# Biomedical Engineering 191: Introduction to Biomaterials

Spring 2021 (TuTh 12 pm -1:15 pm)

**General**

*Faculty Instructor:* Prof. Jennifer Lewis (jalewis@seas.harvard.edu)
*Teaching Fellows*: Jeffrey Aceves (jaceves@g.harvard.edu) & Rodrigo Telles (rtelles@g.harvard.edu)
*Teaching Fellow Office Hours*: 7-8 pm ET Tues (Rodrigo Telles) & 2-3 pm ET Wed (Jeff Aceves)
*Prerequisites*: Math 1b (or co-Math21a, co-AM21a, co-Math23a); PS 1 (or PS11, LS1a)

**Description**

A biomaterial is any form of matter that is produced by or interacts with biological systems. One of the pillars of biomedical engineering is to use naturally derived and synthetic biomaterials to treat, augment, or replace human tissues. This course examines the structure, properties and processing of biomaterials.

**Course Objectives**

At the end of this course, students will be able to:

- Accurately draw the molecular-level structures of several common synthetic and naturally occurring biomaterials.
- Predict the physical properties of synthetic and naturally occurring biomaterials by analyzing their composition and structure.
- Use quantitative models to describe biomaterials performance, including mass transport, rheological, and mechanical properties.
- Use a combination of quantitative and qualitative techniques to design a material that exhibits specified performance criteria while interacting with a biological system.
- Present and defend an original design project, communicating ideas clearly and effectively to peers and teaching staff.

**Expectations**

Students are expected to attend all lectures and participate in all class activities. The course will require a commitment of about 4-8 hours a week outside of lectures for work on homework, projects, and exams. Some portions of the class will be driven by the students so as to give them an opportunity to explore and discuss topics within biomaterials engineering that they find particularly interesting. The success of these assignments will be determined by the students' ability to do independent research, effectively communicate their findings to the class, and field questions from the teaching staff.

**Lectures**

Lectures will be delivered by Prof. Lewis and local experts in various sub-fields. Guest lectures will be valuable opportunities to learn about the latest applications of biomaterials research and their application to modern problems. The lectures in this course will be designed to:

1) Provide students with basic concepts in structure-property-processing relationships of biomaterials
2) Expose students to recent advances in biomaterials research
3) Expose students to emerging designs/applications of biomaterials

**Reading Material**

There is no textbook that will be used as required reading for this class. Two books will serve as reference materials and will be kept on reserve at the library:

• *Biomaterials Science: An introduction to Materials and Medicine*, 3rd Ed. Ratner, Academic Press, 2013
• *Materials Science for Engineering: An Introduction*, William D. Callister, Jr. Wiley, 8$^{th}$ edition.

**Assignments**
The following assignments are planned for the class:

1) *Problem Sets:* will require students to demonstrate knowledge of key concepts introduced during the lectures and in relevant research articles.
2) *Journal Articles:* will require student teams to read seminal research articles and present their findings to the class.
3) *Group Project/Presentation:* student teams will research a biomaterial application of interest and present their findings to the rest of the class. These presentations should emphasize how a naturally occurring or synthetic biomaterial is designed and used in a given application. In addition, students must specify ways in which the given material's performance/functionality can be improved through engineering composition, structure, and assembly pathways.

*Late Assignment Policy*:
It is my goal to provide students with the time they need to complete assignments. Official deadline extensions will be communicated directly to the class by email or in person. In cases of emergency (medical, family, etc.) extensions may be granted upon petition by email. These situations will be dealt with on a case-by-case basis and extensions are not guaranteed. In cases where no extension is granted, 10% of the grade will be deducted from the total for late assignments. An additional 10% will be deducted for every 24 hours past the deadline for late submissions. The goal of this policy is to prevent students from gaining an unfair advantage over their peers.

**Grades**
All grading will be carried out by the BE191 teaching staff. Grades will be assigned based on the following breakdown:
Problem Sets.....30%
Journal Articles.....20%
Group Project/Presentation.....50%

**Expectations of Professionalism**
You are expected to abide by the Harvard University policies on academic honesty and integrity as given in the Student Handbook. Violations of these policies will not be tolerated. Discussion among students, professor, TFs and/or any colleagues is permitted and encouraged. You are free to seek help through all avenues. However, all materials submitted (homework, lab reports, exams, and the design project presentation) must be your own work. Copying from any source without explicit reference is a violation of this policy (plagiarism).

**Policies of Collaboration**

- Before consulting others (students, TFs, instructors) make sure you have made a genuine effort to solve the problems by yourself: this is really important so you can see where your personal roadblocks are and focus on them.
- Collaboration in planning and thinking through solutions to problem sets is encouraged, but no collaboration is allowed in writing up solutions. You are allowed to work with other students currently taking BE 191 in discussing, brainstorming, and walking through solutions to problem sets. However, you must write up your solutions independently. You may check your final answer verbally with a collaborator but there may be no passing of problem sets between collaborators.
- We encourage you to collaborate with other students in the course in the planning and design of solutions to homework problems. At the top of your submitted problem set state with pride the names of the students with whom you collaborated in this manner.
- Some of the homework problems that we assign will be taken from textbooks or other published sources or other courses or previous offerings of this course. It is not acceptable to simply find pre- existing solutions to these problems and treat them as "collaborators."
- Collaboration in the form of planning and thinking is also permitted for oral and written proposals. However,

evidence of plagiarism (as defined by Harvard's plagiarism policies) will result in a grade of zero for the assignment.

**Accommodations for students with disabilities**
Students needing academic adjustments or accommodations because of a documented disability must present their Faculty Letter from the Accessible Education Office (AEO) and speak with the professor by the end of the second week of the term. Failure to do so may result in the Course Head's inability to respond in a timely manner. All discussions will remain confidential, although Faculty are invited to contact AEO to discuss appropriate implementation.

**Course Schedule**

| Date | Topic | Assignments |
|---|---|---|
| Jan 26 (Tu) | **Lecture 1** – Intro to Biomaterials | |
| Jan 28 (Th) | No class | |
| Feb 2 (Tu) | **In-class activity** (TFs lead) | |
| Feb 4 (Th) | **Lecture 2** – Bonding | |
| Feb 9 (Tu) | **Lecture 3** – Crystal Structures | |
| Feb 11 (Th) | **Lecture 3 (con't)** – Defects | |
| Feb 16 (Tu) | **Lecture 4** – Polycrystalline Materials | |
| Feb 18 (Th) | **Lecture 4** – Amorphous Materials<br>**Lecture 5** – Polymers | **PS1 Due** |
| Feb 23 (Tu) | **Lecture 6** – Biopolymers and Hydrogels | |
| Feb 25 (Th) | Journal article presentations | **Article Presentations** |
| March 2 (Tu) | **Lecture 7** – Diffusion and Controlled Release (Part 1) | |
| March 4 (Th) | **Lecture 7** – Diffusion and Controlled Release (Part 2) | |
| March 9 (Tu) | **Guest Lecture** – Microfluidics (Seb Uzel) | |
| March 11(Th) | **In class problem** – Controlled Release | **PS2 Due** |
| March 16 (Tu) | Wellness Day | |
| March 18 (Th) | **Lecture 8** – Mechanical Properties | |
| March 23 (Tu) | **Guest Lecture** – 3D printing of TM grafts (Nicole Black) | |
| March 25 (Th) | **Lecture 9** – Biomaterials Processing Part I (Metals) | **PS3 Due** |
| March 30 (Tu) | **Lecture 10** – Rheological Properties | |
| April 1 (Th) | **Lecture 11** – Biomaterials Processing Part II | |
| April 6 (Tu) | Rapid Fire Design Pitches | **Project meetings (1:1)** |
| April 8 (Th) | **Guest Lecture** – TBD (Prof. Kit Parker) | **Project meetings (1:1)** |
| April 13 (Tu) | Group Project Presentations | **Project description due** |
| April 15 (Th) | Wellness Day | |
| April 20 (Tu) | Group Project Presentations | |
| April 22 (Th) | Group Project Presentations | |
| April 27 (Tu) | No class | |

**Teaching staff (Prof. Lewis, Jeffrey Aceves & Rodrigo Telles) will be available to meet with individual groups during these class periods (or any time upon request). These meetings will be held by Zoom.