Rutgers University
Electrical and Computer Engineering Department

ECE 493/599	Biosensors and Bioelectronics
Index Number	16320
Date:	Fall 2015
Credits:	3
Time:	TBA
Location	CORE 538
Grading	20% HW, 40% Midterm Exams, 10% Paper Presentation, 30% Final Project
Final Exam	None
Instructor	Mehdi Javanmard, PhD.
Course TA:	TBA
Textbook:	Kirby, Micro- and Nanoscale Fluid Mechanics (2010) Class slides will be available on the class website.
Prerequisites:	14:332:361 Electronic Devices
	Further Reading: Saliterman, Fundamentals of BioMEMS and Medical Microdevices (2009) Stryer, Lubert *Biochemistry* 5th Edition (2008)

Description of Course: The course covers state-of-the-art and emerging biosensors, biochips, microfluidics, which will be studied in the context of molecular diagnostics. Students will briefly learn the relevant biology, biochemistry, and molecular biology pertinent to molecular diagnostics and cancer. Students will also become equipped with a thorough understanding of the interfaces between electronics, optics, molecular biology, and cancer biology for engineers. Topics will include microfluidics and mass transfer limits, electrode-electrolyte interfaces, electrochemical noise processes, biosensor system level characterization, determination of performance parameters such as throughput, detection limit, and cost, integration of sensor with microfluidics, and electronic readout circuitry architectures Novel nanobiosensors such as nanopores, nanowire FETS, surface plasmon resonance, surface enhanced Raman scattering, fluorescence and single molecule detection will also be covered. Emphasis will be placed on hands-on in-depth quantitative design of biomolecular sensing platforms.

Course intent
1. To introduce the major biochemical and molecular processes relevant in molecular diagnostics.
2. To introduce the major molecular processes relevant to cancer.
3. To introduce and provide an understanding of emerging micro- and nanotechnologies for biomarker based disease diagnosis.
4. To give insight and understanding to participants to quantitatively evaluate and design biosensing solutions in medical diagnostics.
5. To generate an appreciation of the interface of biology and engineering, in particular microfluidics, sample preparation, and biosensing in current and emerging technologies.
6. For students to gain practical experience in design and characterization of biosensors.

Week Number	Topic
Week 1	**Intro to Molecular Biology for Engineers** - Basic Biochemistry, Nucleic Acid Replication and Synthesis, Protein Synthesis, Immunology.
Week 2	**Intro to Cancer Biology for Engineers** - Signaling Pathways, Biological Circuits, Biological Feedback Loops.
Week 3	**Microfluidics: Hydrodynamic Physics** - Basic Fluid Physics, Lumped Circuit Modeling of Fluidic Elements.
Week 4	**Mass Transfer Affects and Biosensor Performance Limits** - Device Modeling, Diffusion, Drift, Convection, Reaction and Mass Transfer Limiting Systems.
Week 5	**Interfacial Electrochemistry/Electrical Biosensing** - Device Physics Modeling, Electrical Impedance Lumped Modeling, Dielectric Spectroscopy, Charge Based Sensing, DNA Sequencing, Protein Assays, HIV, Cancer Tests, Diagnostics for the Developing World.
Week 6	**In-vitro and In-vivo Bioelectronic Devices and Interfaces** - Electronic Brain Interfaces, Cardiovascular Devices.
Week 7	**Electronic Biosensors, Noise Analysis, Signal Conditioning** - Noise at Device Physics Level, Equivalent Noise Circuits, Input Referred Current and Voltage Noise, Relevance to Cytometry, Protein, Nucleic Acid Detection, Cancer Detection.
Week 8	**Low-Noise Electronic Circuits for Biosensing** - Lock-in Amplifiers, 3- and 4-electrode Circuits, Charge Amplifiers, Capacitive Sensing Circuits, Non-linearity Detection Circuits.
Week 9	**Electric Field/Fluid Interactions: Electrokinetics** - Electrophoresis, Dielectrophoresis, DC and AC Electroosmosis, Electroratation.
Week 10	**Micro/Nanofabrication Techniques** - Top-Down Fabrication, Bottom-Up Synthesis of Channels and Sensors.
Week 11	**Electrokinetics and Sample Preparation** - DNA Extraction and Isolation, Protein Purification, Cancer Cell Isolation, Pathogenic Bacteria Isolation.
Week 12	**Nanoelectronic Biosensing Devices** - Carbon Nanotube Sensors, Silicon Nanowire Sensors, Graphene Based Sensors, Nanopore Sensors.
Week 13	**Optical Microscopy, Optofluidics, Nanophotonic Biosensing** - Fluorescence, Surface Plasmon Resonance, Surface Enhanced Raman Scattering, Nanoresonators, Fluidic Waveguids and Lasers.
Week 14	**Micromechanical and Magnetic Sensing Techniques** - Piezoresistance, GMR Sensing, Hall Effect, Micro-Cantilevers, Ultrasonic Transducers, Shear Force Spectroscopy, Atomic Force Microscopy.
Week 15	**Review and Final Project Presentation**