COURSE OUTLINE

ABE 580

Process Engineering of Renewable Resources

2007
MWF 10:30 a.m.
(ME 117; Computer Lectures SC 231 and ENAD 135)

Instructors: Professors Nathan S. Mosier and Michael R. Ladisch
Agricultural and Biological Engineering Department
Laboratory of Renewable Resources Engineering
Office: Potter Building - Room 216 Phone: x47022

Office Hours: By appointment on Mondays, Wednesdays, and Fridays

Text: **Modern Biotechnology: Connecting Innovations in Microbiology and Biochemistry to Engineering Fundamentals,** (*alpha test version*), John Wiley and Sons, NY, 2007. Manuscript available through Kinko's.
Nathan S. Mosier and Michael R. Ladisch

Software: Excel, MathCAD, MatLab

Objectives of the course:

The goal is to introduce students to biotechnology and tools that enable engineers and process scientists to connect innovations in industrial microorganisms and bioprocess unit operations to the engineering fundamentals, fundamentals of systems biology, and biological tools for design, modeling and evaluation of manufacturing facilities for the production of biofuels, bioproducts and biotherapeutics using a case study approach combined with computer modeling. Specific objectives of the course are to:

1. Apply biological sciences and engineering principles to mathematical modeling of microbial bioreactors, protein biocatalysts, and mammalian cells for manufacture of biofuels, protein pharmaceuticals, antibiotics, and industrial biochemicals,

2. Introduce students to the use of microbial adaptation, engineering and systems biology for directing the metabolic pathways in native or genetically engineered organisms to generate commercially relevant products.

3. Survey new developments in bioenergy, metabolic engineering, bio-nanotechnology and bioprocess engineering.

Prerequisites

Senior or graduate student status (no exceptions), including knowledge of 1. formulating kinetic equations, 2.solution of ordinary differential equations, 3. introductory biochemistry and biology **or** consent of instructor. Basic software skills including MS Office.

Grading

Grades will be based on three tests and a special topic assignment in addition to homework assignments.

Homework Assignments	300 points
Tests (3 x 200)	600 points
Special Topic Project	300 points
TOTAL	1200 points

Statement on Academic Honesty:

Honesty requires that ideas, data, figures, tables, equations or derivation of equations, process concepts, wording of explanations, or other forms of intellectual property of others must be fully acknowledged. The use of such property in reports and papers is acknowledged by citing the source (ALL of the authors; title, journal or other publication in which the information appeared; volume and number; editor(s), if appropriate; publishing house, city, state, if the information is from a book; beginning and ending page numbers of the publication; and year). Property which is conveyed through a letter or other form of personal communication is to be indicated as such. Again, give the authors, title (if appropriate), "Personal Communication," and date.

The offering of materials assembled, collected, or created by others or reported by others in the form of projects, books or parts of books, periodicals, speeches, or the writings of other students as one's own is plagiarism. Dishonesty of any kind with respect to examinations or alterations of records is cheating.

Plagiarism and/or cheating is sufficient for an F. See student handbook for University rules.

(This statement was adapted from Professor Richard Feinberg, "Academic Honesty and Dishonesty," CSR Dept., Jan. 1993.)

ABE 580 Spring 2007 , Lecture Schedule

Section 1

Date	Lecture Topic
1/8	Introduction to the scope of the biotechnology industries –Definitions, technology and products (*Chapter 1: Biotechnology*)
1/10	Microbial Fermentations. Basic metabolic pathways. Classification of fermentations (Type I, II, III). Exponential growth. Yield coefficients. (unstructured models) (*Chapter 4: Microbial Fermentations*)
1/12	**Class meets in SC 231;** Introduction to modeling of cell growth (*Chapter 4*)
1/15	**Martin Luther King Jr. Day – No Class**
1/17	Runge-Kutta Method, Introduction to modeling of ethanol fermentation. Concept of yield coefficient, limiting nutrient. (*Chapter 5: Modeling and Simulation*)
1/19	**Class meets in ENAD 135;** Modeling continued. Using Runge-Kutta technique to solve for time dependent cell mass generation, substrate depletion and product accumulation in a batch fermenter (*Chapter 5*)
1/22	Case study: Batch ethanol fermentation. Monod kinetics with product inhibition. Connecting yield coefficients with model. Continuous stirred tank bioreactor (CSTB). (*Chapter 5*)
1/24	Introduction to aerated bioreactors: 2,3 Butanediol fermentation *(Chapter 6: Aerobic Bioreactors)*
1/26	**Class meets in SC 231;** Modeling oxygen limited growth. 2,3 Butanediol case study *(Chapter 6)*
1/29	Discussion of 2, 3 Butanediol case study.
1/31	Metabolic basis of oxygen limited growth. Oxygen transfer. Gassed (agitation) power (*Chapter 6*)
2/2	Bioproducts: sugars, antibiotics, amino acids, industrial enzymes (*Chapter 3: Bioproducts*)
2/5	Case Study: Antibiotic Fermentation
2/7	Antibiotic fermentation - continued
2/9	**Exam 1**

2/12	Enzymes: properties, classification system, assays, Michaelis-Menten kinetics, thermal stability (*Chapter 7: Enzymes*)
2/14	Enzymes – continued
2/16	Enzyme Kinetics: Rapid equilibrium vs pseudo steady-state kinetics. King Altman method; integrated vs initial rate equations. Metabolic flux analysis (*Chapter 8: Enzyme Kinetics*)
2/19	Enzyme kinetics - continued
2/21	Metabolism: catabolism, anabolism; glycolysis (anaerobic metabolism); lactic acid fermentation; citric acid cycle (aerobic); extremophiles (*Chapter 9: Metabolism*)
2/23	Metabolism – continued
2/26	Bioenergetics: Redox reactions, coupling of oxidation to ATP production, NAD^+, NADH; ΔG and redox reactions; Microbial heat generation. (*Chapter10: Biological Energetics*)
2/28	Bioenergetics – continued
3/2	Metabolic Pathways: strategies for redirecting branched and linear pathways: auxotrophs; protoplast fusion; recombinant microorganisms. Role of biotin; lysine, MSG production, penicillin pathway; antibiotic resistance and new antibiotics (*Chapter 11: Metabolic Pathways*)
3/5	Metabolic pathways – continued
3/7	**Exam 2**
3/9	Discussion of special topic reports due at end of semester. "Researching" a new topic. How to organize, prepare, and communicate a technical summary. The web: when to use, how to cite. (*Class handout*)
3/12	**Spring Break – No Class**
3/14	**Spring Break – No Class**
3/16	**Spring Break – No Class**

3/19	Overview of recombinant techniques, hybridomas (mammalian cells used to make protein biotheraputics). Size and character of the biotechnology industry (*Chapter 2: New Biotechnology*)
3/21	New biotechnology – continued
3/23	Metabolic Engineering: redirecting metabolic pathways through genetic engineering. Microarray techniques and transcriptional profiling; yeast, bacteria examples: xylose to ethanol; 1,3, propanediol from glucose; acrylamide by biocatalytic process. (*Chapter 12: Metabolic Engineering*)
3/26	Biotechnology in the information age: how cells do it. Chromosomal vs plasmid DNA. (*Chapter 13: DNA, RNA and Genes*)
3/28	Trp operon, a biotechnology industrial standard
3/30	Sequencing the human genome. Basic DNA structure. Microbial Genomes. DNA chips. (*Chapter 14: Genomes and Genetic Techniques*)
4/2	Genomes to Life – Sequencing Bioenergy Crops
4/4	Southern, Northern, Western blots. Electrophoresis. Genetic Markers: STS, SNPs. Application of PCR. Examples of how these methods are used in biomedicine, forensic applications. (*Chapter 14*)
4/6	Genetic techniques - continued
4/9	Introduction to monoclonal antibodies and new vaccines: manufacturing methods (mammalian cells, hybridomas, and virus-like particles) (*Chapter 15: Monoclonal Antibodies*)
4/11	Purification and liquid chromatography basics (*Chapter 15*)
4/13	Case study: Virus-like particles
4/16	**Exam 3**
4/18	Bioenergy: issues and answers
4/20	Basic biofuel processing concepts: grain and cellulose
4/23	Pretreatment and hydrolysis
4/25	Fermentation and recovery
4/27	Economics of bioenergy
5/2	**Final Project Reports Due**

SPECIAL TOPIC REPORT

The special topic report is intended to be a means by which the concepts, learned in this course, are applied to learning a new topic from the biotechnology literature. Exercise of creativity, as will be explained later, is encouraged. The special topic report serves as the final examination in this class.

The report is initiated by the student(s) who select a technical subject that is of mutual interest and within the background of both the student(s) and instructors. This activity entails learning about the topic from selected literature references (typically 5 to 7 journal articles) and preparing a concise (10 pages, double spaced, typewritten) report which critically reviews the selected literature references. A team of 2 to 3 students may work together and then would submit one report.

Selection of topics are discussed in class on March 9th. The topics will vary from one year to the next since the field of biotechnology is fast-moving, and relevant areas of interest for which there is a pertinent base of technical publications is also evolving. Possible topics for Spring, 2007 may include:

- bioenergy and models of bioprocessing systems for cellulose, grain, or sugar cane ethanol production,
- economic model for transition of world liquid fuels from oil to renewable sources, and economics of conservation and biofuels on reduction of CO2 generation,
- applications of genomics for sequencing of microbial genomes, forensic applications in bird flu or food pathogens tracking,
- bioprocess design and process for production of monoclonal antibodies and human binding factors for anticancer therapeutics, or antiviral drugs - tamiflu, protease inhibitors,
- bioprocess design for production of vaccines (biologics, virus like particles, DNA) and the role of Gates Foundation in vaccine dissemination and World health,
- design and microfabrication of DNA or protein biochips for human and animal diagnostics,
- microfluidics for liquid based nanotechnology for design of micro-bioreactors for biotechnology process development.