

Course Number:	ChE 360
Course Title:	Bioprocess Engineering
Calendar Term(s):	W,S
Credit Weight:	0.50
Hours per week:	3L + 1T
Calendar Description:	Review of elementary aspects of molecular biology, genetic engineering, biochemistry, microbiology. Biological systems for the production of commercial goods and services: foods, pharmaceuticals, chemicals, fuels, equipment, diagnostics, waste treatment, and biomaterials. Properties of microbial, plant and animal cells, and of enzymes used in bioprocess applications. Classification and characterization of biological agents and materials; quantification of metabolism, biokinetics, bioenergetics. Introduction to design of bioprocess systems, including biosafety and good manufacturing practices.
Prerequisite:	3A Chemical or Environmental Engineering
CEAB Math:	
CEAB Basic Sc.:	
CEAB Eng. Sc.:	
CEAB Eng. Dgn.:	
CEAB CSE:	
Instructor(s):	Marc Aucoin
Textbook:	Bioprocess Engineering Basic Concepts Second Edition. Michael L. Shuler and Fikret Kargi. 2002. Prentice Hall PTR. New Jersey, U.S.A. ISBN 0-13-081908-5.
Software:	
Resources used :	<p>1 TA</p> <ul style="list-style-type: none"> • Assignment: 5 assignments * 10 hours per assignment = 50 hrs • Office hours: 12 wks * 1hr/wk = 12 hrs • Proctoring exams: 3 hrs (final) = 3 hrs <p>Total: 65 hrs</p>
Resource needs :	<p>1 TA</p> <ul style="list-style-type: none"> • Tutorials: 13 wks * 2 hours/wk = 26 hrs • Quizzes: 4 quizzes * 5 hours per quiz = 20 hrs • Assignments: 4 assignments * 10 hours per assignment = 40 hrs • Office hours: 13 wks * 1/wk = 13 hrs • Proctoring exams: 2 hrs (midterm) + 3 hrs (final) = 5 hrs <p>Total: 104 hrs</p>

Weekly Description of Topics Covered	
Week 1	Cells and cell biology (lipids, lipid bilayers, micelles, liposomes, organelles and membrane enclosed vesicles, cell envelope and cells)
Week 2	Proteins and protein chemistry. Relationship to nucleic acids, protein properties, effect on localization and function. Relationship to organelles.
Week 3	Enzymes. Enzyme nomenclature. Gibbs free energy. Metabolism (primarily glycolysis, TCA and electron transport chain). Microbial fuel cells and lactic acid are used examples for metabolism. Metabolic flux analysis introduced – pseudo-steady state assumption and material balance around a cell.
Week 4	Metabolic flux analysis (cont.) – setting up linear equations relating network components. Enzyme function - catalytic mechanism of serine proteases. Introduction to the use of enzymes outside of a cell. Introduction to reaction intermediates and enzyme-substrate complexes. Development of Michaelis-Menten and Briggs-Haldane approaches to enzyme kinetics.
Week 5	Development of enzyme inhibition kinetics and graphical approaches to determine K_m and V_{max} , and inhibition parameters. Effect of environmental conditions on enzymes kinetics.
Week 6	Enzyme immobilization – focus on covalent vs non-covalent binding and the importance of amino acid ionizable and reactive groups. Introduction of mass transfer through a stagnant boundary layer, and steady state balance of surface substrate.
Week 7	Enzyme immobilization (cont.). Focus on Damköhler number and effectiveness factor. Midterm.
Week 8	Cell growth. Introduction to physical aspects of cell growth including techniques to count cells or measure biomass. Introduction to modeling cell growth explaining simplifications of unstructured unsegregated models. Introduction to growth curves and the concept of a reactor. Biomass material balance around a batch reactor is presented.
Week 9	Effect of environmental conditions on cell growth. Introduction of the importance of dissolved oxygen as an environmental condition. Substrate material balance and yield coefficients. Gas-liquid interface as barrier was introduced but mass transfer equation was not developed. Oxygen uptake rate was treated with yield coefficients instead. Heat generation.
Week 10	Product formation kinetics introduced. Introduction of a CSTR – chemostat reactor. Material balances around this type of reactor for biomass and substrate were developed. Maintenance energy and endogenous metabolism reinforced. Productivity of a CSTR in terms of product or biomass introduced.
Week 11	Mixed vs single organism cultures. Wastewater, food applications, specialty chemicals and recombinant proteins discussed in context. Importance of aseptic technique and sterilization. Sterilization methods introduced. Death rate as a function of temperature is reinforced, and heat sterilization is discussed. Decimal reduction time is introduced.

Week 12	Downstream processing is introduced. Product identification: cells and proteins as two model products. Intracellular vs extracellular products. Soluble vs insoluble components. Cell disruption techniques. Centrifugation as a process that can be modeled. Protein charge is reintroduced as being an important characteristic in downstream processes.
Week 13	Solubility as a function of ionic charge of a protein. Isoelectric point calculation. Solvent (liquid-liquid) extraction to extract proteins having no net charge. Salting out proteins by increasing ionic charge of solution. Ionic charge of proteins as an important element in ion exchange chromatography.
Examination type:	
Midterm:	Closed Book
Final:	Open Book + 1 8 ½" x 11" Cheat Sheet
Marking Scheme:	
Assignments:	5 (17%)
Quizzes:	1 (3%)
Labs:	None
Midterm exam:	35%
Final exam:	45%
Special marking rule:	Optional marking scheme: 20% midterm, 60% final.

Comments: The next time I give this course I will change the order so that enzyme kinetics and enzyme immobilization will be the last aspect covered in the course.