Course Outline

Instruction Team
- Dr. Song Liu, P.Eng.
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- Dr. David Levin.
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Student Hours
- Individual assistance is available by appointment.

Teaching Assistant
- Farinaz Jonidi Shariatzadeh
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Location
- EITC E2-164
  M/W/F 11:30-12:20 am

Contact Hours
- 3 credit hours
- Lectures:
  3 hours x 12 weeks = 36 hours

Prerequisites:
- All Biosystems graduate students are welcome to take this course

Course Website:
http://umanitoba.ca/umlearn

The Department of Biosystems Engineering has devised a plan so that there is minimal impact on the delivery and content of the course should the instructor fall sick and be unable to continue lectures in-person. Please be assured that the alternative plan outlining any deviation from the normal mode of instruction will be communicated to you as quickly as possible if/when the need arises.

BIOE 7380 Biomaterials Science and Engineering

Course Description

This course offers a comprehensive overview of biomaterials and biopolymers, encompassing their sources, physical, chemical, and biological properties, as well as their diverse applications. Students will delve into the synthesis, fabrication, and characterization of these materials, exploring the intricate relationship between their structure and properties. The curriculum will introduce students to a range of material characterization techniques at the morphological, structural, chemical, and biological levels.

Topics

1. Introduction to Biomaterials and biopolymers: definitions, sources, and importance.
2. Sources of Biomaterials and biopolymers (Synthesis, isolation, and fabrication): chemical synthesis (polymerization), microbial synthesis, fabrication (examples: melt-extrusion, electrospinning, 3-D bioprinting), and isolation of natural fibers.
3. Characterization and evaluation: physical/thermal properties, chemical properties, biological interaction (immune response, biodegradation).
4. Applications: Biomedical applications (vascular grafts, hip replacement, orthopedics, wound dressings, and tissue engineering), bio-composite materials, and food packaging.

Suggested Reading

Textbooks:
- 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.
- Wagner William R, Sakiyama-Elbert Shelly E , Yaszemski Michael J and Zhang Guigen. Biomaterials Science: An Introduction to Materials in Medicine, Forth edition. Elsevier 2020.

Journals:
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

Database:
PubMed, SciFinder, Web of Science, and Scopus

Lectures:
- Lecture notes will be posted on the UM Learn portal.

Course Goals

This course aims to equip students with a comprehensive understanding of biomaterials and biopolymers, including their diverse sources, physical, thermal, chemical, and biological properties, and their wide-ranging applications in environmental and biomedical fields.

Intended Learning Outcomes

1. Become familiar with various biomaterials and biopolymers.

2. Gain knowledge of the synthesis of biopolymers and the 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

Weeks 1-2: An overview of Biomaterials and biopolymers: biomaterials are nonviable materials 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 3-9: 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).

Week 10: 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 the viscoelasticity of biological tissues and basic mechanical models as well as those commonly used characterization techniques: TEM, SEM/EDXA, XPS, FTIR imaging, and AFM.

Week 11: Characterization: Levin will lecture on the biodegradation of Biopolymers and the biocompatibility of biomaterials (tissue response to implants). Applications: Biomedical applications (vascular graft, hip replacement, orthopedics) and food packaging applications. (Liu will lecture on biomedical applications; Levin will lecture on bio-composite materials and food packaging applications).

Week 12: Quiz and Student Presentations.

Course Schedule

University of Manitoba

University Calendar for Holidays

- Orange Shirt Day: Sep 30, 2025
- Thanksgiving Day: Oct 13, 2025
- Remembrance Day: Nov 11, 2025
- Fall Term Break: Nov. 10 – 14, 2025
- Winter Holiday: Dec 21, 2025, to Jan 1, 2025

Lecture	Date	Week	Description
L1	Sept 3	1	**Course Introduction and Smart Biomaterials**
L2	Sept 5	1	**An Overview of Biomaterials-Three Generations of Biomaterials** (Part 1)
L3	Sept 8	1	**An Overview of Biomaterials-Tissue Engineering** (Part 2)
L4	Sep 10	2	**An Overview of Biomaterials- Successful Biomaterials** (Part 3)
L5	Sep 12	2	**Classes of Materials Used in Medicine-Polymers**
L6	Sep 15	2	**Polymers-1: key characteristics of polymer molecules--- molecular weight, chemical composition, tacticity, and molecular structure (chain architecture)**
L7	Sep 17	3	**Polymers-2: Physical States of Linear Polymers and Shape Memory Polymers**
L8	Sep 19	3	**Polymers-3: relationship between molecular characteristics and macroscopic properties** (part 1)
L9	Sep 22	3	**Polymers-4: relationship between molecular characteristics and macroscopic properties** (part 2)
L10	Sep 24	4	**Polymers-5: polymer synthesis (1)**
L11	Sep 26	4	**Polymers-6: polymer synthesis (2)**
L12	Sep 29	4	**Polymers-7: polymer synthesis (3)**
L13	Oct 1	5	**Biopolymers: PHA from Bacteria- Dr. Levin**
L14	Oct 3	5	**Biodegradation of Biopolymers- Dr. Levin**
L15	Oct 6	5	**Metals**
L16	Oct 8	6	**Hydrogels-1**
L17	Oct 10	6	**Hydrogels-2 Muscle-like trainable hydrogel**
-	Oct 13	6	**Thanksgiving Day (University Closed)**
L18	Oct 15	7	**Electrospinning Fundamentals**
L19	Oct 17	7	**Electrospinning Applications**
L20	Oct 20	7	**3D Printing**
L21	Oct 22	8	**3D Bioprinting-Part 1**
L22	Oct 24	8	**Demo of Electrospinning and 3D bioprinting**
L23	Oct 27	8	**3D Bioprinting-Part 2**
L24	Oct 29	9	**Microparticles**
L25	Oct 31	9	**Nanoparticles**
L26	Nov 3	9	**Surface Properties/Modification of Materials Used in Medicine**
L27	Nov 5	10	**Surface Characterization of Biomaterials-1**
L28	Nov 7	10	**Surface Characterization of Biomaterials-2**
Nov. 10-14		-	**Fall Break**
L29	Nov 17	10	**Tissue Engineering- Farinaz**
L30	Nov 19	11	**Tour MIM**
L31	Nov 21	11	**Biocompatibility of Biomaterials- Dr. Levin**
L32	Nov 24	11	**Application of Biopolymers- Dr. Levin**
L33	Nov 26	12	**Quiz**
L34	Nov 28	12	**Student Presentation 1**
L35	Dec 1	12	**Student Presentation 2**
L36	Dec 3	13	**Student Presentation 3**

Important Dates

- **Early Withdrawal Deadline**
  Sep 16, 2025
- **Fall Term Break**
  Nov 10—Nov 14, 2025
  No classes or examinations
- **Voluntary Withdrawal Deadline**
  Nov 18, 2025
- **Last Day of Classes**
  Dec 8, 2025

Grading Scale

Letter Grade	Percentage out of 100
A+	92-100
A	85-91
B+	78-84
B	72-77
C+	66-71
C	60-65
D	50-59
F	Less than 50

Assignment Feedback

Students can expect to receive graded assignments within two weeks of their submission.

Late Submission Policy

Assignments submitted after the due date will be docked 10% per day.

Deliverables

Deliverable	Date (Tentative)
Assignments	Check UMLearn for the deadlines
Quiz	Week 12, Nov 26
Oral Presentation	Part 1 Nov 28 Part II Dec 1 Part III Dec 3
Written Proposal	Dec 12, 2025

Evaluation

Assignment	Allocation	Description
Assignments	50%	#1. This assignment will evaluate your understanding of polymer molecular weight, polydispersity index, biomaterial failure prediction, and the correlation between molecular characteristics and macroscopic properties. It constitutes 9% of your overall grade. 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 will assess your understanding of metal fabrication, hydrogel, and electrospinning techniques. It comprises 16% of your overall grade.
		#3. To demonstrate your problem-solving skills, you will be tasked with addressing the challenges associated with printing hearts. This component constitutes 9% of your final grade
		#4. You will be assessed on your knowledge of surface modification techniques and characterization methods. This component comprises 16% of your final grade.
Quizzes	15%	A combination of true/false, multiple choice, short answer, and long ans derived from lecture material.
Oral presentation	15%	Each student will deliver a 3-minute presentation to the class based on their proposal topic.
Written Proposal	20%	Each student will write a short research proposal on a chosen topic (3 pages). The research proposal should be typed in 12-point Times New Roman font, single-spaced, with 2 cm margins. **Potential Proposal Topics:** 3D bioprinter composite scaffolds for bone and cartilage regeneration Injectable scaffolds for tissue engineering (choose a specific tissue) Targeted drug delivery systems for cancer therapy Engineering immunomodulatory biomaterials 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

Integrity

All graduate students and pre-master's students must complete two online tutorials – GRAD 7500 Academic Integrity and GRAD 7300 Research Integrity – as part of the Bona Fide Academic Requirements of their graduate program.

Academic Integrity

Students are expected to conduct themselves in accordance with the highest ethical standards of the Profession of Engineering and evince academic integrity in all their pursuits and activities at the university. As such, in accordance with the *General Academic Regulations* on *Academic Integrity*, students are reminded that plagiarism or any other form of cheating in examinations, term tests, assignments, projects, or laboratory reports is subject to serious academic penalty (e.g., suspension or expulsion from the faculty or university). A student found guilty of contributing to cheating by another student is also subject to serious academic penalties.

Requirements/Regulations

- Students may not use artificial intelligence tools for taking tests, writing research proposals, or completing course assignments. However, these tools may be useful when gathering information from across sources and assimilating it for understanding. *genAI tools*

- All email communication must conform to the Communicating with Students university policy.

  Communicating with Students

- Attending lectures and laboratories is essential for the successful completion of this course. Self-declaration forms may be completed for missed tests, exams, or assignments during short-term absences (≤72 hours) for extenuating circumstances. Students don't need to share personal information about their situation beyond declaring the nature of the extenuating circumstance on the self-declaration form.

  Self-Declaration Form for Brief or Temporary Absence

- This form cannot be used for planned absences like vacations. It is also not to be used for longer-term absences or ongoing circumstances (e.g., Authorized Withdrawals, Leaves of Absence, or other accommodations), which will still require additional documentation.

  Self-Declaration Policy for Brief or Temporary Absences

- It is the responsibility of each student to contact the instructor in a timely manner if they are uncertain about their standing in the course and about their potential for receiving a failing grade. Students should familiarize themselves with the University's *General Academic Regulations*.

  General Academic Regulations

- Students should be aware that they have access to an extensive range of resources and support organizations. These include Academic Resources, Counselling, Advocacy, and Accessibility Offices, as well as documentation of key University policies, e.g., Academic Integrity, Respectful Behaviors, Examinations, and related matters.

  Supplemental Resources

Retention of Student Work

Students are advised that copies of their work submitted in completing course requirements (i.e., assignments, laboratory reports, project reports, test papers, examination papers, etc.) may be retained by the instructor and/or the department for the purpose of student assessment and grading. This material shall be handled in accordance with the University's *Intellectual Property Policy* and the protection of privacy provisions of *The Freedom of Information and Protection of Privacy Act (Manitoba)*. Students who do not wish to have their work retained must inform the Head of Department, in writing, at their earliest opportunity.

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