ES452: BIOMATERIALS AND BIOMEDICAL ENGINEERING APPLICATIONS
Spring 2012

Department: Chemical and Biomolecular Engineering

Catalog Data: ES452 Biomaterials and Biomedical Engineering Applications Credits: (3)

This course will examine the biomaterials, biotransport phenomena, biomolecular engineering and tissue engineering aspects of biomedical engineering. Topics covered will include the interactions of biomolecules with synthetic materials, tissue-biomaterial interactions, the tailoring of material chemistry toward rational design of biomaterials, application of the principles of transport phenomena to physiological systems, understanding the principles governing rates of drug transport in advanced drug delivery systems, the microarray technology, and biosensors.

Pre-requisites: BY160 Biology II – Cellular and Molecular Biology
CM241 Organic Chemistry I, or ES260 Materials Science and Engineering

Course Type: Elective

Textbook: Dee, K. C.; Puleo, D. A.; Bizios, R. *An Introduction to Tissue-Biomaterial Interactions*; Wiley-Liss: New Jersey, 2002.

References: Fournier, R. L. *Basic Transport Phenomena in Biomedical Engineering*, 2nd ed.; Taylor & Francis: New York, 2007.

Saltzman, W. M. *Drug Delivery: Engineering Principles for Drug Therapy*; Oxford University Press: New York, 2001.

Temenoff, J. S.; Mikos, A. G.; *Biomaterials—The Intersection of Biology and Materials Science*; Pearson Prentice Hall: New Jersey, 2008.

Biomaterials Science, 2nd ed.; Ratner, B. D.; Hoffman, A. S.; Schoen, F. J.; Lemons, J. E., Eds.; Elsevier: California, 2004.

Instructor: Sitaraman Krishnan (CAMP 229, 268-6661, skrishna@clarkson.edu)

Office Hours: Open door policy or by appointment

Course Objectives:

1. To introduce fundamental concepts of biomaterials science to engineering majors;

2. To guide students in the selection or design of materials for biomedical applications, with a fundamental understanding of: (a) chemical and mechanical properties of materials, and (b) interactions between the human body and implanted biomaterials;
3. To introduce students to biomaterial characterization techniques;
4. To provide experience in formulating and analyzing models of transport phenomena and reaction processes applied to problems in biomedical engineering.

Learning Outcomes: After completing this course you will be able to:

1. make decisions, based on structure-property analysis, on the choice of a synthetic biomaterial for a particular biomedical application
2. discuss factors that influence the adsorption of proteins at solid-liquid interfaces, and explain the significance of protein adsorption in blood-biomaterial interactions
3. explain the mechanism of platelet adhesion to a biomaterial surface; design surfaces that can prevent blood coagulation; and discuss strategies to impart blood-biomaterial compatibility (in vascular grafts, blood oxygenators, and heart valves)
4. describe the cellular and molecular basis of wound healing around an implant, the body's response to infectious agents at the implant site, and recent advances in imparting antibacterial properties to biomaterial surfaces
5. choose appropriate physicochemical techniques and biological assays for biomaterial surface characterization
6. modify chemistry of drug delivery systems—based on an understanding of the immune system and the physiology of organs such as kidney and liver—to improve retention, and target drug therapy toward diseased tissue alone
7. evaluate pharmacokinetic models for distribution and elimination of an intravenously injected drug
8. apply principles of transport phenomena in the design of artificial organs (extracorporeal devices) such as blood oxygenators and dialyzers
9. explain the working of biosensors and diagnostic arrays that employ surface immobilized biomolecules and cells
10. evaluate the advantages, disadvantages, and ethical issues related to in vivo animal tests and studies involving human subjects

Evaluation Methods:

1. One take-home mid-term exam (20 %)
2. Term paper and seminar for final exam (70 %)

3. Homework & Attendance (10 %)

Policies:

Moodle: Announcements and course material will be posted on Moodle.

Attendance: Attendance is required at all classes.

Homework: Homework will be collected at the beginning of the class on the due date. Cooperative learning is encouraged.

Take-home exam: The exam must be attempted independently, without discussions with others.

Term paper: Select a research topic with the instructor's guidance and write a literature review citing at least 20 references.

Seminar: Prepare a 15-min long technical presentation on the topic you have researched. The presentation should reflect your understanding of the material covered in the course.

Course Outline:

- Introduction
- Biomaterials: metals, ceramics, glass, polymers (Chapter 1)
- Proteins: molecular structure (Chapter 2)
    - Protein databases (Chapter 2)
    - Genetic code: DNA–RNA–protein
- Protein–surface interactions: effects of concentration, molecular weight, and isoelectric point (Chapter 3)
- Tissue Engineering
    - Structural organization in organisms (cells, tissues, organs, organ systems, organism)
    - Tissue types (epithelial tissue, connective tissue, muscle tissue, and nervous tissue)
    - Bones and joints; bone remodeling
    - Blood cells (Chapter 4)
    - Vascular grafts, heart valves (Chapter 4)
- Blood–biomaterial interactions: coagulation cascades, anticoagulants, fibrinolysis, thrombi and emboli formation, intimal hyperplasia (Chapter 4)
- The Krogh tissue cylinder: a mathematical model for transport of a solute between a capillary and the surrounding tissue
- Engineering biomaterial surfaces: self-assembled monolayers, polymer brushes, polymer coatings, bio-functionalization of surfaces, surface characterization methods, biocompatibility (Chapter 9)
- Inflammation and infection (Chapter 5)

- The immune system (Chapter 6)
- Term-paper topics include: antisense therapy, protein-based drugs, neural tissue engineering, controlled drug delivery systems, transdermal drug delivery, drug delivery across the blood–brain barrier, bioartificial organs (pancreas, liver, kidney)

Class Schedule: TuTh 8–9:15 a.m., 244 Rowley Labs (**Jan** 12, 17, 19, 24, 26 & 31; **Feb** 2, 7, 9, 14, 21, 23 & 28; **Mar** 1, 6, 8, 13, 15, 27 & 29; **Apr** 3, 5, 10, 12, 17, 19, 24 & 26)

Contribution: 3 credits of engineering science; a materials science ES elective

Prepared By: Sitaraman Krishnan, January 10, 2012