University of Manitoba
Faculty of Agricultural & Food Sciences
Department of Biosystems Engineering

Course Details

Course Title & Number:	BIOE 7380 Biomaterials Science and Engineering
Number of Credit Hours:	3
Class Times & Days of Week:	10:30-11:20 am, Lecture 3 times a week (MWF)
Location for classes/labs/tutorials:	EITC E2 310
Pre-Requisites:	All Biosystems graduate students are welcome to take this course.

Course Description:
This course provides students with an overview of biomaterials and biopolymers, including their sources, physical/chemical/biological properties and applications. The course includes the synthesis/fabrication and characterization of biomaterials and biopolymers, and the structure-property relationship of those materials. Students will be exposed to concepts on several material characterization techniques at the morphological, structural, chemical and biological level.

Instructor Information

Instructor Names	**Dr S. Liu**	**Dr. D Levin**
Office Location	W581 Duff Roblin	E1-354 EITC Bldg
Office Hours:	TBA	TBA
Office Phone No.	204-474-9616	204-474-7429
Emails:	Song.Liu@umanitoba.ca	David.Levin@umanitoba.ca

Course Topics

Intro to Biomaterials and *biopolymers*: definitions, sources and importance.

Sources of Biomaterials and *biopolymers* (Synthesis, isolation and fabrication): chemical synthesis (polymerization), microbial synthesis, fabrication (examples: melt-extrusion, electrospinning, 3-D printing), and isolation of natural fibers.

Characterization and evaluation: physical/thermal properties, chemical properties, biological interaction (immune response, biodegradation).

Applications: Biomedical applications (vascular grafts, hip replacement, orthopedics, wound dressings and tissue engineering), bio-composite materials, 3-D printing applications, and food packaging.

Course Goals

The intent of this course is for the student to understand the sources of biomaterials, physical/thermal/chemical and biological properties, and their environmental and biomedical applications.

Intended Learning Outcomes

At the conclusion of the course, the student should:

1. Become familiar with various biomaterials and biopolymers;
2. Gain the knowledge of synthesis of biopolymers, and synthesis and fabrication of biomaterials for biomedical applications;
3. Understand how high levels of control over the spatial deposition of cells, materials, and other factors in 3D-bioprinting can be achieved by using polymer bioinks and suspension baths with Non-Newtonian behavior.
4. Be able to choose appropriate surface modification techniques to address specific challenges of clinical biomaterial applications.
5. Be able to choose appropriate analytical tools to conduct chemical and physical characterization of biomaterials;
6. Be able to search for, gather, and organize appropriate information on a topic of interest related to Biomaterials, and write a research proposal.

Course Contents

Week 1: *An overview of Biomaterials and biopolymers*: biomaterials are nonviable material used in a medical device, intended to interact with biological systems; biopolymers are polymers produced by living organisms (polymeric biomolecules) such as polynucleotides (RNA and DNA), polypeptides, and polysaccharides. (**Liu**)

Weeks 2-6: *Expand on the sources of biomaterials and biopolymers*: chemical synthesis (polymerization), microbial synthesis, and fabrication (examples: molding, emulsion fabrication of nano-/micro-particles, electrospinning, and 3-D printing) etc. (**Liu** will cover chemical synthesis of biomaterials, such fabrication methods as emulsion fabrication of nano-/micro-particles and electrospinning, and surface modification of biomaterials; **Levin** will teach microbial synthesis of bioplastics).

Weeks 7-9: *Characterization and evaluation* (TEM, SEM/EDXA, XPS, FTIR imaging and AFM): physical properties, chemical properties, and biological interaction (immune response, biodegradation and antimicrobial activity). [**Tour of MIM facility].** (**Liu** will cover viscoelasticity of biological tissues and basic mechanical models as well as those commonly used characterization techniques: TEM, SEM/EDXA, XPS, FTIR imaging and AFM; **Levin** will lecture on biodegradation of Biopolymers and biocompatibility of biomaterials (tissue response to implants).

Weeks 10-12: *Applications*: Biomedical applications (vascular graft, hip replacement, orthopedics), and food packaging application.

(**Liu** will lecture on biomedical applications; **Levin** will lecture on bio-composite materials and food packaging application).

Class Schedule

LECTURES Three hours per week for one term (13 weeks, Rm. HUMAN ECOLOGY 300)
(L# = Lecture number)

L1. (Sept. 9) **Course Introduction and Smart Biomaterials** (Week 1)

L2. (Sept. 12) **An Overview of Biomaterials-Three Generations of Biomaterials (Part 1)**

L3. (Sept. 14) **An Overview of Biomaterials-Tissue Engineering (Part 2)**

L4. (Sept. 16) **An Overview of Biomaterials- Successful Biomaterials (Part 3)** (Week 2)

L5. (Sept. 19) **Classes of Materials used in Medicine-Polymers**

L6. (Sept. 21) **Polymers-1:** key characteristics of polymer molecules--- molecular weight, chemical composition, tacticity, and molecular structure (chain architecture)

L7. (Sept. 23) **Polymers-2:** Physical States of Linear Polymers and shape memory polymers (Week 3)

L8. (Sept. 26) **Polymers-3:** relationship between molecular characteristics and macroscopic properties (part 1)

L9. (Sept. 28) **Polymers-4:** relationship between molecular characteristics and macroscopic properties (part 2)

Sept. 30 **National Truth and Reconciliation Day (University Closed)** (Week 4)

L10. (Oct. 3) **Polymers-5:** polymer synthesis (1)

L11. (Oct. 5) **Polymers-6:** polymer synthesis (2)

L12. (Oct. 7) **Polymers-6:** polymer synthesis (3) (Week 5)

Oct. 10 **Thanksgiving Day (University Closed)**

L13. (Oct. 12) **Biopolymers: PHA from Bacteria** (Dr. Levin)

L14. (Oct. 14) **Biodegradation of Biopolymers** (Dr. Levin) (Week 6)

L15. (Oct. 17) **Metals**

L16. (Oct. 19) **Hydrogels-1**

L17. (Oct. 21) **Hydrogels-2 Muscle like trainable hydrogel** (Week 7)

L18. (Oct. 24) **Electrospinning Fundamentals**

L19. (Oct. 26) **Electrospinning Applications**

L20. (Oct. 28) **3-D Printing** (Week 8)

L21. (Oct. 31) **3-D Bioprinting-Part 1**

L22. (Nov. 2) **No lecture; For you to work on Assignment #3.**

L23. (Nov. 4) **3-D Bioprinting-Part 2** (Week 9)

Nov. 7-10 Fall Term Break

L24. (Nov. 14) **Microparticles** (Week 10)

L25. (Nov. 16) **Nanoparticles**

L26. (Nov. 18) **Surface Properties/Modification of Materials Used in Medicine**

L27. (Nov. 21) **Surface Characterization of Biomaterials-1** (Week 11)

L28. (Nov. 23) **Surface Characterization of Biomaterials-2**

L29. (Nov. 25) **Tissue Engineering by Farinaz**

L30. (Nov. 28) **Tour MIM** (Week 12)

L31. (Nov. 30) **Biocompatibility of Biomaterials** (Dr. Levin)

L32. (Dec. 2) **Application of Biopolymers** (Dr. Levin)

L33. (Dec. 5) **Quiz** (Week 13)

L34. (Dec. 7) **Student Presentation-1**

L35. (Dec. 9) **Student Presentation-2**

Course Evaluation Methods

The grade for this course will be based on three assignments, in-class quizzes, one written research proposal, and an oral presentation. The specific distribution is shown below:

Assignments	50%
Quizzes	15%
Oral Presentation	15%
Written Proposal	20%

Assignment Descriptions

Assignments:

#1. Polymer molecular weight, polydispersity index, failure prediction of biomaterials, and correlation between molecular characteristics and macroscopic properties. (9%)

For example, Nylon 6 and poly(ε-caprolactone) have similar polymer backbone structures, with one carbonyl, five methylenes and a heteroatom, nitrogen or oxygen, respectively. Each is able to undergo crystallization. However, their thermal transition temperatures differ significantly. The glass transition temperature (Tg) for nylon 6 is 52 °C, whereas the Tg for poly(ε -caprolactone) is 112 degrees lower at -60 °C. Similarly, the melting transition temperature (Tm) for nylon 6 is 225 °C, whereas the Tm of poly(ε-caprolactone) is 60 °C. Briefly explain in words and provide a molecular structure diagram that explains the significant differences in thermal properties for these two polymers.

#2. This assignment includes questions about metal fabrication, hydrogel and eletrospinning (16%)

#3. For you to work on the challenge of printing hearts (9%).

#4. Surface modification and characterization. (16%)

Research Proposal and Oral Presentation:

Proposal (20%): Each student will write a short research proposal on a chosen topic (3 pages) and deliver a 3-minutes presentation (15%) to the class. The research proposal should be typed with 12 point Times New Roman font, single-spaced, with 2 cm margins.

Potential Proposal Topics:

- Fast and sensitive detection of Monkeypox
- Electrospinning or 3-D printing of polyhydroxyalkanoate (PHA) bioplastics
- Anti-scar skin substitutes
- Self-healing vascular grafts
- Triggered and targeted drug delivery using nanotechnology
- Environmental responsive biomaterials
- Scaffoldless tissue engineering

Databases

- PubMed, Scifinder, Web of Science, and Scopus

Suggested Reading

Joon Park. *Biomaterials Science and Engineering*. Elsevier 1984.
Joon Park and R.S. Lakes. *Biomaterials: An Introduction.* Elsevier 2007.
Peter Fratzl and Matthew J. Harrington. Introduction to Biological Materials Science. Wiley 2015.
Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen and Jack E. Lemons. *Biomaterials Science: An Introduction to Materials in Medicine*, third edition. Elsevier 2013.

List of Journals containing information on biopolymers and biomaterials

Biomaterials; Acta Biomaterialia; Advanced Functional Materials; Advanced Healthcare Materials; Macromolecules; Biomacromolecules; Polymer; Carbohydrate Polymers; Macromolecular Chemistry and Physics; European Polymer Journal; Journal of Colloid and Interface Sciences; Journal of Applied and Polymer Sciences; Polymer Degradation and Stability Progress in Polymer Science; Applied and Environmental Microbiology; Applied Microbiology and Biotechnology; Annual Review of Microbiology; Antonie van Leeuwenhoek; Canadian Journal of Microbiology; Chemical Society Reviews; Journal of Bacteriology; Journal of Biotechnology; Journal of Physical Chemistry

Special Notification:

Should an instructor fall sick during the term and is unable to deliver in-person lectures, they must notify their Department Head and students of their inability to come to the class. They have the following options available to them:

- Have a plan in place to make their teaching material accessible to a colleague, senior graduate student, or TA, who can take over their teaching while they are sick;
- Deliver the lecture(s) online synchronously; or
- Make the lecture(s) available to students asynchronously

If the latter two options are chosen, the Department Head should notify the Dean's Office of the course name, number and the number of classes delivered remotely.

If the instructor's illness is confirmed as Covid by a positive test, they should refrain from coming to campus for 5 days (from the day of the test) AND until they test negative on a rapid test. [We may need to check if any UM or PHA directive supersedes this clause.]