CHBE 410 Metabolic Engineering and Systems Biology (3) Syllabus

Calendar entry

The course covers foundational concepts, experimentation methodologies, research horizons, and industrial applications of microbial cell engineering. Topics of note include genome-scale modeling, genome editing, biological circuits, protein engineering and the design-build-test-learn (DBTL) workflow.

Pre-requisites

One of CHBE 381, CHBE 419 or BMEG 374.
Graduate student in CHBE or SBME.

Instructor

Vikramaditya G. Yadav (vikramaditya.yadav@ubc.ca)

Student evaluation

Assignments – 30%
Term project (team-based) – 20%
Paper critiques (individual) – 10%
Term paper (individual) – 40%

Syllabus and course schedule

Week	Theme	Topics
1	Introduction to Metabolic Engineering, Synthetic Biology and Systems Biology	Overview, historical perspectives, and current trends
2	Basic Concepts in Metabolic Engineering	Metabolic pathways, enzyme kinetics, metabolic flux analysis
3	Tools and Techniques in Synthetic Biology	Standard biological parts, synthetic circuits, genome editing
4	Systems Biology: Omics Technologies	Genomics, transcriptomics, proteomics, metabolomics
5	Computational Modeling in Systems Biology	Introduction to computational models, dynamic modeling of biological systems
6	Synthetic Genomes and Genome Editing	CRISPR-Cas systems, synthetic chromosomes, genome-scale engineering

7	Metabolic Pathway Analysis and Optimization	Pathway analysis, metabolic balancing, yield optimization
8	Regulatory Networks in Synthetic Biology	Transcriptional regulatory networks, signal transduction, feedback loops
9	Bioreactors and Industrial Applications	Bioreactor design, scale-up challenges, industrial biotechnology
10	Workflows for Automated Design-Build-Test-Learn (DBTL)	Robotic tools for molecular biology, LIMS for data harmonization, high-throughput analytical technologies, biosensors
11	Ethical, Legal, and Social Implications	Bioethics, biosafety, intellectual property, public perception
12	Case Studies and Current Research	Student-led presentations of current research and innovative projects in the field
13	Course Wrap-up and Future Directions	Summary of key concepts, future trends, career opportunities, research horizons

Textbooks and reference books

1. *“Metabolic Engineering: Principles and Methodologies”*, G. N. Stephanopoulos, A. A. Aristidou & J. Nielsen

2. *"Synthetic Biology: A Primer"*, P. S. Freemont & R. I. Kitney

3. *"Systems Biology: A Textbook"*, E. Klipp, W. Liebermeister, C. Wierling, A. Kowald, H. Lehrach, & R. Herwig

4. *"Bioinformatics: Sequence and Genome Analysis"*, D. W. Mount

5. *"An Introduction to Systems Biology: Design Principles of Biological Circuits"*, U. Alon

6. *"Bioprocess Engineering: Basic Concepts"*, M. L. Shuler and F. Kargi

Each of these books is considered a classic. Students will be provided weekly readings to cover the theoretical foundations, methodological approaches, and practical applications discussed in the course. The books will provide students with the necessary theoretical grounding to pursue research and develop applications in these rapidly evolving fields.

Big picture goals

The course seeks to equip students with a comprehensive understanding of the interdisciplinary principles, methodologies and applications of microbial cell engineering and the development of microbial cell factories. Students will be able to design and conduct experiments that use the latest tools and techniques to generate novel strains that can either produce fuels, chemicals and materials or remediate pollution or be consumed as food products, and thereafter formulate plans for scaling up their solutions to industrial processes. Students will be encouraged to think creatively and innovatively about grand challenges such as climate change and sustainability and thereafter design novel biological systems and processes to address them. The course also aims to instill a strong sense of ethical responsibility and an understanding of the societal implications of biotechnological advancements. The inclusion of a team-based term project will expose students to interdisciplinary problem-solving and promote collaborative thinking.

Learning outcomes

At the conclusion of the course, students will be able to:

1. Demonstrate an advanced understanding of metabolic pathways, genomic engineering techniques and systems-level analyses
2. Effectively integrate computational and experimental approaches for designing and constructing microbial cell factories
3. Design and conduct experiments that inform steady-state and unsteady-state metabolic fluxes in cells
4. Identify and use appropriate bioinformatics tools to retrieve, analyze, interpret and use biological data towards the design of gene circuits, novel metabolic pathways and in applications such as protein engineering
5. Interpret genomic, proteomic and metabolomics experiments and data
6. Integrate bioethics and regulatory considerations in their work
7. Appreciate that biological systems are climate technologies and design systems for applications such as carbon capture and conversion and water remediation
8. Exhibit proficiency in communicating complex scientific concepts and research findings effectively to both scientific and non-scientific audiences, through both written and oral means
9. Demonstrate the ability to work effectively in interdisciplinary teams, integrating knowledge and methods from different disciplines to address complex challenges in biotechnology
10. **Attain** skills relevant for careers in academia, industry, or policy, including critical thinking, problem-solving, project management, and ethical decision-making
11. Understand the process of translating scientific discoveries into commercial applications or start-up ventures in the field of biotechnology