University of New Hampshire

Introduction to Biofabrication

BIOT 510 - Spring 2023

Objectives: This project-based course introduces students to the techniques and challenges of biofabrication. Students learn how additive manufacturing is used to combine cells with a variety of materials to create living tissues such as skin, cartilage, vascularized bone, and blood vessels. During this process students learn how to design for and operate 3D printing and bioprinting equipment. An emphasis will be placed on the ways in which this emerging technology impacts our society.

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Office Hours (Room 137): T/Th 9:00 am -10:00 am, W 12:00-1:00 pm

Prerequisite: None.

Grading: Your final grade will be computed as follows:

- Participation: 10%
- Discussion Board 15%
- Journal Article Analysis: 25%
- Projects: 50%

Grades for the course will be determined solely by the points earned from the assignments listed in the syllabus. There are no opportunities to earn extra points through special assignments or additional work beyond what is given to all other students. This ensures that the grading system is fair and consistent for everyone. Please note that it is not possible to request extra credit assignments at the end of the semester in an effort to improve your grade. It is important to stay caught up with the course material and complete all assignments to the best of your ability throughout the semester.

Class Structure: BIOT510 is a 4-credit course that meets in-person for 3 hours per week, for a total of 15 weeks. The course is divided into eight modules, each of which includes a biomanufacturing project, a discussion board, and either a journal analysis or a site visit to a local biomanufacturing company with a written reflection. Each class begins with a lecture covering the necessary terms and concepts from biomanufacturing that are relevant to the design. After the lecture, you will be taught how to use various computer-aided design software such as Fusion 360 or Blender to create the basic design. You will then be left to use your newly acquired skills to complete the project. Since completing a 3D print can take several hours, you are expected to use the lab outside of the scheduled 3-hour class block to finish your projects. In this course, you will design and 3D print a variety of projects using either a standard FDM printer, a DLP resin printer, or a bioprinter. This course is focused on the design and successive iteration of these projects, which represent the majority of your grade. Each project is graded based on the successful completion and functionality of the design.

Participation: Attending class and being punctual are important for full participation in the course. By being present and on time, you are able to make the most of the class and contribute to the learning experience. Evaluating class participation is a subjective process that takes various factors into consideration. These include class engagement, the frequency of lateness or un-excused absences, and the use of electronic devices during class. I strive to be fair and considerate in my evaluations and appreciate your efforts to actively participate in the class and show respect for your peers and myself. In the event of inclement weather, it is important to make an effort to arrive on time and find a parking spot. However, I understand that sometimes the weather can be more severe than anticipated or the roads may be unexpectedly slower. If unforeseen weather conditions cause you to be late, please don't worry about it affecting your class participation grade. The safety of you and your fellow students is the top priority, so please take the necessary precautions and drive safely. I want to recognize and reward students who come to class ready to learn and engage with their peers. That's why I've implemented a class participation policy that allows students to earn an A for 10% of their final grade simply by being present, attentive, and respectful in class. By showing up and making the most of every class session, you'll not only be demonstrating your own dedication to your education, but you'll also be contributing to a positive and productive learning environment for everyone. So don't miss out on this opportunity to boost your grade and be a valued member of our class community.

Discussion Board: Each module in the course includes a discussion board where you will explore the societal impacts of biofabrication. For each post, you must identify at least one impact and provide a meaningful reply to a classmate's initial post, comparing or contrasting these impacts with additional examples from published literature. Through these online discussions, you will be tasked with considering the various ways in which biofabrication may affect society. You will also debate the pros and cons of these impacts with your peers.

Journal Article Analysis: To motivate your designs and expose you to current research in biomanufacturing, each module includes a recently published journal article for you to read and analyze. In your analysis, you will summarize the purpose, hypothesis, major findings, and testing methods of the paper, as well as provide your opinion on its scientific importance. Through this process, you will consider the aims and objectives of the article, evaluate the results and methods used, and reflect on the overall significance of the work.

Grades are assigned as follows:

A starts at 92.5	C starts at 72.5
A- starts at 89.5	C- starts at 69.5
B+ starts at 86.5	D+ starts at 66.5
B starts at 82.5	D starts at 62.5
B- starts at 79.5	D- starts at 59.5
C+ starts at 76.5	F below 59.5

Students with Disabilities: The University is committed to providing students with documented disabilities equal access to all university programs and facilities. If you think you have a disability requiring accommodations, you must register with the Disability Services Office. The Disability Services Coordinator at UNHM is Jenessa Zurek. Jenessa can be contacted at (603) 641-4170, jenessa.zurek@unh.edu or in person in the Student Services Suite, Room (#410H). Please be aware that I cannot make any accommodations prior to you meeting with disability services.

Project Descriptions

3D Printing Medical Devices: Surgical Forceps Design and Fabrication This project is the first in the course and is therefore designed to be relatively straight forward. The project involves designing and 3D printing surgical forceps using Fusion 360 and then printing it on a FDM 3D printer. The goal of the project is to provide students with an overview of the design process as well as how 3D printing can be used to create basic biomedical devices. To go along with this design, students analyze the journal article "3D Printed Surgical Instruments – The Design and Fabrication Process" to connect their work on this project to recent research and applications in the field. One application of 3D printing that is discussed in this article helps to link this project to the module's discussion. In the discussion students are asked to find examples where 3D printing is being used in developing countries where access to medical equipment may be limited.

Self-Assembling Spherical Cube: Viral Capsid and Drug Delivery Models In this project, students design and 3D print a self-assembling spherical cube made up of 6 components and 48 cylindrical magnets. They investigate the symmetries of the cube to discover an arrangement of the magnet poles embedded in the sides of each component that will cause the components to self-assemble when shaken in a container. These structures "can serve numerous functional roles, including microencapsulation and delivery of drugs and biomolecules, epitope presentation to allow for an efficient immunization process, synthesis of nanoparticles of uniform size, observation of encapsulated reactive intermediates, formation of structural elements for supramolecular constructs, and molecular computing." The goal of the project is for students to successfully 3D-print a stable self-assembling structure with potential applications in a range of fields.

Innovations in Orthopedic Surgery: PLA Screw Design and Analysis Titanium screws, which are commonly used in surgical procedures often must be removed or replaced after a certain period of time. In contrast, poly-lactic acid (PLA) screws are stable for 8-10 months post-operation and are gradually absorbed by the body over a period of 24 months. For this project, students design and 3D print a PLA medical screw based on a design inspired by a real-world medical screw, the MegaFix P1135. The students then test the accuracy of their design by ensuring that it fits into an existing 3D printed model of the tibiofemoral joint used for a mock anterior cruciate ligament (ACL) repair. The goal of the project is to explore the potential benefits of using PLA screws in medical procedures, and to give students practice in designing and 3D printing a functional medical device.

Fractal Structures: From Nature to Transplants In this project, students investigate the mathematics behind fractal patterns, which are commonly found in many natural structures such as the branching patterns in our lungs, the network of blood vessels in our circulatory system, the neurons in our brains, and even the patterns of fractures in our bones. The project coincides with a site visit to United Therapeutics Lung Division, where students learn about the company's use of 3D printing to create scaffolds for artificial lungs using cutting edge resin-based 3D printers. One of United Therapeutics' goals is to make organ transplants more accessible and affordable for those in need, and to reduce the waiting list for transplant patients. As part of the project, students must write a short essay discussing their experience on the site visit. In their essay, they should highlight any particularly surprising or interesting aspects of the visit, as well as any lingering questions or thoughts they have. They should also reflect on how the visit has impacted their understanding of fractal geometries, 3D printing technology, and organ transplantation. Using their newfound knowledge, students design a model of a fractal branching pattern based on the structure of the tracheobronchial tree and 3D print it on a resin-based 3D printer. Ultimately, students aim to replicate the basic process used by United Therapeutics and create their own 3D printed fractal branching patterns.

From CT scans to 3D Models: An Introduction to Personalized Biofabrication In this project, students learn how to create a 3D printable model from a CT scan, which is an important first step in a personalized biofabrication process. Students choose a CT scan from Embodi3D's online database and use their free online software democratiz3D to convert it to a watertight mesh model. They also learn how to manipulate a mesh in order to optimize its structure for 3D printing, repair any errors or distortions in the scan data, and prepare the model for post-processing. This includes techniques such as smoothing and refining the mesh, filling holes, and removing unwanted features. By the end of this project, students are proficient in creating 3D models from CT scans and have a solid understanding of how to manipulate a mesh for various purposes. This is a valuable skill for a variety of applications in the field of biofabrication, including the creation of custom medical devices, prosthetics, and personalized surgical guides.

Digital Dentistry: 3D Scanning and Printing Orthodontic Aligners In this project, students continue learning about the process of creating a 3D model from a digital scan. Using an EinScan-SE 3D scanner, they complete a scan of an upper dentition model that was generously donated by the company SprintRay. They identify and correct any flaws or inconsistencies in the scan data and use the cleaned-up model to create a dental aligner. They then print the model using a resin-based 3D printer and test its accuracy by making sure it fits the original dentition model. To further their understanding of this project, students also analyze the article "Direct 3D Printing of Clear Orthodontic Aligners: Current State and Future Possibilities." This article discusses the advantages of 3D printed aligners in comparison to thermoformed ones and the current state of the art in this field. The goal of this project is for students to gain practical experience with 3D scanning and printing technology and to develop their skills in creating accurate 3D models of dental structures. Through this project, students are better equipped to use these processes and workflows in many areas of biotechnology, as well as other fields that rely on 3D modeling and printing.

Exploring 3D Bioprinting: Hands-on Exploration with Tissue-Mimicking Tubes This project introduces students to the differences between 3D printing with a bioprinter and a standard FDM printer. For this project, students explore the hardware aspects of 3D bioprinting as they adjust various settings, such as pressure and speed, on a bioprinter to influence the final print. The design for this project is a simple tube representing various structures that can be found in the human body, such as blood vessels or airways. As part of the project, students also analyze the article "Scaffold-free trachea regeneration by tissue engineering with bio-3D printing" to learn about different techniques for constructing a scaffold-free 3D structure similar in form and function to the tube they create. Through this project, students gain an understanding of the potential applications and limitations of bioprinting and develop their skills in using a bioprinter to create 3D structures.

Designing 3D Tissue Scaffolds: G-Code Control and Bioprinting Most 3D printed tissues begin with a basic scaffold on which cells can adhere and grow. In this project, students learn how to control a bioprinter by directly writing its toolpath through the use of G-code to print a simple crosshatch scaffold using a Pluronic hydrogel. To complement this project, students also go on a site visit to Advanced Solutions where they have the opportunity to learn about the company's multi axis bioassembly bot and see it in action. Through this project and site visit, students gain an understanding of the role of scaffolds in 3D bioprinting, learn about state-of-the-art bioprinting technology, and develop their skills in using G-code to direct a bioprinter to create 3D structures.