NE 487/ECE 730: Nanobiotechnology Systems and Microfluidics, [offered: W 2024]

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TA office hours: TBD
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Course Description

This course will provide students with an overall view of molecular biology and cover the basic principle of design and fabrication methods for biomedical devices which are the basis of modern nanobiotechnology systems. During the first two weeks of the course, students will acquire a basic molecular biology background about DNA, RNA and protein structure and their function in the body. Student will be familiarized with some of the conventional techniques used in the clinic for disease diagnosis such as ELISA (enzyme-linked immunosorbent assay) and then with the current state-of-the-art of technologies and lab-on-a-chip devices and biosensors developed to simplify and improve molecular and cellular diagnostic approaches. Students will learn about microfluidic systems which have been developed rapidly in recent years and emerge as a powerful tool in the field of biomedical engineering. During this course, we will discuss microfluidic device fabrication focusing on device design and cleanroom fabrication (soft lithography, hot embossing, micro-milling) and testing. COMSOL simulation will be presented for different microfluidic systems. At the end of the course, students will become conversant with the advances and design methods of nanobiotechnology that are used for medical diagnostics.

Pre-req: ECE 730-001

Assessment

- Assignment (15%)
- Course project: (Class presentation (40%) + Final project report (40%)) = 80%
- Class participation (5%)

Assignment

There is one assignment for the course, and it will be discussed in detail in class. Assignment will be uploaded on **Feb 9** (tentative); Submission Deadline: **Feb 18** (tentative). The assignment will have a simulation component.

Class presentation

Class presentation will be done in group. Your group (2-3 students; the exact number of group members will be determined on **Jan 28** after add/drop) should present one paper in the field of **microfluidic application for biomedical engineering** from top tier journals such as (nature nanotechnology, nature biomedical engineering, nature medicine, science, and etc.) in class. The presentation must include in detail introduction, methods, results, and analysis. Presenter must be

well-prepared to discuss the paper with other students. Presenter should include their opinion about the future direction of paper and what kind of experiments authors could have done to better articulate their message. The rest of the class should be prepared to challenge these views or offer alternative explanations or insights.

The group must pick a time from **March 9** to **April 4.** A google Excel sheet will be shared to set the time and title of papers. The group members and the paper should be finalized no later than **Feb 28**. The selection of time and papers is based on first come first serve.

Final project report

Final project is about a literature review and a proposal based on the application of microfluidics in biomedical engineering. Some examples of subjects are application of microfluidics in cancer diagnosis, organ on a chip systems, microfluidics for infectious disease diagnosis, paper-based microfluidics, and etc. The final project topic can be aligned with the paper that you select for presentation. For final project, you should submit a 10-page report. The final project should be also delivered in a group (the exact number of group members will be determined on **Jan 28** after add/drop). The topic and group members must be selected and finalized no later than **March 17**. Instructions to prepare the presentation and report will be posted on **March 21** and will be discussed in the class.

- Final report due: **April 13**

Late submission penalty

You will be penalized 10% from your final overall grade per 24-hour period past the deadline, to a maximum of the assigned value.

Class Syllabus

Week#1-2: Review of molecular biology (DNA, RNA, and Protein)

Weel#2-3: Molecular diagnostic tools: ELISA assays

Week#3: Nano-biosensors

Week#4: Introduction to Microfluidics (principle and fabrication) and RT-ELISA system

Week#5: Introduction to COMSOL

Week#6: Sorting & mixing in microfluidics + COMSOL simulation

Week 7: Microfluidic chain reaction of structurally programmed capillary flow events

Week#8-9: Guest lectures

Week#10 &11 & 12: Student presentation

* The content of lectures may be subject to change. I will make every effort to notify you of changes in advance.

Learning Outcomes

By the end of the term, the students will be able to:

1. Demonstrate a clear understanding of fundamentals of Molecular Biology, Nucleic Acids, DNA, RNA, and protein, and their transcription and hybridization
2. Develop more in-depth knowledge of proteins (aminoacids and peptides), their structure, side chains and folding, general functional classes
3. Understand the role of Hydrophobic and hydrophilic elements in protein structure as well as substrate ligands and enzymes
4. Demonstrate different molecular diagnostic techniques and ELISA
5. Design ELISA on a microfluidic chip
6. Develop a clear understanding of biosensors, bioreceptors, aptamers, and biomolecule immobilization on substrates
7. Apply Microfluidics into Biotechnology and biosensors design
8. Understand different fabrication methods of microfluidic devices for specific applications in mixing and sorting for cancer diagnosis application
9. Use numerical simulation software, COMSOL, to design the microchips
10. Select course projects for a wide range of microfluidic devices, from paper-based microfluidics to organ-on-a chip, disease modelling, and synthesis on chip
11. Devise cell sorting microfluidic chips using label-free microparticles
12. Select fitting advanced fabrication technique for the designed microfluidic device given the (bio) application and chip material
13. Demonstrate teamwork skills through the final project and methodology development and evaluation for the topic of the project

Exceptions and extensions

A University of Waterloo Verification of Illness Form (http://www.healthservices.uwaterloo.ca/Health_Services/verification.html) is required within one week if a student is sick and requests an exception. Any other exceptions to the above policies will require documentation and, wherever possible, considerable warning.

Academic integrity

Plagiarism, copying and other similar forms of intellectual dishonesty will be punished to the fullest extent of the appropriate University of Waterloo Student Academic Discipline Policies. The penalties can be quite severe and ignorance is rarely a good excuse. Please be advised to consult the new UW academic integrity website http://www.uwaterloo.ca/academicintegrity/Students/index.html for further details about expectations and possible penalties, and to contact the TA or myself for guidance. All cases of academic misconduct will be reported to the Department Chair and to the Dean of Engineering. There is no exception to this rule!