PLNT-316 **PLANT SPECIALIZED METABOLISM**

Macdonald Campus, McGill University
Winter 2024

Course instructor: Dr. Mehran Dastmalchi
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Credit weight: 3
Pre-requisites: AEBI-210 (Organisms I); LSCI-211 (Biochemistry)
Recommended: LSCI-202 (Molec Cell Biology); LSCI 204 (Genetics)
Online enrollment: Open to U2+ students**;** exceptions can be made by instructor

Lectures: Weekly, 3-hr seminar; Time TBA; Location TBA
Textbook (*recommended*): Medicinal Natural Products; A Biosynthetic Approach – Paul Dewick (ISBN: 978-1-119-96457-5); E-Book format available
Office hours: TBA; starting from 2nd week of lectures
Zoom link (contingency): TBA

COURSE OBJECTIVES

Students will be introduced to the basic principles of **plant biochemistry** in the context of **cell biology, genetics, and synthetic biology**. Plants function as autotrophs by absorbing energy from light to assimilate carbon dioxide and produce complex organic structures – we will focus on the class of plant metabolism, termed **specialized metabolism**.

In this course, students will explore how simple compounds, such as sugars and amino acids, are transformed into complex natural products, including a) phenylpropanoids, b) terpenoids, and c) alkaloids. We will investigate the conserved and varying features of chemical pathways within an evolutionary framework – recurring motifs, such as hydroxylation and *O*/*N*-methylation, driven by gene duplication and enzyme neo-functionalization.

Furthermore, the regulation and organization of metabolism will be analyzed at multiple tiers, from gene expression to compartmentalization. Pathway elucidation will be taught from the perspective of research methods, allowing students to follow the discovery process. Throughout, we will consider traditional and state-of-the-art techniques to tackle plant biochemistry, including the growing field of synthetic biology. Students will be exposed to a large conceptual toolkit to answer plant biochemistry and biotechnology questions.

<u>Specific learning objectives:</u>

- Understanding the principle of carbon fixation and flux as it relates to plant specialized metabolism
- Common construction reactions in plant biochemistry
- Common enzyme types, including, *N*-/*O*-/*C*-methyltransferase, oxidoreductases, etc.
- An understanding of the many layers of pathway regulation, from transcription to compartmentalization of pathways at the cellular level
- An understanding of the three major classes of specialized metabolites: phenylpropanoids, terpenoids, and alkaloids.
- Knowledge of biotechnological tools for pathway elucidation
- Develop ability to design a research plan for specific pathway elucidation
- Scientific communication skills, including broad-audience (infographic posters) and niche-audience (2-page research proposal) content

INSTRUCTIONAL METHODS

Lectures will be in-person. Slides and recordings will be made available, but the course will *not* be offered in the hybrid model. Important announcements will be made in class and reiterated on the course webpage. Active engagement will include polling (using *SLIDO*) and discussion forums. Post your questions to the discussion forum (do not email content-related questions, please). You can direct personal queries to me by email or attending office hours. Follow the links below for resources on remote learning:
https://www.mcgill.ca/tls/students/remote-learning-resources
https://mcgill.ca/polling/

LECTURE TOPICS

1. Introduction
    a. An overview of the course syllabus, resources, goals, assignments, and grades
    b. *Plants are the greatest chemists*. Why is plant metabolism unique?
    c. (Re)introduce concepts: Units of life (e.g., amino acids, fatty acids, etc.), enzymes, metabolites, plant physiology, and cellular structures

2. Metabolism and Carbon
    a. Basic principles of metabolism
    b. Photosynthesis, respiration, and photorespiration
    c. Variation in carbon reactions in C_3, C_4 plants and others
    d. Carbohydrate metabolism

    Quiz 1 – Units of life

3. Construction Mechanisms
    a. Alkylation
    b. Wagner-Meerwein
    c. Aldol and Claisen
    d. Imine formation / Mannich reaction
    e. Amino acids

    Quiz 2 – Carbon fixation

4. Enzymes & Metabolism
    a. Enzymes and enzyme regulation
    b. Metabolic pathways; regulation, inhibition, metabolons, flux, transport, and storage
    c. Organic chemistry of biosynthesis; methods of chemical analysis (brief description of utility of methods, such TLC, HPLC-MS, GC-MS, etc.)

    Assignment 1 – Presentation on reaction mechanisms

5. Core to Specialized Metabolism
    a. Acetate pathway: fatty acids and polyketides
    b. Shikimate pathway: aromatic amino acids and phenylpropanoids
    c. Mevalonate and methylerythritol phosphate pathways: terpenoids and steroids

    Quiz 3 – Enzymes and regulation

6. Phenylpropanoids
    a. Cinnamic acids and esters
    b. Lignans and lignin
    c. Flavonoids

d. Isoflavonoids

Quiz 4 – Core metabolism

7. Alkaloids
    a. Derived from ornithine
    b. Derived from nicotinic acid
    c. Derived from tyrosine
    d. Derived from tryptophan
    e. Special storage for specialized metabolites: Monoterpenoid indole alkaloids (MIAs)
    f. *Extra:* cyanogenic glycosides

8. Terpenoids
    a. Hemiterpenes
    b. Monoterpenes
    c. Iridoids
    d. Sesquiterpenes
    e. Diterpenes
    f. Triterpenes (including saponins)

    Assignment 2: Infographic poster

9. Gene discovery and metabolic engineering
    a. Omics: Genomics, transcriptomics, proteomics, and metabolomics
    b. Protein purification and biochemical assays
    c. Heterologous expression systems
    d. Gene silencing, knockouts, transposons, and gene-editing
    e. Plug-and-play yeast systems

    Quiz 5 – The 3 classes of specialized metabolism

10. Review sessions
    a. How to write a research proposal
    b. Linking principles: E.g., how does nutrient assimilation or stress perception affect metabolic flux?
    c. Biosynthetic gene clusters in specialized metabolism
    d. State-of-the-art in plant biochemistry today

    Quiz 6 – Gene discovery tools

    Assignment 3: Gene discovery – resolve a pathway using your toolkit

EVALUATION

	Component	*Type*	*Week*	*Value*
1	*Quizzes (6)*	Online quiz (MC & written response)	Through-out	30%
2	*Presentation on reaction mechanisms*	Team oral presentation	5	20%
3	*Infographic poster*	Poster	10	25%
4	*Gene discovery – resolve a pathway using your toolkit*	Research proposal	13	25%

Description of components:

1. **Quizzes (20%)**: Online quizzes will be available for 24 h. Each quiz will be comprised of 5 questions, 3 multiple choice and 2 written-response, to gauge understanding of the previous lecture module's material. Each quiz is worth 5%, adding up to 30% of the final grade.

2. **Presentation on reaction mechanisms (15%)**: Students will form groups of 3 and deliver a 10-min presentation on a reaction type, describing I) the possible mechanisms, II) different classes of enzymes that catalyze such reactions, and III) showcasing one example of the reaction from specialism metabolism. A detailed rubric will be provided to help with presentation organization and delivery. Select one reaction type/enzyme category from below (topics will be assigned in coordination with the instructor):

    a. Dehydrogenases
    b. Oxidases
    c. Monooxygenases
    d. Dioxygenases
    e. Amine oxidases
    f. Decarboxylation
    g. Phenolic oxidative coupling
    h. Halogenation
    i. Glycosylation

3. **Infographic Poster (25%)**: Each student will choose a pathway (e.g., noscapine biosynthesis) and will develop an infographic poster. More than one student can choose the same pathway, and choices can be discussed with the instructor but do not have to be confirmed. The poster should be aimed at a broad scientific audience and should be self-explanatory. Key features should include: I) the biochemical pathway, II) the enzymes, III) tissue and subcellular locations, IV) the significance of compounds for the plant and human use, V) ecophysiology, and VI) unknowns.

    Posters will be displayed for a full day (interactive learning facility), and members of the campus will be invited to come and visit the posters. Students should be present during class hours to present and explain their posters to the instructor and peers. A detailed rubric will be provided.

Example from human health, an infographic for the public on COVID-19 variants: https://www.sciforall.org/covidvariants

4. **Gene discovery – resolve a pathway using your toolkit (35%):** Students should pick an unresolved or partially unresolved pathway in specialized metabolism typical of one or a group of plant species. Then, they will prepare **a 2-page research proposal** (**1 page references**) to tackle the unknown step(s). It should be formatted to follow the guidelines below:

   "Be as specific as possible. Provide background information to position your proposed research within the context of current knowledge in the field. State the objectives and hypothesis, and outline the experimental or theoretical approach to be taken (citing literature pertinent to the proposal) and the methods and procedures to be used. State the significance of the proposed research to a field or fields in the health sciences, natural sciences and/or engineering or social sciences and/or humanities, as appropriate."

   This exercise will build on student knowledge of specialized metabolism and the approaches that can be used to elucidate biosynthetic pathways. A rubric will be provided based on the requirements and instruction of NSERC CGS-M or the FRQ-NT Masters Training Scholarships:
   https://www.nserc-crsng.gc.ca/students-etudiants/pg-cs/cgsm-bescm_eng.asp
   https://frq.gouv.qc.ca/en/program/frqnt-masters-training-scholarships/

MCGILL POLICY STATEMENTS

"McGill University is on land which has long served as a site of meeting and exchange amongst Indigenous peoples, including the Haudenosaunee and Anishinabeg nations. We acknowledge and thank the diverse Indigenous peoples whose presence marks this territory on which peoples of the world now gather."

Language of Submission

"Every student has the right to submit in English or in French written work that is to be graded. This does not apply to courses in which acquiring proficiency in a language is one of the objectives."

"Chaque étudiant a le droit de soumettre en français ou en anglais tout travail écrit (sauf sans le cas des cours dont l'un des objets est la maîtrise d'une langue)."

Student Accessibility & Achievement

As the instructor of this course, I endeavor to provide an inclusive learning environment. However, if you experience barriers to learning in this course, do not hesitate to discuss them with me and Student Accessibility and Achievement, 514-398-6009. For more information, please refer to the SAA webpage: https://www.mcgill.ca/access-achieve/

Academic Integrity

" McGill places a great deal of importance on honest work, the art of scholarship, and the fair treatment of all members of the university community and demands a rigid insistence on giving credit where credit is due. Offences such as cheating and breaches of research ethics undermine not only the value of our collective work, but also the academic integrity of the University and the value of a McGill degree." Follow this link for more information:

https://www.mcgill.ca/students/srr/academicrights/integrity

Additional Policies

- The details of the course outline (e.g., dates) are subject to change. Any changes will be advertised on MyCourses, and students will be reminded in the lectures. "In the event of extraordinary circumstances beyond the University's control, the content and/or evaluation scheme in this course is subject to change."
- All assignments are due at 5 pm on the due date.
- Late submissions will receive a 5% penalty per day.
- Students must wait 24 hours before contacting the instructor regarding grades or assignment outcomes.
- Students can follow this link to explore their personal rights and responsibilities: https://www.mcgill.ca/students/srr/personalrights/treatment
- "© Instructor-generated course materials (e.g., handouts, notes, summaries, exam questions) are protected by law and may not be copied or distributed in any form or any medium without the explicit permission of the instructor. Note that infringements of copyright can be subject to follow up by the University under the Code of Student Conduct and Disciplinary Procedures."