Northeastern University
Chemical Engineering Department
CHE U630: Biochemical Engineering Fundamentals
Spring 2004

Course Objectives / Topics / Outcomes

The main goal of this course is to provide an overview of the fascinating field of biotechnology and the role of a chemical engineer in bringing about this technology. The topics and concepts in this course are presented within a framework, i.e. designing a process for producing a drug made from cell culture starting from drug discovery to large-scale production. You will learn and apply biological concepts and engineering principles to understanding how a drug is discovered and approved, to how a drug is made from cell culture, to how to design a process for producing and recovering the drug from cell culture. In addition, you will learn about new research areas in biochemical engineering, such as genomics, proteomics, and metabolic engineering.

By engaging in the course's activities, you will gain knowledge, experience, and skills to work in biochemical engineering and to prepare you as a life-long learning and developing engineer. Below is a preview of the knowledge, experience, and skills you will gain from this course. Presented below are the overall course objectives, specific course topics / outcomes, specific Chemical Engineering Program Educational Objectives (PEOs) & Outcomes (POs), and Academic Common Experience (ACE) objectives met by the CHE U630.

Course Objectives: in general, the knowledge you will gain from this course

- apply chemical engineering principles such as material balances, kinetics, transport phenomena, & separations to understanding cell culture or biological problems
- become familiar with the steps involved in the process from drug discovery to manufacturing of the drug
- understand mechanisms by which drugs intercept a disease, i.e. by interfering with the transcription of the diseased cell's genes or by inhibiting an enzyme associated with the disease
- become familiar with types of products produced from cell cultures, i.e. proteins, small molecules such as antibiotics
- become familiar with the characteristics of certain types of cultures which allow specific products to be made, i.e. bacterial cultures, mammalian cell cultures, plant cell cultures
- understand how certain products can be produced in a foreign host using genetic engineering
- characterize and optimize growth of the cell culture
- characterize and optimize production of the desired product from cell culture
- select the appropriate cultivation method and operating conditions for production from cell culture
- select the appropriate reactor type and operating conditions for production from cell culture
- consider complications associated with the scale-up of a reactor involving living cells
- consider the steps involved in recovering and purifying the product made from cell cultures

Specific Course Topics & Course Outcomes: specific knowledge and skills gained from this course
Chapter 2: An Overview of Biological Basics

- The main classification of organisms (procaryotes versus eucaryotes) and their application in biotechnology

- The structure (i.e. organelles, gram positive versus gram negative bacterial membranes) of the cell and the differences between prokaryotes and eukaryotes which confer different biosynthetic capabilities
- The macromolecules which make up the cell (their chemical structure, role and composition in the cell) and hence molecules from which drugs may be chemically derived from
- The nutrient requirements of cell cultures for survival and for producing the drug of interest

Chapter 3: Enzymes

- Learn how enzymes catalyze a reaction
- Model enzyme kinetics using the Michaelis-Menten and Briggs-Haldane approach
- Calculate the kinetic parameters of an enzymatic reaction (i.e. Vmax, Km) from experimental data
- Identify and model competitive, non-competitive, and uncompetitive inhibitor kinetics and the effect of the various inhibitors on V max, Km
- Understand how temperature and pH affects enzyme function and kinetics
- Determine whether a reaction is mass-transfer limited or reaction-rate limited in a surface-immobilized or a gel-immobilized enzyme system (i.e. the Damkohler number, the Thiele Modulus, the effectiveness factor)

Chapter 4: How Cells Work

- Appreciate the complexity and order of DNA replication, transcription and translation
- Understand the regulation of protein synthesis at the transcription level and the metabolic level

Chapter 5: Major Metabolic Pathways

- Be familiar with the purpose and characteristics of the major metabolic pathways in the cell

Chapter 6: How Cells Grow

- Understand the growth profile of a cell culture in batch growth, i.e. lag, exponential, stationary phases
- Understand unstructured growth models such as the Monod Model and understand the principles behind developing structured growth models
- Determine the kinetic growth parameters from experimental data, i.e. the maximum specific growth rate, Ks, the yield coefficient
- Determine the biomass concentration, the substrate concentration, the product concentration, the optimum dilution rate, the maximum biomass productivity, and washout dilution rate of a single CSTR

Chapter 8: How Cellular Information is Altered

- Understand how products can be produced in foreign hosts using genetic engineering

Chapter 9: Operating Considerations for Bioreactors for Suspension & Immobilized Cultures

- Design chemostat with recycle, multiple fermenters in series, fed-batch systems

Chapter 10: Selection, Scale-up, Operation, and Control of Bioreactors

- Learn about the types of reactors for cultivating cells (i.e. airlift reactors, stirred tank reactors)
- Determine the oxygen demand of a culture and the required volumetric oxygen transfer rate (i.e. kla) to sustain the culture above the critical oxygen concentration

- Calculate the kla for an air-sparged fermenter or a mechanically-agitated fermenter from correlations or experimentally
- Determine the power requirement and the impeller speed upon scale-up based on maintaining geometric and dynamic similarity or on maintaining constant power consumption per unit volume

Chapter 11: Recovery and Purification of Products

- Know the main methods for separating insoluble products (filtration, centrifugation, coagulation, flocculation)
- Know the main methods for cell disruption
- Know the main methods for separating soluble products (i.e. liquid-liquid extraction, precipitation, adsorption, dialysis, ultrafiltration & microfiltration, chromatography, electrophoresis)

Chemical Engineering Program Educational Objectives (PEOs) and Program Outcomes (POs):
Specific skills that prepare you as an engineer for solving a broad range problems or projects

- Identify and solve chemical engineering problems.
- Understand, analyze, & design chemical processes.
- Be proficient in the use of modern engineering tools.
- Be proficient in oral and written communications of their work & ideas.
- Become independent learners & workers; participate effectively in intradisciplinary & interdisciplinary groups.
- Understand the global & societal impacts of engineering problems & solutions.
- Conduct themselves in accordance with the highest ethical & professional standards.
- Be prepared for lifelong learning & continuing education.

Northeastern's Academic Common Experience (ACE) Objectives:
Specific skills that prepare you as a life-long learning for gaining breadth and versatility

- Effective thinking
- Quantitative thinking
- Effective communication: written
- Information literacy
- Interpersonal skills
- Natural world awareness
- Ethical perspective
- Personal perspective
- Connections across disciplines
- Connections between college & work
- Connections between individual & society
- Connections between individuals & lifelong study