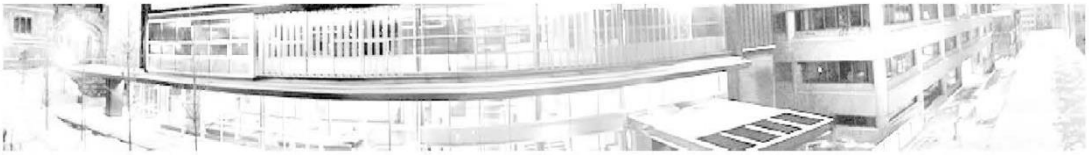
McGill
Faculty of Engineering



Department of Bioengineering
BIEN 585 - Metabolic Engineering
Syllabus

Course outline:
Introduction of an emerging field focusing on interaction of engineering, biochemistry and microbiology, emphasizing creation of bioproducts from renewable feedstocks, rearrangement of biochemical interactions to make life work better and development/optimization of involved processes. Featured topics include metabolic engineering's role in the transition from fossil resources to a bio-based society; the design-build-test-learn cycle of metabolic engineering; design, genetic engineering and optimization of microbial biocatalysts; metabolic network analysis, constraint-based modelling of metabolism, microbial production of valuable chemicals. General biochemical engineering practices, cell chemistry, structure and function, growth models, fermentation, strain development, recombinant DNA technology, enzyme function, kinetics and regulation will be also covered.
This course is designed to have a blend of lecture, seminars and laboratory components, a combination which will provide an overview of both theory and practice. Lectures will be structured around defining the key concepts of metabolic engineering and microbial cell factories. Emphasis will be placed on the conceptual theory behind these topics and applications towards a bio-based society. Students will present assigned literature and one case study about feats of metabolic engineering at the mid-term and final part of this course.

Prerequisites: Permission of instructor

Audience: This course is appropriate for upper-level undergraduate and graduate students.

Instructor: Assist. Prof. Codruta Ignea (codruta.ignea@mcgill.ca)
Office Hours: By appointment.

Course material: There is no required textbook. Required reading materials (consisting of selected original research papers and review articles), lecture slides and assignments will be posted on the McGill myCourses (accessible via www.mcgill.ca/lms).
Recommended textbooks:

- John Villadsen, Jens Nielsen, and Gunnar Lidén, *Bioreaction Engineering Principles*, Third Edition, Springer Publishing, 2011
- Gregory N. Stephanopoulos, Aristos A. Aristidou and Jens Nielsen *Metabolic Engineering. Principles and Methodologies*, Elsevier, 1998
- Vipin Chandra Kalia, Adesh Kumar Saini, *Metabolic Engineering for Bioactive Compounds*, Springer, 2017

Course evaluation and grading:

- Active participation during coursework 10%
- Written assignments and quizzes 10%
- Literature presentation 20%
- Group case-study reports 20%
- Final exam / Individual project - presentation 40%

Final Exam:

- Type of assessment**:**

Individual oral examination, 20 min (no preparation time) based on discussion/questions on the presentation of case study, lab reports and on biochemical engineering in general.

- Exam registration requirements:

The exam requires submission of all assignments and laboratory reports and a passing average grade in quizzes.

- Re-exam

Re-exam as ordinary exam. If the requirements are not met a report on a given topic must be handed in no later than 2 weeks before the re-exam.

Learning Objectives:

Participants enrolled in this course should:

- Have a fundamental understanding of cellular metabolism (including yield coefficients and metabolic quotients) (KB.3, KB.7).
- Be able to choose and apply the models of cell growth and product formation including the Michaelis-Menten equation with and without inhibition and the Monod growth equation (PA.1, PA.2, IT.1, IT.3).
- Be able to understand the principles of enzyme function, kinetics and regulation (KB.4, KB.8).
- Be able to describe the design-build-test-learn cycle of metabolic engineering (KB.7, PA.1, IT.1).
- Be able to describe how metabolism is constrained and how biological and physical constraints can be applied for simulating metabolism (KB.7, IT.1, CS.1, CS.3)
- Be able to describe how genetic engineering techniques can be used to implement metabolic engineering strategies (KB.7, KB.8, PA.3, PA.4).
- Be able to apply metabolic engineering principles for microbial metabolism design for production of target metabolites (IN.1, IN.2, DE.1, DE.2, DE.3, DE.4, IT.2).
- Have acquired experimental methods used in metabolic engineering (IN.1, IN.2, DE.1, DE.2).
- Be able to collect and analyze experimental data (PA3. PA4, DE.4, IT.2).
- Have improved written communication skills (CS.1, CS.2, CS.4, LL.1, LL.2).

Preliminary Course Schedule:

Week 1 - Importance of metabolic engineering in transition towards a fossil-free society
Week 2 - Review of Cell chemistry, structure, function and metabolism. Cell growth models
Week 3 - Enzyme function, kinetics and regulation. Journal Club.
Week 4 - Regulation of metabolic pathways. Metabolic fluxes. Journal Club.

Week 5 - Design-build-test-learn cycle. Metabolic engineering strategies. Journal Club.
Week 6 - Recombinant DNA techniques. Heterologous expression. Strain development. Journal Club.
Week 7 - Microbial production of high-value chemicals. Cell factories, non-conventional hosts. Journal Club.
Week 8 – Next generation metabolic engineering. New tools and their applications. Journal Club.
Week 9 - Case study: Engineering production of essential oils in yeast
Week 10 - Case study: Engineering subcellular compartmentalization
Week 11 - Case study: Engineering improved insulin production in yeast
Week 12 - Case study: Engineering co-culture systems/microbiomes
Week 13 - Individual project - presentations.

Teaching and learning methods:

Delivery of material in lecture format (40%)

Group work, active learning, seminars (30%)

Demonstrations, experiments, simulations (30%)

Assignments and Quizzes:

There will be literature presentations and written assignments, which should be handed in at announced due date. Late written assignments will not be accepted. Quizzes (15-20 min) will usually be on seminar days covering all material to date. The lowest quiz score will not count towards the student's final grade. There will be no make-ups for missed quizzes. Students are encouraged to work together on assignments; individual solutions must be handed in, however.

Laboratory Component:

There will be laboratory experiments conducted in groups. Each experiment will include brief individual laboratory reports. Details will be uploaded on myCourses.

Literature Presentation: One research article will be assigned for each team of students. The group will be responsible for leading a roughly 15-20 minute discussion about the article and its relevance to the course, based on a slide presentation. All students are to read these assigned topics and discussion participation will be graded. Team composition and details about presentations will be provided on myCourses

Case Study Presentation: Each student will be assigned one research topic (molecule) near the middle of the course. Students will research this topic/molecule and prepare a 1 page summary of the metabolic engineering achievements associated with selected molecule. This summary should include the biochemical context of the molecule (i.e. where in metabolism this molecule originates) and how progress has been made to increase titers and yields. Each student will be responsible for also providing a 5 min slide presentation about the molecule during the last week of class. Due date for handing in for the written summary will be announced on myCourses.

Language of Written Work:

In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French any written work that is to be graded.

Academic Integrity:
McGill University values academic integrity. Therefore all students must understand the meaning and consequences of cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures (see www.mcgill.ca/students/srr/honest/ for more information).

Disabilities:
If you have a disability, please contact the instructor to arrange a time to discuss your situation. It would be helpful if you contact the Office for Students with Disabilities at (514) 398-6009 before you do this.