جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

Course Syllabus: Foundations of Bioengineering - BioE 201

Division	Biological and Environmental Sciences & Engineering Division
Course Number	BioE 201
Course Title	Foundations of Bioengineering
Academic Semester	Fall
Academic Year	2019/2020
Semester Start Date	08/25/2019
Semester End Date	12/10/2019
Class Schedule (Days & Time)	09:00 AM - 10:30 AM | Sun Wed

Instructor(s)

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Teaching Assistant(s)

Name	Email

Course Information

Comprehensive Course Description	This course contains elements of programing, statistics, electronics, materials and synthetic biology. It describes the fundamental principles and methods of different engineering fields to provide the necessary background for future specialization in the tracks of this program. The course aims to apply engineering principles to understand the physical, chemical, and mathematical basis of biological systems. The students will learn the origin of electrical biosignals, fundamental operation principles of modern electronics (sensing and control instrumentation) used at the interface with biological systems including EEG, ECG, biochemical sensors. They will learn about the basics of fabrication of devices involving microfluidics and microarray device design principles. The students will be then introduced to the different types of reactor configurations commonly used as bioreactors, operational parameters related to these reactors, and optimization of the reactors to maximize cell yield. The course will then introduce the principles of material science interfacing with biology, in order to design artificial implants and matrices for biomedical applications. This will broaden the knowledge of the chemical, physical and biological properties of the materials, focusing on the materials recently used in the biomedical field. In particular, students will develop critical analysis of biomaterial development and methods of characterization. Furthermore, it will also introduce cutting-edge techniques associated with 3D bioprinting. Finally, the students will be introduced to data-analytics and modeling with particular focus on R and MATLAB through hands-on exercises. Using R students will learn to plot data-distributions, calculate summary statistics, perform dimension reduction analysis (PCA, and other related techniques) and to run elementary bioinformatics scripts. In the modeling part students will work with simple mathematical models for synthetic biology (biological switch and oscillator) and basic predictive models (KNN, decision trees and SVM) using MATLAB.
Course Description from Program Guide	This course contains elements of programing, statistics, electronics, materials and synthetic biology. It describes the fundamental principles and methods of different engineering fields to provide the necessary background for future specialization in the tracks of this program. The course aims to apply engineering principles to understand the physical, chemical, and mathematical basis of biological systems. The students will learn the origin of electrical biosignals, fundamental operation principles of modern electronics (sensing and control instrumentation) used at the interface with biological systems including EEG, ECG, biochemical sensors. They will learn about the basics of fabrication of devices involving microfluidics and microarray device design principles. The students will be then introduced to the different types of reactor configurations commonly used as bioreactors, operational parameters related to these reactors, and optimization of the reactors to maximize cell yield. The course will then introduce the principles of material science interfacing with biology, in order to design artificial implants and matrices for biomedical applications. This will broaden the knowledge of the chemical, physical and biological properties of the materials, focusing on the materials recently used in the biomedical field. In particular, students will develop critical analysis of biomaterial development and methods of characterization. Furthermore, it will also introduce cutting-edge techniques associated with 3D bioprinting. Finally, the students will be introduced to data-analytics and modeling with particular focus on R and MATLAB through hands-on exercises. Using R students will learn to plot data-distributions, calculate summary statistics, perform dimension reduction analysis (PCA, and other related techniques) and to run elementary bioinformatics scripts. In the modeling part students will work with simple mathematical models for synthetic biology (biological switch and oscillator) and basic predictive models (KNN, decision trees and SVM) using MATLAB.
Goals and Objectives	At the end of this course, student will be able to apply the methods of physical/chemical sciences and mathematics to biological systems. Students will learn basic electronic circuits, biosignals and interfaces of electronics with biological systems. Explain EEG, ECG and biochemical sensors. Understand the benefits and consequences of scaling. Understand basics of microfabrication of devices and microfluidics. This course will also equip students with the basic knowledge on bioreactor types and their operating fundamentals. Moreover, the students will develop critical analysis of biomaterial synthesis together with the methods commonly used for their characterization and use. They will gain the ability to design simple cell cultures to achieve differentiated biological tissues in vitro, to compare different biomaterials and generate ideas for their use in tissue engineering, use of the most common biological screening tests to evaluate the biocompatibility of synthetic biomaterial, and understand the 3D bioprinting process (the problem, design, material selection and structure fabrication). Finally, the objective is to provide the students with a working knowledge of importing, analyzing, and modeling data.
Required Knowledge	Basic engineering background
Reference Texts	Introductory Bioelectronics by *R. Pethig and S. Smith* -ISBN 9781119970873 Introduction to Biomedical Engineering by *J. Enderle and J. Bronzino* -ISBN 978-0-12-374979-6 Fundamentals of Microfabrication (2nd ed.) by M. Madou - ISBN 9781482274004 https://www.coursera.org/learn/r-programming https://www.coursera.org/learn/matlab
Method of evaluation	**20.00**% - Homework /Assignments **80.00**% - Exam 1
Nature of the assignments	Concept presentation and paper summary
Course Policies	Attendance at classes and exams is mandatory. The students are responsible to be informed about all material covered in the lectures, and the supplementary materials assigned for reading or handed out in class.
Additional Information	For the grading system, 20% assigned for grading of homework would be made up by 5% per module. For the exams, 80% assigned for grading of exams would be made up by 20% per module.

Tentative Course Schedule *(Time, topic/emphasis & resources)*		
Week	**Lectures**	**Topic**
1	Sun 08/25/2019 Wed 08/28/2019	Introduction to bioelectronis
2	Sun 09/01/2019 Wed 09/04/2019	Basic electronics (sensing and control) instrumentation
3	Sun 09/08/2019 Wed 09/11/2019	Biosensors: concepts, design and operation
4	Sun 09/15/2019 Wed 09/18/2019	Biosensors and bioelectronic device fabrication
5	Sun 09/22/2019 Wed 09/25/2019	Microbial bioengineering: - Design fundamentals, classification of reactors, method of operation will be discussed - Associated terminologies include retention time, dilution rate, yield, mass/mole balances, stoichiometry
6	Sun 09/29/2019 Wed 10/02/2019	Microbial bioengineering: Batch reactors, calculation of reactor size for known kinetics and specified production rates, discussion of rate limiting reactions
7	Sun 10/06/2019 Wed 10/09/2019	Microbial bioengineering: Continuous stirred tank reactors, derivation of design equation for steady state well-mixed flow, optimization of product yield via reactor control
8	Sun 10/13/2019 Wed 10/16/2019	Introduction to tissue engineering
9	Sun 10/20/2019 Wed 10/23/2019	Biomaterials and stem cells
10	Sun 10/27/2019 Wed 10/30/2019	Introduction to 3D bioprinting
11	Sun 11/03/2019 Wed 11/06/2019	Use of Bioinks
12	Sun 11/10/2019 Wed 11/13/2019	Data-mining. Basic Ideas and Tools. Summary statistics and visualization: - Introduction to data-mining. Basic concepts, ideas, and algorithms - Summary statistics and visualization
13	Sun 11/17/2019 Wed 11/20/2019	Data-analytics. Unsupervised clustering and PCA: - Dimension reduction analysis and PCA, and elementary bioinformatics scripts - Basic clustering algorithms and tools
14	Sun 11/24/2019 Wed 11/27/2019	Data-modeling. Basic Ideas, Tools, and Analysis: - Introduction to mathematical modeling in Life Sciences. Why modelling. Introduction to Tools, MATLAB. Generative dynamical systems modelling versus machine learning. Modeling data using Regression - Mathematical models for Dynamical Systems. Fixpoints and Oscillations. Stability analysis. Introduction to mathematical models in life-sciences general and synthetic biology in particular
15	Sun 12/01/2019 Wed 12/04/2019	Dynamical Systems Modeling for Synthetic Biology – Switches and Oscillators: - Mathematical models for synthetic biology – the genetic switch and the repressilator – a genetic oscillator, - Analysis of synthetic biology models, parameter estimation, sensitivity, and structure learning
16	Sun 12/08/2019	Break

Note

The instructor reserves the right to make changes to this syllabus as necessary.