 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 the 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.

### **Course Resources**

#### **Recommended Text**

Bowsher, Steer & Tobin (2008) Plant Biochemistry. Garland Science, Taylor & Francis Group, LLC, New York, New York. Available in the Bookstore (\$210.50 new); also on library reserve. There will also be lecture presentations and handouts posted on Courselink, including Required Readings and selected references from the scientific literature.

### 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.
- 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.

## University Policies

### Academic Consideration:

The University of Guelph is committed to supporting students in their learning experiences and responding to their individual needs and is aware that a variety of situations or events beyond the student's control may affect academic performance. Support is provided to accommodate academic needs in the face of personal difficulties or unforeseen events in the form of Academic Consideration.

Information on regulations and procedures for Academic Consideration, Appeals and Petitions, including categories, grounds, timelines and appeals can be found in [Section VIII \(Undergraduate Degree Regulations and Procedures\) of the Undergraduate Calendar](#).

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.

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 Friday, February 17<sup>th</sup>, 2017, 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 1<sup>st</sup> Essay and T. Akhtar for the 2<sup>nd</sup> Essay); an alternative submission date for the 1<sup>st</sup> Essay must be no later than Monday, February 27<sup>th</sup>, 2017 since the 1<sup>st</sup> Essay will be returned at that time.

## **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.

Detailed information regarding the Academic Misconduct policy is available in [Section VIII \(Undergraduate Degree Regulations and Procedures\) of the Undergraduate Calendar](#).

## **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 the Student Accessibility Services (SAS), formerly Centre for Students with Disabilities (CSD), as soon as possible.

For more information, contact SAS at 519-824-4120 ext. 56208 or email [sas@uoguelph.ca](mailto:sas@uoguelph.ca) or visit the [Student Accessibility Services website \(http://www.uoguelph.ca/csd/\)](http://www.uoguelph.ca/csd/).

## Course Evaluation Information

End of semester course and instructor evaluations provide students the opportunity to have their comments and opinions used as an important component in the Faculty Tenure and Promotion process, and as valuable feedback to help instructors enhance the quality of their teaching effectiveness and course delivery.

While many course evaluations are conducted in class others are now conducted online. Please refer to the [Course and Instructor Evaluation Website](#) for more information.

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 T. Akhtar and B. Micallef are in different Colleges, their course evaluations will be conducted separately.

## Drop Period

The drop period for single semester courses starts at the beginning of the add period and extends to the Fortieth (40th) class day of the current semester (the last date to drop a single semester courses without academic penalty) which is listed in [Section III \(Schedule of Dates\) of the Undergraduate Calendar](#). In the Winter 2017 semester, the 40<sup>th</sup> class day is March 10<sup>th</sup>, 2017.

The drop period for two semester courses starts at the beginning of the add period in the first semester and extends to the last day of the add period in the second semester.

Information about Dropping Courses can be found in [Section VIII \(Undergraduate Degree Regulations and Procedures\) of the Undergraduate Calendar](#).

## 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.

## **Additional Course Information**

### **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 both students and the instructors. For the Essays or Midterm, if a student requests a reconsideration of grade the entire marked Essay or Midterm will be provided to the instructor, and the ENTIRE essay or ALL Midterm answers will be re-marked by the instructor.

### **Important Dates**

The Midterm is on Wednesday, February 8<sup>th</sup> outside of class from 19:00-20:30 (location TBA); time conflicts should be reported immediately to B. Micallef once the conflict is identified.

The introductory paragraph, introductory sentences, and a minimum of 4 references for the 1<sup>st</sup> 3-page essay are due on Friday, January 27<sup>th</sup> by 4 pm to B. Micallef as both an electronic copy emailed to B. Micallef and a hard copy.

The completed 1<sup>st</sup> 3-page essay is due by Friday, February 17<sup>th</sup> at 4 pm to B. Micallef as both an electronic copy emailed to B. Micallef and a hard copy.

The 2<sup>nd</sup> 3-page essay is due by Monday, April 3<sup>rd</sup> at 4 pm to T. Akhtar as both an electronic copy emailed to T. Akhtar and a hard copy.

The Final Exam is on Saturday, April 22<sup>nd</sup> from 11:30-13:30 (location TBA).

The Winter Break is February 20<sup>th</sup>-24<sup>th</sup>, and the 40<sup>th</sup> day of classes is March 10<sup>th</sup>.