ENG BE500 – Spring 2023
Engineering tissue injury, repair, and foreign body responses

Lectures: Tue, Thur 1:30pm-3:15 pm

Instructor: Prof. Tim O'Shea, PhD, Assistant Professor, BME toshea@bu.edu
Office hours: Tuesdays and Thursdays, 4-5pm, ERB 521

Course Description:

Tissue injuries and diseases involving foreign bodies such as infection continue to be massive global challenges. Developing appropriate engineering solutions to these challenges requires understanding the pathological mechanisms of tissue injury and foreign bodies as well as knowledge of current state-of-the-art methods used to diagnose and treat the related disorders across the various organ systems of the body. This course will provide the foundational content on the cell and molecular mechanisms of injury and foreign body responses, introduce pathology methods, and explore advanced concepts in the engineering of tissue and organ repair and engineering approaches to regulating foreign body responses. In addition to lectured content, students will dissect and present new multidisciplinary peer-reviewed studies from the literature on emerging topics related to injury, repair, and foreign body responses. This course will also give students an opportunity to formulate their own innovative research approaches to address injury and foreign body challenges and practice preparing proposals to describe their ideas.

Course Goals:

This course is designed to be taken by Seniors, Masters and PhD students majoring in BME to provide an introduction to the pathological mechanisms of cell/tissue injury and foreign body responses and to explore advanced concepts in the engineering of tissue and organ repair and the regulation of foreign body responses. Emerging engineering approaches to diagnose and treat injury will be discussed using current scientific literature.

The **objectives of this course** are to provide:

1. **Introduction to basic pathological mechanisms that cause cell/tissue injury and foreign body responses (FBRs).** This course aims to introduce some of the fundamental concepts of injury and FBRs often covered in first year pre-clinical medical school pathology classes but delivered in an accessible way for engineering students.
2. **Introduction to pathology methods used to diagnose and characterize cell and tissue injury and FBRs and how engineering is being used to improve these outcomes.** This course will provide insight into how to interpret results from pathology methods used in the characterization of injury, repair and FBRs and introduce engineering approaches used to improve the speed and reliability of these interpretations. Pathology methods studied will include: histology, hematological tests, urinalysis, genetic testing, and autopsy.
3. **Overview of cutting-edge engineering methods used to investigate cell and tissue injury pathophysiology and bioengineering strategies to stimulate repair.** This course will expose students to emerging concepts under active research investigation in the areas or injury, repair and FBRs through direct lecture instruction from experts working in these fields and by evaluating new peer reviewed research literature. Students will dissect and present on emerging research recently published in peer-reviewed scientific literature. Emerging engineering approaches used in pathology will be introduced through classroom discussions of techniques used in these new peer-reviewed scientific articles.
4. **Skills and techniques to critically evaluate current peer-reviewed literature on injury, repair, and FBR topics.** This course will develop the problem solving, analytical, and teamwork skills of biomedical engineering students through practical team-based Journal Club Presentations and team-based grant proposal writing. These activities will allow students to come up with innovate new solutions in these research areas.
5. **An opportunity to develop skills in scientific proposal writing skills as individuals and in teams.** Students will develop their individual skills in succinct proposal writing by generating Specific Aims pages on work inspired by classroom discussions while also practicing how to bring together a cohesive research proposal narrative effectively as a team.

6. **A pathology vocabulary and analytic skill set to enable students to effectively communicate with clinicians and relevant industries.** This course will provide biomedical engineering students with a working pathology vocabulary and familiarize them to experimental and quantitative techniques used to evaluate tissue injury, repair and FBR that will improve their preclinical and clinical research capabilities and allow them to thrive after graduation in industries that rely heavily on these concepts such as medical device, biotechnology, and engineering consulting.

Prerequisites: An introductory cell biology course such as BE209.

Textbook: No prescribed textbook for this class. New peer-reviewed scientific articles will be assigned as required reading throughout the semester.

Grading:	**Weighting**
Participation and attendance in lectures	20%
Group Presentations (Journal Club style – one time during semester)	20%
Individual Specific Aims Page Topic#1 (Due March 2nd)	15%
Individual Specific Aims Page Topic#2 (Due April 6th)	25%
Team Proposal (6-page R21 style research strategy (Due April 27th)	20%

Course Materials:
In addition to provided peer-reviewed literature, course handouts and presentation slides will be provided to students using Blackboard.

Assessments:
This class will include both individual and team-based assessments.

1. Individual Assessments – 2x Specific Aims Pages and Lecture participation
Each student will prepare two different Specific Aims pages throughout the semester on two separate research proposal concepts of their choosing. Students will be required to: (i) identify an important problem that they want to tackle, (ii) find a gap in current knowledge in the problem area, (iii) suggest a novel solution, (iv) develop a research approach that can be used to realize their solution, and (v) identify the impact of their work on the research field if successful. Specific Aims pages should be one single page and should follow established NIH conventions for structure, formatting, and layout.

2. Team-based Assessments – Journal Club Presentation and Team Proposal:
Students will form teams of 2-3 students that will work together to lead one Journal Club style presentation and discussion delivered during one of the regularly scheduled lectures throughout the semester. Teams will present their critical evaluations on an allocated peer-reviewed article that has been recently published and lead a discussion with the class on techniques and topics covered in the paper. Using the article presented for their Journal Club as motivation, students will generate a 6-page R21 style research strategy that describes a new research project that explores an exciting new area related to this published work. The 6-page research strategy should follow established NIH conventions for structure, formatting and layout.

Any suspected violation of the Academic Conduct Code will be immediately referred to the College of Engineering Academic Conduct Committee. (http://www.bu.edu/academics/policies/academic-conduct-code/)

References:
Robbins and Cotran, Pathologic Basis of Disease, 10th ed, 2020, Ed: Kumar, Abbas, and Aster, Elsevier/Saunders; ISBN: 9780323531139.
Wheater's Functional Histology, 6th ed, 2013. Woodford and O'Dowd, Elsevier; ISBN: 9780702047473.
Temenoff J and Mikos A, Biomaterials: The Intersection of Biology and Materials Science, 2nd Edition, 2022, Pearson, ISBN: 9780137625963.
Wagner, Sakiyam-Elbert, Zhang, Yaszemski, Biomaterials Science: An Introduction to Materials in Medicine, 4th edition, 2020, Elsevier; ISBN:978-0128161371.

Learning Outcomes:

Those students who participate fully in the course will be able to:

1. Explain the mechanisms by which cells and tissues can be injured and rationalize the pathological consequences on an organ and systems level.
2. Interpret the results of pathology tests such as histology, hematological tests, and urinalysis as it pertains to cell and tissue injury.
3. Explain the similarities and differences in the pathophysiology of tissue injury across multiple organ systems.
4. Develop new therapeutic bioengineering strategies, informed by the literature, for repairing tissues and organs.
5. Explain the biology of FBRs and critically evaluate appropriate engineering methods to regulate FBRs.
6. Understand how to read, critically analyze, and interpret multidisciplinary research literature.
7. Describe current and emerging engineering methods used to diagnose and treat tissue injury and direct specific FBRs.
8. Prepare clear and succinct research proposals including specific aims pages and research strategy documents.

Course Topics:

This course is divided into 3 modules: 1) Injury; 2) Repair; 3) FBR. The planned lecture schedule for Spring 2023 is attached at the end of this document. Throughout these topics the current and emerging use of engineering, including in the areas of materials science, mechanical engineering, and imaging, will be discussed.

Injury Module

1. Introduction and review of cell biology concepts relevant to course.
2. Overview of the organization of tissues and organs (parenchyma and stroma).
3. Introduction to pathology methods (histology, hematological tests, urinalysis, autopsy). Engineering methods in pathology.
4. Cell injury (apoptosis, autophagy, aging). Bioengineering methods to study cell injury.
5. Tissue injury (modes of injury, necrosis, acute inflammation, chronic inflammation).
6. Immune-mediated injury (mechanisms, autoimmune diseases).
7. Analysis of literature on injury in Nervous, Cardiovascular, Skin and Muscoskeletal organ systems.

Repair Module

1. Overview of natural wound repair mechanisms (angiogenesis, fibrosis, EMT, adaptive reprogramming).
2. Management of chronic wounds-clinical considerations and engineering solutions.
3. Engineering stem cells and cell transplantation for tissue injury repair.
4. Tissue engineering approaches applied to injury repair.
5. Graft vs host disease; engineering solutions to graft vs host disease.
6. Analysis of literature on engineering approaches for repair of Nervous, Cardiovascular, Skin and Muscoskeletal organs.

FBR Module

1. Overview of foreign body response (FBRs), types of foreign bodies, and relation to infection.
2. FBRs to implanted biomaterials; Materials engineering considerations
3. FBRs to microbes and biofilms; medical device design considerations.
4. FBRs to protein aggregates (focus on Neurodegenerative disease).
5. Analysis of literature on FBRs and engineering approaches to regulating FBRs.

Planned lecture schedule

Lecture Number	Date	Day	Module	Content	Presenter(s)	Notes
1	1/19/2023	Thursday	**Injury L1-10**	Introduction to course; Review of cell biology concepts relevant to this course	T.O	
2	1/24/2023	Tuesday		Overview of the organization of tissues and organs (parenchyma and stroma)	T.O	
3	1/26/2023	Thursday		Introduction to pathology methods (histology, hematological tests, urinalysis, autopsy)	T.O	
4	1/31/2023	Tuesday		Cell injury (apoptosis, autophagy, aging)	T.O	
5	2/2/2023	Thursday		Tissue injury (modes of injury, necrosis, acute inflammation, chronic inflammation)	T.O	
6	2/7/2023	Tuesday		Immune-mediated injury (mechanisms, autoimmune diseases)	T.O	
7	2/9/2023	Thursday		Dissecting CNS injury paper	Student group 1	
8	2/14/2023	Tuesday		Dissecting Cardiac injury paper	Student group 2	
9	2/16/2023	Thursday		Dissecting Skin injury paper	Student group 3	
10	2/23/2023	Thursday		Dissecting Musculoskeletal injury paper	Student group 4	No Tuesday class due to make up day for President's Day holiday
11	2/28/2023	Tuesday	**Repair L11-19**	Overview of natural wound repair mechanisms (angiogenesis, fibrosis, EMT, adaptive reprogramming)	T.O	
12	3/2/2023	Thursday		Management of chronic wounds-clinical considerations and engineering solutions	T.O	Last Class before Spring Break; Individual Specific Aims Page Topic#1 Due
13	3/14/2023	Tuesday		Engineering stem cells and cell transplantation for tissue injury repair	T.O	
14	3/16/2023	Thursday		Tissue engineering approaches applied to injury repair	T.O	
15	3/21/2023	Tuesday		Graft vs host disease; engineering solutions to graft vs host disease	T.O	
16	3/23/2023	Thursday		Dissecting paper on engineering CNS injury repair	Student group 5	
17	3/28/2023	Tuesday		Dissecting paper on Engineering Cardiac injury repair	Student group 6	
18	3/30/2023	Thursday		Dissecting paper on engineering Musculoskeletal injury repair	Student group 7	
19	4/4/2023	Tuesday		Dissecting paper on engineering Skin injury repair	Student group 8	
20	4/6/2023	Thursday	**FBR L20-27**	Overview of foreign body response (FBR), types of foreign bodies, and relation to infection	T.O	Individual Specific Aims Page Topic#2 Due
21	4/11/2023	Tuesday		FBR to implanted biomaterials; Materials engineering considerations	T.O	
22	4/13/2023	Thursday		FBR to microbes and biofilms; medical device design considerations	T.O	
23	4/18/2023	Tuesday		FBR and protein aggregates (Neurodegenerative disease)	T.O	
24	4/20/2023	Thursday		Dissecting Paper on FBR to Biomaterials I	Student group 9	
25	4/25/2023	Tuesday		Dissecting Paper on FBR to Biomaterials II	Student group 10	
26	4/27/2023	Thursday		Dissecting Paper on FBR to Biomaterials III	Student group 11	Team Proposals Due
27	5/2/2023	Tuesday		Dissecting Paper on FBR and bioflims; Course Wrap-up and feedback session	Student group 12 / T.O	