Medical Biophysics
UNIVERSITY OF TORONTO

MEDICAL BIOPHYSICS

COURSE MODULES

2018 – 2019

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Course Enrolment

To enroll in courses, students must request courses on ACORN/ROSI. Instructions are available at *http://medbio.utoronto.ca/content/course-enrolment*. Students who do not register (pay or defer fees) by the deadline will be removed from their course registration. Courses such as RST9999Y and the seminar course, MBP1015Y are preloaded and requests are not necessary. Students should check ACORN/ROSI to make sure they are enrolled in these two courses.

If students encounter difficulty when enrolling in their courses, they should contact either Donna (uptown students) or Annette (downtown students).

Withdrawing from a module

Students can withdraw from a module up until the end of the 3rd class or as long as no more than 50% of the module has been completed. While many instructors and programs consider it best practice to provide students with an interim evaluation of their performance in the course prior to the drop date, this is not a requirement for graduate courses (as per the University Assessment and Grading Practices Policy 2012).
To request withdrawal from a module, please email the Coordinator of the module and cc Chau Dang.

Policy for students receiving a failing grade in a module

Under the modular curriculum, students will enroll in 0.5 credit courses and select two modules for each course in which they enroll. The modules corresponding to a given course are chosen in advance and cannot be retrospectively reassigned to another course for the purpose of grading. The grade that a student receives in a course will be the average of the grades received for the two modules. In the case where a student receives a failing grade in a module (less than 70%), the grade for that course will be 'in progress'. To complete the course, the student will need to retake the module or, if that module is not offered the following year, another module. If the student passes this module, the initial failing grade will be ignored and the grade for the course computed normally. If the student fails the module (or its replacement) again, the student will be assigned a failing grade for the course.

Module availability

All biology stream modules will be offered in alternate years. A core set of physics stream modules is offered every year while more specialized topics will be offered in alternate years or based on student and faculty response to the new curriculum.

Module selection is available to students via *https://www.surveymonkey.com/r/TZ7N8H3*

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COURSE MODULES
2018 - 2019

Mandatory modules

Introductory Biostatistics	Sept.10 - Sept.14
Scientific Exposition and Ethics	Sept.14 - Nov.2

BIOLOGY	DATES
Cell Signaling & Metabolism	Sept.13 - Oct.25
Clinical & Experimental Radiobiology I & II	Apr.8 - Apr.12
Experimental Models for Cancer Research	Nov.1 - Dec.13
Predictive Oncology & Therapeutics	Mar.4 - Apr.29
Quantitative Cancer Genomics	Jan.10 - Feb.21
Structural Biology & Proteomics	Mar.7 - Apr.25

PHYSICS	DATES
Advanced Magnetic Resonance Imaging	Nov.7 - Dec.19
Advanced Ultrasound	Feb.27 - Apr.17
Biological Imaging	Mar.4 - Apr.29
Biophysics of Focused Ultrasound, Thermal Biophysics	Oct.30 - Dec.18
Cell and Molecular Biology for Physicists	Mar.7 - Apr.25
Introduction to Bio-Microscopies	Jan.15 - Feb.26
Introduction to Biophotonics	Mar.8 - Apr.26
Magnetic Resonance Imaging - Overview	Mar.5 - Apr.23
Medical Device Commercialization Essentials	Sept.13 - Dec.6
Medical Device Innovation and Entrepreneurship	Sept.6 - Nov.29
Nanotechnology for Medicine	Jan.16 - Feb.27
Overview of Medical Imaging	Sept.12 - Oct.24
Ultrasound Overview	Jan.11 - Feb.22

PLANNED COURSE MODULES
2019 - 2020

Mandatory modules

Introductory Biostatistics
Scientific Exposition & Ethics

BIOLOGY
Cancer Immunotherapy
Clinical & Experimental Radiobiology I & II
Development, Stem Cells and Cancer
Epigenetics
Radiation Biology and DNA Repair
Tumour Microenvironment

PHYSICS
Advanced Ultrasound
Biological Imaging
Introduction to Biophotonics
Biophysics of Focused Ultrasound
Cell Biology for Physical Scientists
Clinical Imaging for Physical Scientists
Introduction to Bio-Microscopies
Magnetic Resonance Imaging - Overview
Medical Device Innovation and Entrepreneurship
Overview of Medical Imaging
Ultrasound Overview

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List of Modules 2018 - 2019

Fall 2018

Advanced Magnetic Resonance Imaging

Biophysics of Focused Ultrasound, Thermal Biophysics

Cell Signaling & Metabolism

Experimental Models for Cancer Research

Introductory Biostatistics - MANDATORY

Medical Device Innovation and Entrepreneurship

Medical Device Commercialization Essentials

Overview of Medical Imaging

Scientific Exposition and Ethics - MANDATORY

Winter 2019

Advanced Ultrasound

Biological Imaging

Cell and Molecular Biology for Physicists - Introduction

Clinical & Experimental Radiobiology I & II

Introduction to Bio-Microscopies

Introduction to Biophotonics

Magnetic Resonance Imaging - Overview

Nanotechnology for Medicine

Predictive Oncology & Therapeutics

Quantitative Cancer Genomics

Structural Biology & Proteomics

Ultrasound Overview

NOTE: Should there be insufficient enrolment in any of the above modules, it will be offered the following year

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Fall 2018		
Topic	**Advanced Magnetic Resonance Imaging**	
Coordinator	Dr. Charles Cunningham	
Day & Time	Wednesdays, 12:30 – 2:30 pm	
Location	Sunnybrook, 2075 Bayview Ave. M-Wing, M6-620	
Recommended Prerequisites	Overview of Medical Imaging, Magnetic Resonance Imaging – Overview	
Module Goals	To gain an advanced understanding of how MRI works	
Evaluation Method	Assignments only	
Schedule		
Date	**Instructor**	**Lecture**
November 7	Charles Cunningham	Phase encoding, frequency encoding, hybrids, RF pulses
November 14	Christopher Macgowan	Effects of motion, ghosting, motion compensation methods (e.g., gradient moment nulling, navigators, fast imaging).
November 21	Christopher Macgowan	Phase contrast and flow (2D & 4D), non-contrast angio, myocardial tagging, clinical implementation
November 28	Giles Santyr	MRI Contrast Mechanisms, endogenous and exogenous
December 5	Giles Santyr	paramagnetic, susceptibility-based, CEST contrast, magnetization transfer, hyperpolarized agents
December 12	Philip Beatty	Image reconstruction - non-cartesian sampling and gridding
December 19	Philip Beatty	Multi-channel signal acquisition and image reconstruction

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Fall 2018		
Topic	**Biophysics of Focused Ultrasound, Thermal Biophysics**	
Coordinator	Dr. Meaghan O'Reilly	
Day & Time	Tuesdays, 12:30 – 2:30 pm	
Location	Sunnybrook, 2075 Bayview Ave. C-Wing C736A	
Recommended Prerequisites	NONE	
Module Goals	Focused ultrasound can induce both thermal and non-thermal effects in biological tissues. These biophysical interactions form the basis of a range of therapeutic applications in current medical practice and in leading-edge research. The first half of this course will focus on thermal biophysics, drawing examples from focused ultrasound therapy as well as from other thermal modalities, such as radiofrequency and microwave. The physical and biophysical interaction mechanisms between the energy sources and tissue will be emphasized. Fundamentals of thermal dosimetry will be covered, with reference to the relevant tissue properties, the models of energy propagation within tissues, experimental techniques for dosimetry measurements, and the resulting biological effects. In the second half of this course non-thermal bioeffects of focused ultrasound will be examined. The physical mechanisms behind these mechanical effect will be covered, with an emphasis on cavitation and cavitation-mediated effects. Treatment monitoring considerations for non-thermal therapies will be discussed. The current status of thermal medicine and of focused ultrasound therapies will be reviewed using select clinical and pre-clinical examples.	
Evaluation Method	Exam	
Schedule		
Date	**Instructor**	**Lecture**
October 30	Meaghan O'Reilly	Biology/Rationale/Nomenclature
November 6	*No Lecture*	
November 13	Meaghan O'Reilly	Blood Flow/Modelling/Energy Delivery
November 20	Meaghan O'Reilly	Energy Delivery(Cont'd)/Thermometry/Treatment Monitoring
November 27	Meaghan O'Reilly	Non-Thermal Mechanisms of Ultrasound/Bioeffects
December 4	Meaghan O'Reilly	Cavitation/Cavitation Nucleating Agents
December 11	Meaghan O'Reilly	Treatment Monitoring for Non-Thermal Therapies
December 18	**Exam**	

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Fall 2018			
Topic	**Cell Signaling & Metabolism**		
Coordinators	Drs. Jane McGlade & Vuk Stambolic		
Day & Time	Thursdays at 9:00 am – 11:00 am		
Location	Princess Margaret Cancer Centre (PMCC), 610 University Avenue Princess Margaret Cancer Research Tower (PMCRT), 101 College Street		
Recommended Prerequisites	NONE		
Module Goals	This module will cover a spectrum of topics in cell biology and biochemistry, including cell-to-cell communication, sensing of extracellular signals, surface receptors as signaling modalities, second messengers, modular architecture of proteins, post-translational modifications as instructive signals, intracellular signal transduction and signaling pathways, effectors of signaling pathways, protein stability and turnover. The module will also encompass a series of themes in cellular metabolism, including cellular energetics, nutrient transport and utilization, plasticity in metabolic networks, cellular metabolism in disease and the interface between cell signaling and cell metabolism. The use of model systems in the study of signaling and metabolism, as well as methodologies for cell signaling research will be discussed. The students should expect to get an advanced understanding of signaling networks and metabolic pathways and knowledge of means for their interrogation.		
Evaluation Method	Students will be evaluated based on a written summary, analysis and critique of a research article related to one of the topics covered in the module. The course coordinators will provide a list of articles to chose from at least two weeks before the due date.		
Schedule			
Date	**Instructor**	**Location**	**Lecture**
September 13	David Andrews	PMCC - Rm 7-605	Cell Death Signalling
September 20	Jorge Filmus	PMCC - Rm 7-605	Wnt and Hedgehog Signalling Pathways
September 27	Vuk Stambolic	PMCC - Rm 7-605	Obesity and Cancer Signaling
October 4	Linda Penn	PMCC Rm - 6-702/703/704	Tumour Metabolism and the Mevalonate Pathway
October 11	Robert Rottapel	PMCC - Rm 7-605	Receptor Tyrosine Kinases
October 18	Mitsu Ikura	PMCC - Rm 7-605	Ras/MAPK signalling
October 25	Gairdner Symposium	PMCRT - Rm 4-204	Optogenetics

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Fall 2018		
Topic	**Experimental Models for Cancer Research**	
Coordinator	Drs. Laurie Ailles & Shane Harding	
Day & Time	Thursdays at 9:00 am – 11:00 am	
Location	PMCRT, 101 College Street, Room 4-204	
Recommended Prerequisites	NONE	
Module Goals	We will discuss the various model systems used in cancer research, including in vitro models, mouse models, and others as well as models with a specific focus (e.g. metastasis models). There will be an emphasis on the pros and cons of each and the importance of using the correct model for the specific research question. There will be an introductory lecture, then the students will select and present/critique papers that exemplify the best (or worst) use of different types of models. The course evaluation will be based on presentations and a written assignment.	
Evaluation Method	The course evaluation will be based on presentations and a written assignment	
Schedule		
Date	**Instructor**	**Lecture**
November 1	Laurie Ailles & Shane Harding	Experimental Models for Cancer Research
November 8	Laurie Ailles & Shane Harding	Student presentations of selected papers
November 15	Laurie Ailles & Shane Harding	Student presentations of selected papers
November 22	Laurie Ailles & Shane Harding	Student presentations of selected papers
November 29	Laurie Ailles & Shane Harding	Student presentations of selected papers
December 6	Laurie Ailles & Shane Harding	Student presentations of selected papers
December 13	Laurie Ailles & Shane Harding	Student presentations of selected papers

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Fall 2018		
Topic	**Introductory Biostatistics - MANDATORY**	
Coordinator	Dr. Jason Lerch	
Day & Time	Week of September 10	
Location	Please note various locations below	
Recommended Prerequisites	Required module – no prerequisites	
Module Goals	This course will serve as a rapid introduction to probability and statistical thinking. Students will gain a thorough understanding of how statistical inference is conducted and will, by the end of the course, be able to critically assess our use of statistics in the search for scientific truths. It will be organized as an intense one week "statistics boot-camp", with a significant emphasis on applied problem solving in small groups.	
Evaluation Method	Small group applied problem solving, short quizzes daily, short presentations and an exam at the end.	
Schedule		
Date	**Various Locations**	**Lecture**
Mon. Sept 10 **9 am – 3 pm**	**Morning:** Princess Margaret Cancer Centre, 610 University Avenue. In the mornings (9 am - 12 noon), we will be in the 6th floor Auditorium (Room 6-604). **Afternoon:** TGH: Medical Education Department 200 Elizabeth Street, Eaton ground floor, Seminar Room 1 & 2	Introduction. Data organization, introduction to R, descriptive statistics, plotting, basic linear models.
Tues. Sept. 11 **9 am – 3 pm**	**Morning:** Princess Margaret Cancer Centre, 610 University Avenue. In the mornings (9 am - 12 noon), we will be in the 6th floor Auditorium (Room 6-604). **Afternoon:** PMCRT, 101 College Street, Room 4-204	Probability in all its glory. Multiple linear models, interactions, p values, multiple comparisons.
Wed. Sept. 12 **1 pm – 4 pm**	Princess Margaret Cancer Centre, 610 University Avenue, Room 7-605	Hypothesis testing, searching for truth, and the crisis of replicability
Thurs. Sept 13 **1 pm – 4 pm**	Princess Margaret Cancer Centre, 610 University Avenue, Room 7-605	Introduction to Bayesian statistics. Review.
Fri. Sept 14 **9 am – 12 pm**	Princess Margaret Cancer Centre, 610 University Avenue, Room 6-604	**Exam**

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Fall 2018		
Topic	**Medical Device Innovation and Entrepreneurship**	
Coordinators	Drs. Graham Wright; Brian Courtney; Ahmed Nasef	
Day & Time	Thursdays at 5:00 PM – 6:00 PM 13 weeks starting September 6 to November 29, inclusive Lectures will also be webcast and available for review	
Location	Sunnybrook Health Sciences Centre 2075 Bayview Ave. Lecture Theatre M6-502	
Recommended Prerequisites	No prerequisites.	
Module Goals	Innovations in Medical technology have led to revolutionary advancements in health care. As new devices and technologies are developed, patients are benefiting from more targeted, less invasive treatments. However, new standard of care technologies won't reach the bedside unless inventors have the skills to bring them to market. The Medical Device Innovation and Entrepreneurship course is an opportunity to explore and navigate the principles underlying the challenges of medical device development. The course is designed to engrain the key mindsets and skill sets that help make successful medtech entrepreneurs. The course addresses the fundamental aspects from developing an idea to commercial success, enabling students to gain knowledge of the role of intellectual property management, regulatory pathways, reimbursement mechanisms, funding models, and business strategy in the successful commercialization of new medical device technologies. The course is delivered using a mix of lectures, guest speakers, team projects, recommended readings and online learning materials. In addition, students get the opportunity to network with local experts and thought leaders in the medtech field. The module is recommended for students who would like to: (1) catalyze innovation in major medtech companies; (2) build their own medtech start-ups; (3) draw on world-class innovative research conducted in Canadian universities, research institutes and hospitals; and (4) lead translational research projects.	
Evaluation Method	Group presentations on clinical need, market and stakeholder analysis, prior art, and preliminary concept with associated regulatory and reimbursement plans for identified clinical need (+ Participation in weekly lectures)	
Schedule		
Date	**Instructor**	**Lecture**
September 6	Graham Wright	Orientation *starts at 4:00 pm at location - S615*
September 6	Ryan Van Wert	The Biodesign Process: From Needs Finding to Commercialization
September 13	William Mitchell & Brian Lewis	The Medical Devices Industry in Canada: Industry Insights and Strategic Trends
September 20	Nick Kuryluk	Market Research & Analysis
September 27	Harold Wodlinger	Business Modelling in Medtech
October 4	Steve Leonard	An Introduction to Patenting
October 11	Shahira Bhimani	Reimbursement Basics

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October 18	TBD	Ideation & Brainstorming in Biomedical Technology Invention
October 25	Frank Shannon	The ABCs of Medical Technology Regulation
November 1	John Walmsley	Medical Device Design + Group Presentations
November 8	Jane Cooke-Lauder	The Art of the Pitch
November 15	Stefano Picone	Medtech Start-ups: Valuations, Cap Tables, Cash Flow Budgeting, and Financial Models
November 19 2:00 – 5:00pm	Stefano Picone	Fundamentals of Medical Device Finance
November 22	Pamela Winsor	Marketing & Sales Strategy
November 29	Marian Petelycky	Medtech Quality and Process Management

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Fall 2018		
Topic	**Medical Device Commercialization Essentials**	
Coordinators	Dr. Graham Wright, Dr. Brian Courtney, Dr. Ahmed Nasef	
Day & Time	Thursdays at 6:15 PM – 8:00 PM 9 weeks starting September 13 to November 15. Final report due Dec.6	
Location	Sunnybrook Health Sciences Centre 2075 Bayview Ave. Lecture Theatre M6-502	
Recommended Prerequisites	Medical Device Innovation & Entrepreneurship is a co-requisite (must be taken at the same time)	
Module Goals	Not all medical device innovations will make it into patient care. Without a compelling, accessible market, a sustainable business model and operating plan, a well-thought-out plan for acquiring and managing intellectual property, and strong regulatory and reimbursement strategies, even the seemingly most important medical innovations are unlikely to be commercialized. The Medical Device Commercialization Essentials course complements the Medical Device Innovation and Entrepreneurship module and provides students with an experiential connection to the process of commercializing novel medical discoveries. The course focuses on systematic examination of issues and factors that directly affect the financial viability and sustainability of a medical device innovation and impact the innovator's ability to successfully commercialize a solution. The delicate and frequently conflicting interplay between intellectual property, regulatory environment, reimbursement mechanisms, business strategy and financial modelling are explored with hands-on exercises and interactive workshops. The module is recommended for students who would like to: (1) catalyze innovation in major medtech companies; (2) build their own medtech start-ups; (3) draw on world-class innovative research conducted in Canadian universities, research institutes and hospitals; and (4) lead translational research projects.	
Evaluation Method	Group assignment: High-level report/preliminary business plan for a potential medical device solution including technology overview, market opportunity, industry analysis, business model/value proposition, and associated preliminary IP and reimbursement strategies. (+ Participation in workshops)	
Schedule		
Date	**Instructor**	**Lecture**
September 13	William Mitchell & Brian Courtney	The Medical Devices Industry in Canada: Start-up Strategy
September 20	Nick Kuryluk	Market Segmentation & Competitive analysis Workshop
September 27	Nilay Goyal	Business Model Canvas
October 4	Steve Leonard	IP Strategy Bootcamp
October 11	Shahira Bhimani	Reimbursement Strategy
October 18	TBD	Design Thinking Workshop
October 25	Frank Shannon	Regulatory Strategy Workshop

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November 8	Jane Cooke-Lauder	The Essential Elements of a Sound Business Case
November 19 2:00-5:00pm	Stefano Picone	Medtech Start-ups Financing Workshop
December 6	**No class, Final Report due**	

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Fall 2018		
Topic	**Overview of Medical Imaging**	
Coordinators	Dr. John G. Sled	
Day & Time	Wednesdays, 9:30 – 11:30 am	
Location	Sunnybrook, 2075 Bayview Ave. Room SG22	
Recommended Prerequisites	Students are expected to have a foundation in undergraduate level mathematics including differential and integral calculus, complex numbers, linear algebra, and probability theory. Students entering from an engineering or physics undergraduate program will likely need no additional preparation. Students from another discipline may need additional preparation and should contact the module coordinator well in advance as to whether self-directed reading prior to the module start is recommended.	
Module Goals	This module provides the mathematical preliminaries of medical imaging and introduces concepts of image formation, inverse problems, stochastic processes and instrument performance that are common to many medical imaging modalities. An introduction and historical perspective on the major medical imaging technologies is also presented. This course is a recommended prerequisite for many the imaging modules offered by MBP including those on MRI and ultrasound.	
Evaluation Method	Exam (70%) and lab report (30%)	
Schedule		
Date	**Instructor**	**Lecture**
September 12	Martin Yaffe	Introduction to Medical Imaging: a brief history
September 19	John G. Sled	Linear Systems and Fourier Transform Theory I
September 26	John G. Sled	Linear Systems and Fourier Transform Theory II
October 3	John G. Sled	X-rays and Projection
October 10	John G. Sled	Tomography and Inverse problems
October 17	James Mainprize	X-ray CT lab (may need to be scheduled on multiple days to accommodate the number of lab groups)
October 24	**Exam**	

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Fall 2018		
Topic	**Scientific Exposition and Ethics - MANDATORY**	
Coordinators	Drs. David Malkin & Jim Woodgett	
Day & Time	Friday 2:00 – 4:00 pm	
Location	PMCRT, 101 College Street, Room 4-204	
Recommended Prerequisites	NONE	
Module Goals	Scientific exposition, discourse and ethics are fundamental principles to the conduct of responsible basic, translational and clinical research. This course will use a combination of didactic lectures and interactive group discussion to explore key elements of these principles under the broad headings of: 1) Principles of Ethical Conduct and Protection of Research Subjects; 2) Scientific Fraud, Plagiarism and Data Misrepresentation – Flagrant and Unintended; 3) Privacy and Confidentiality in the Genome Era (Data Sharing/Validation/Clinical Translation); and 4) Authorship Responsibility in the Spirit of Collaboration and Intellectual Property Protection. The format of each lecture will be both didactic, with the lecturer discussing fundamental issues and principles relevant to the topic, and interactive with opportunity for open discussion of a foundational aspect of the subject being addressed in the lecture.	
Evaluation Method	End of course exam with a combination of short- and long- answer questions based on information discussed in the lectures, and supplemented with materials provided by the lecturers, and an end-of-course assignment which will be an essay discussing one aspect of the course – topics provided by the course co-directors. The 'exam' will count for 50% of the final mark and the in-class problem/discussion session will count for 50%.	
Schedule		
Date	**Instructor**	**Lecture**
September 14	Stephen Scherer	Privacy and Confidentiality in the Genome Era (Data Sharing/Validation/Clinical Translation)
September 21	Elizabeth Stephenson	Principles of Ethical Conduct and Protection of Research Subjects
September 28	David Malkin	Authorship Responsibility in the Spirit of Collaboration and Intellectual Property Protection
October 5	Ivan Toposirovic	Biomedical Research: Ethos, Logos... and Pathos (on research misconduct)
October 12	*No Lecture*	
October 19	Jim Woodgett	Research Ethics: Responsibilities and Best Practices
October 26	Jim Woodgett & David Malkin	Problem-Based Discussion – class participation
November 2	**Exam**	

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Winter 2019		
Topic	**Advanced Ultrasound**	
Coordinator	Dr. David Goertz	
Day & Time	Wednesdays, 12:30 – 2:30 pm	
Location	Sunnybrook, 2075 Bayview Ave. S-Wing S-615	
Recommended Prerequisites	Ultrasound Overview module or its equivalent.	
Module Goals	This module builds upon the introductory material covered in the Ultrasound Overview course and is intended to provide a more substantial foundation for students pursuing thesis research involving biomedical ultrasound. Linear and nonlinear wave interactions with tissue will be covered, along with their implications for imaging and therapeutic applications. Selected topics will then be presented, including transducer principles of design and fabrication, advanced beamforming methods, cavitation and contrast agents.	
Evaluation Method	Exam	
Schedule		
Date	**Instructor**	**Lecture**
February 27	David Goertz	Wave interactions with tissue
March 6	David Goertz	Wave interactions with tissue
March 13	David Goertz	Beamforming
March 20	David Goertz	Transducers
March 27	David Goertz	Cavitation and contrast agents
April 3	David Goertz	Selected Topics
April 10	*No Lecture*	
April 17	**Exam**	

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Winter 2019		
Topic	**Biological Imaging**	
Coordinators	Drs. Brian Nieman & Chris Macgowan	
Day & Time	Mondays 10:00 am to 12:00 pm	
Location	PMCRT, 101 College Street, Room 15-710	
Recommended Prerequisites	NONE	
Module Goals	The first goal of the module is to develop an understanding of how imaging can be used to probe important questions in biology. A series of topics will address: (1) the knowledge gaps in a recent area of research where imaging proved beneficial; (2) the methodological developments and advances required to address those gaps; and (3) how imaging advanced our knowledge of the field. The second goal of the module is to become familiar with grant proposals and application processes. Each lecture will be paired with reading from a successful grant application. Grantsmanship insights, strategies and pitfalls will be discussed. Through the module, students will generate their own project ideas, participate in peer feedback, and craft their own short proposals.	
Evaluation Method	Students will be asked to write a short grant proposal on a novel project to answer a question in biology using state of the art imaging. In addition, there will be marks for course participation.	
Schedule		
Date	**Instructor**	**Lecture**
March 4	Brian Nieman	Module introduction, Lecture 1
March 11	John Rubinstein	Lecture 2
March 18	John Sled	Lecture 3
March 25	Brian Nieman & Chris Macgowan	Grant Pitches
April 1	Chris Macgowan	Lecture 4
April 8	*No Lecture*	
April 15	Brian Nieman Chris Macgowan	Peer Review of Grant Proposals
April 22	*Easter weekend*	
April 29	Final Grant Proposals Due, Module Feedback	

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Topic	Cell and Molecular Biology for Physicists - Introduction
Coordinators	Drs. Margarete Akens and Arash Zarrine-Afsar
Day & Time	**Thursdays, 12:00 – 2**:00 **pm**
Location	PMCRT, 101 College Street, Room 14-203
Recommended Prerequisites	**NONE**
Module Goals	This course introduces physical scientists to the basic concepts of anatomy, cell molecular and cancer biology. Recent advances in DNA, RNA, metabolomics and protein technologies will also be discussed (omics approaches). The course will stress breadth rather than depth and is designed to introduce physical scientists whose research impinges on biology to the concepts and methodologies of molecular biology.
Evaluation Method	75% Final exam; 25% Participation

Schedule

Date	Instructor	Lecture
March 7	M. Akens/A.Zarrine-Afsar	Cell and developmental biology
March 14	M. Akens	Basic anatomy and visualization techniques
March 21	T. Pugh	Cancer genomics and transcriptomics to guide patient care
March 28	D. Hill	Interventional radiobiology and tumour microenvironment
April 4	M. Rauth	Signal transduction
April 11	*No lecture*	
April 18	A. Zarrine-Afsar	Proteomics, metabolomics and molecular analysis of tissues
April 25	Evaluation (Classroom exam)*	

The final exam will be a classroom test. Each lecturer will provide one set of questions to evaluate mastery of the content.

Recommended background reading: Information will be supplied closer to the course.

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Winter 2019	
Topic	**Clinical & Experimental Radiobiology I & II**
Coordinator	Dr. Marianne Koritzinsky
Day & Time	April 8 - 11, 8:45 am – 5:00 pm and Apr 12 8:45 am – 12:30pm
Location	McLennan Physical Laboratory, 60 St. George Street, Room MP 137 (Apr. 8-10, 12) Room MP 134 (Apr. 11)
Recommended Prerequisites	The suggested textbook for this course is Basic Clinical Radiobiology, Fourth Edition. It is strongly recommended that you read this book before attending the course.
Module Goals	This program provides a comprehensive overview of radiation biology with a particular emphasis on aspects of direct relevance to the practice of radiation oncology. It addresses the molecular and cellular responses to radiation-induced damage that influence cell death in both tumors and normal tissues. Quantitation of radiation effects and the underlying biological basis for fractionation of radiotherapy and dose-response relationships in the clinic are covered in depth. The biological basis for current approaches to improve radiotherapy will be described including novel fractionation schemes, retreatment issues, targeting hypoxia, biological modifiers and combined radiotherapy/chemotherapy. Suggested textbook for this topic is: https://www.amazon.ca/Clinical-Radiobiology-Fourth-Michael-Joiner/dp/0340929669/ref=sr_1_5?ie=UTF8&qid=1465580914&sr=8-5&keywords=clinical+and+radiobiology This topic is also offered through the Department of Radiation Oncology to residents in radiation oncology and physics, as well as other radiobiology researchers.
Evaluation Method	Exam (100% of the grade) on April 24, 9 am – 12 pm, location TBA
Schedule	

MONDAY APRIL 8, 2019

Time		Lecture	Faculty speakers
8:45-9:00		*Coffee served*	
9:00-9:30	0	Introduction to course	Marianne Koritzinsky
9:30-10:15	1	Importance of radiobiology in the clinic	Scott Bratman
10:15-10:30		*Break*	
10:30-11:15	2	Hallmarks of cancer	Marianne Koritzinsky
11:15-12:00	3	Radiation induced damage and the DNA damage response	Brad Wouters
12:00-1:00		*Lunch*	
1:00-1:30	T1	Tutorial and Question period (L2,3)	Marianne, Brad
1:30-2:15	4	Molecular basis of cell death	Brad Wouters
2:15-3:00	5	Cell survival - in vitro and in vivo	Bert van der Kogel
3:00-3:15		*Break*	
3:15-4:00	6	Quantifying cell kill and cell survival	Mike Joiner
4:00-5:00	T2	Tutorial and Question period (L4,5,6)	Brad, Bert, Mike

TUESDAY APRIL 9, 2019

Time		Lecture	Faculty speakers
8:45-9:00		*Coffee served*	
9:00-9:45	7	LET and RBE	Dick Hill
9:45-10:30	8	Particles in radiotherapy	Mike Joiner

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10:30-10:45		*Break*	
10:45-11:15	T3	Tutorial and Question period (L7,8)	Dick, Mike
11:15-12:00	9	Dose response relationships in radiotherapy - TCP, NTCP, therapeutic ratio	Mike Joiner
12:00-1:00		*Lunch*	
1:00-1:45	10	The linear-quadratic approach to fractionation	Mike Joiner
1:45-2:15	T4	Tutorial and Question period (L9,10)	Soren, Mike
2:15-2:30		*Break*	
2:30-3:30	11	Modified fractionation schedules (and limits)	Scott Bratman
3:30-3:45	T5	Tutorial and Question period (L11)	Scott Bratman
3:45-5:00	W	The LQ-model workshop	Mike Joiner and Marianne Koritzinsky

WEDNESDAY APRIL 10, 2019

Time		Lecture	Faculty speakers
8:45-9:00		*Coffee served*	
9:00-9:30	12	Dose rate effect - intro to RB concepts	Bert van der Kogel
9:30-10:15	13	Clinical radiobiology of brachytherapy	Gerard Morton
10:15-10:45	T6	Tutorial and Question period (L12,13)	Bert, Gerard
10:45-11:00		*Break*	
11:00-11:45	14	Pathogenesis of normal tissue side effecets	Shun Wong
11:45-12:30	15	The volume effect in radiotherapy	Bert van der Kogel
12:30-1:30		*Lunch*	
1:30-2:15	16	Retreatment tolerance of normal tissues	Shun Wong
2:15-3:00	T7	Tutorial and Question period (L14-16)	Shun, Bert
3:00-3:15		*Break*	
3:15-4:00	17	Stromal effects	Stan Liu
4:00-4:45	18	Tumor growth, stem cells, and response to irradiation	Stan Liu
4:45-5:00	T8	Tutorial and Question period (L17-18)	Stan

THURSDAY APRIL 11, 2019

Time		Lecture	Faculty speakers
8:45-9:00		*Coffee served*	
9:00-9:45	19	Radiation-induced malignancies	David Hodgson
9:45-10:00		Tutorial	David
10:00-11:00	20	Oxygen effect and tumor microenvironment	Marianne Koritzinsky
11:00-11:15	T9	Tutorial	Marianne
11:15-11:30		*Break*	
11:30-12:15	21	Stereotactic and high dose radiotherapy	Arjun Saghal
12:15-12:30	T10	Tutorial and Question period (L21)	Arjun
12:30-2:00pm		*Lunch*	
2:00-2:45	22	Clinical approaches to target hypoxia	Kathy Han
2:45-3:30	23	Predictive biomarkers and patient individualization	Scott Bratman
3:30-4:00	T11	Tutorial and Question period (L22,23)	Kathy, Scott

FRIDAY APRIL 12, 2019

Time		Lecture	Faculty speakers
8:45-9:00		*Coffee served*	
9:00-9:45	25	Combined radiotherapy and chemotherapy	Andrew Hope
9:45-10:30	26	Biological response modifiers in tumors – concepts	Marianne Koritzinsky
10:30-10:45		*Break*	

10:45-11:30	27	Biological response modifiers in tumors – clinical implementation	Alejandro Berlin
11:30-12:00	T13	Tutorial and Question period (25-27)	Andrew, Marianne, Alejandro
12:00-12:30		Concluding remarks	Marianne

Medical Biophysics
UNIVERSITY OF TORONTO

Winter 2019		
Topic	**Introduction to Bio-Microscopies**	
Coordinator	Dr. Brian Wilson	
Day & Time	Tuesdays at 9:00 am – 11:00 am	
Location	Princess Margaret Cancer Centre, 610 University Avenue, Room 7-605	
Recommended Prerequisites	NONE	
Module Goals	Various forms of microscopy are widely used in biomedical research as well as in clinical medicine. Major classes of microscopy include: A) optical microscopy (wide-field, fluorescence, laser-scanning confocal, Raman, bioluminescence, near-field, super-resolution, non-linear, light-sheet, intravital), together with a variety of fluorescent and other probes (dyes, fluorescent proteins, small-molecules); B) electron microscopy, in both transmission and surface-scanning modes and: C) scanning-probe microscopy (atomic force, scanning tunneling, near-field). The goal of this Module is to introduce the basic physical principles of the different forms of microscopy and survey the different techniques, instruments and probes used in studying bio-specimens (cells, tissues, biomaterials), illustrating these with examples of biomedical applications. The role of digital techniques and image processing/analysis will be considered. Hands-on experience in microscopy will take place at the Advanced Optical Microscopy Facility (AOMF).	
Evaluation Method	Multiple-choice examination	
Schedule		
Date	**Instructor**	**Lecture**
January 15	Brian Wilson	Introduction and Optical Microscopies-I
January 22	Brian Wilson Chris Yip	Optical Microscopies-IIa Scanning Probe microscopy
January 29	Brian Wilson John Rubenstein	Optical Microscopies-IIb Electron Microscopy
February 5	Brian Wilson	Optical Microscopies-III
February 12	Brian Wilson Sergio Grinstein	Microscopy Image Processing & Analysis Biology Applications of Microscopy
February 19/20	AOMF	Hands-On Lab
February 26	**Exam**	

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Winter 2019	
Topic	**Introduction to Biophotonics**
Coordinators	Drs. Alex Vitkin & Lothar Lilge
Day & Time	Fridays, 10:00 am – 12:00 noon
Location	PMCRT, 101 College St, Room 14-203
Recommended Prerequisites	NONE
Module Goals	The use of light in medical diagnostics, therapeutics and biomedical research is increasing, driven by the advent of new light sources, inexpensive imaging detectors, advanced fiber-optic delivery systems, better understanding of light-tissue interactions, and proven clinical and research applications. The course will focus mostly on in vivo photonics and initially cover (1) the relevant issues of light propagation in / interaction with turbid media such as tissue. The bulk of the course will focus on (2) particular technical implementations and research / pre-clinical / clinical results in photo-diagnostics (effects of tissue on light) and photo-therapeutics (effects of light on tissue). Advanced topics such as (3) molecular imaging, nanophotonics, optical clearing and theragnostics will also be briefly covered. As such, the course goals include basic competencies in these there [(1)-(3)] areas.
Evaluation Method	Class participation and short oral exit exam

Schedule

Date	**Instructor**	**Lecture**
March 8	Alex Vitkin	Basic biophotonics – light propagation in tissue is the physical basis of all optical therapeutic and diagnostic approaches. Photon-tissue interactions, tissue optical properties, fundamentals of photodiagnostics and phototherapeutics are explained. Analytical and statistical approaches for quantifying light transport in tissue will be discussed, including (Maxwell's equations, transport / diffusion theory and statistical Monte Carlo methods.
March 15	Lothar Lilge	Diagnostic spectroscopy techniques are explained based on the spectral information content of the biological tissue and or biomarkers. These include diffuse reflection, fluorescence and Raman spectroscopy Extensions are towards hyperspectral imaging Raman based imaging techniques. Impact is exemplified by clinical studies or common clinical procedures.

March 22	Alex Vitkin	Diagnostic imaging, discussions of resolution, contrast, turbidity, imaging depth issues. High resolution diagnostics including optical coherence imaging, photoacoustics, optical projection tomography, confocal and multi-photon techniques; low(er) resolution approaches including diffuse optical imaging
March 29	Lothar Lilge	Photo-therapeutics based on non-thermal interactions (photo bio-modulation therapy, photodynamic therapy). This lecture will emphasis the need for accurate dosimetry to maximize therapeutic efficacy
April 5	Lothar Lilge	Photo-therapeutics based on temporally-controlled (rapidly pulsed) laser delivery, including photo-ablation and selective photothermolysis.
April 12 **Start Time (1 – 3pm)**	Alex Vitkin	Selected advanced topics such as nanophotonics, molecular imaging, optical clearing and theragnostics
April 26	**Oral exit exam**	
NOTE: Changes in the sequence of the lectures may occur and an update will be posted in early February.		

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Winter 2019		
Topic	**Magnetic Resonance Imaging - Overview**	
Coordinators	Drs. Jean Chen & Mihaela Pop	
Day & Time	Tuesdays, 12:30 – 2:30 pm	
Location	Sunnybrook, 2075 Bayview Ave. S-Wing S-615	
Recommended Prerequisites	A foundation in signals and systems theory and Fourier transforms is required. Students are strongly advised to take Overview of Medical Imaging prior to this module.	
Module Goals	Since development of the first hospital-grade systems in the 1980s, magnetic resonance imaging (MRI) continues to make a profound impact on how physicians evaluate soft tissues within the human body. This course provides students with an overview of MRI technology covering the underlying physical principles of signal generation, signal contrast mechanisms, process of image formation, and basic instrumentation. The course is a prerequisite for students who subsequently wish to take Advanced Topics in MRI.	
Evaluation Method	Lab (40 %) and Exam (60 %)	
Schedule		
Date	**Instructor**	**Lecture**
March 5	Jean Chen	Basic Physics 1
March 12	Jean Chen	Basic Physics 2
March 19	Brian Nieman	Imaging Physics 1
March 26	Brian Nieman	Imaging Physics 2
April 2	Mihaela Pop	Laboratory
April 9	*No Lecture*	
April 16	Mihaela Pop	Instrumentation
April 23	No Lecture	
April 30	**Exam**	

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Winter 2019		
Topic	**Nanotechnology for Medicine**	
Coordinator	Dr. Gang Zheng	
Day & Time	Wednesdays, 12:30 – 2:30 pm	
Location	PMCRT, 101 College St, Room 12-710 Feb 27 class will be held at 9:00 – 11:00 am PMCRT Room 15-710	
Recommended Prerequisites	NONE	
Module Goals	This course is not a basic survey, but a critical and timely analysis of the current state of the nanomedicine field, how it has become incorporated in to multiple disciplines, and the factors that must be considered for its future progress and successful clinical implementation. The course will begin with an introduction to nanotechnology, the unique physical properties that define nanoscale materials, and the state of art techniques to study the nanobiointerface. The course will focus on the design considerations for nanoparticles will be considered through a discussion of how they interface with biology, which make them advantageous additions to the toolkit of agents for disease diagnosis and therapy. The course will then progress to sophisticated approaches for nanomedicine applications. Finally, the course will conclude by covering challenges and opportunities in translation of nanomedicines to the clinic.	
Evaluation Method	Each student will produce a written report of a topic covered in the course but unrelated to their thesis project plus an oral presentation on the March 1st class. Format: journal mini-review style, max. 5 pages (1.5 space, pt 12 font) with one figure plus references. Evaluation criteria will be heavily weighted on quality of analysis. The grade will be a combination of attendance and participation (10%),written report (70%) and oral presentation (20%).	
Schedule		
Date	**Instructor**	**Lecture**
January 16	Warren Chan	Nanomedicine Intro
January 23	Gilbert Walker	Physical Properties Unique to Nanoscale Materials
January 30	Christopher Yip	State of Art Techniques to Study NanoBioInterface
February 6	Shana Kelly	Nanodiagnosis
February 13	Shirley Wu	Nanoparticles for Drug Delivery
February 20	Gang Zheng	Nanotheranostics and Clinical Translation
February 27	Evaluation	***Note class will be in the morning** PMCRT Room 15-710*

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Winter 2019		
Topic	Predictive Oncology & Therapeutics	
Coordinators	Drs. Benjamin Haibe-Kains & Ming Tsao	
Teaching Assistant	Megha Kumar (meg.kumar@mail.utoronto.ca)	
Day & Time	Mondays 1:00 pm – 3:00 pm	
Location	PMCRT, 101 College St, Room 14-203	
Recommended Prerequisites	**NONE**	
Module Goals	One of the main challenges in precision medicine is the selection of the therapeutic strategy that will benefit the most to each individual patient. With the advent of high-throughput profiling technologies, more and more data can be generated to deeply characterize the molecular state of cancer cells and the phenotypes resulting from drug treatment both in vitro and in vivo. The "Predictive Oncology & Therapeutics" course will be composed of a series of lectures on the key topics related to drug development. The goal of this course is to provide students with a translational view of drug development, from basic research to clinical implementation. The students are expected to learn about the biological, computational and clinical aspects of the development of cancer therapeutics and their associated biomarkers (companion tests). For each session, 3 groups of 2 students will be formed. The lecturer gives a 45-minute lecture. Each group will then present one paper (10 minutes presentation + 5 minutes for questions). The paper will be selected by the students from a set of 3 papers provided by the lecturer, as well as one question to be discussed by the students for each paper, 2 weeks prior to the session.	
Evaluation Method	Evaluation of the presentation (30%) + exam with multiple-choice questions (70%)	
Schedule		
Date	Instructor	Lecture
March 4	Aaron Schimmer	Drug discovery and development
March 11	*No Lecture*	
March 18	Benjamin Haibe-Kains Scott Bratman	Biomarker discovery in preclinical setting
March 25	Geoffrey Liu	Pharmacogenetics and pharmacokinetics
April 1	Tracy Stockley Ming Tsao	Implementation and application of biomarkers in clinical settings

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April 8	*No Lecture*	
April 15	Philippe Bedard	Design of clinical trials for cancer therapeutics
April 22	*Easter Weekend*	
April 29	David Cescon	Preclinical testing of experimental therapeutics ** Note this lecture will be from 12:30-2:00 PM**
May 3	Benjamin Haibe-Kains Ming-Sound Tsao	Evaluation - short exam with multiple-choice questions **Note this exam will take place at Medical Science Building Rm 4279 from 10:00-12:00**

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Winter 2019		
Topic	**Quantitative Cancer Genomics**	
Coordinators	Drs. Mathieu Lupien & Trevor Pugh	
Day & Time	Thursdays at 9:00 am – 11:00 am	
Location	PMCRT, 101 College St, Room 14-203	
Recommended Prerequisites	Undergraduate molecular biology and genetics	
Module Goals	Each class will consist of a 1-hour student lecture reviewing the day's topic in detail, followed by interactive discussion around a specific paper, case report, or mini-workshop illustrating the application of research findings in a novel way (e.g. clinical application, meta-analysis, new use for old data). The organizing Instructor will provide a list of topics that must be covered by the student in the review portion of the class and moderate discussion during the more open portion.	
Evaluation Method	Each student will be responsible for a Lecture Topic Review to be held in the first hour (35% of their grade) and for a Scientific Manuscript Presentation in the second hour (35% of their grade) of each lecture. All other students are expected to contribute to the Scientific Manuscript Discussion in each lecture (30% of their grade). The class accepts a minimum of 6 and maximum of 14 students. Instructors are to provide the lecture topic and can suggest manuscripts to be discussed in the second hour at least one week prior to the start date. The selected Scientific Manuscript is to be shared with all students at least 3 days before the lecture (usually Monday the week of the class). Lecturers will be available in person or by email to provide an optional review of the student's proposed presentation and discussion plan up to 3 days prior to student's presentation. The Instructors are responsible for assigning the student's grade using an evaluation form common across all of the lectures.	
Schedule		
Date	**Instructor**	**Lecture**
January 10	Mathieu Lupien & Trevor Pugh	Course overview and setting expectations.
January 17	Trevor Pugh	Clinical cancer genomics: Approaches to analysis of cancer genomes to guide patient care
January 24	Hansen He	Cancer transcriptomics: Identification of new biomarker and therapeutic targets within the cancer transcriptome
January 31	Michael Hoffman	Cancer epigenomics: Clinical opportunities beyond the DNA
February 7	Benjamin Haibe-Kains	Pharmacogenomics: Identifying opportunities for drug repositioning in cancer through aggregation of public data sets
February 14	Mathieu Lupien	Understanding the non-coding cancer genome: Delineating the functional consequences of genomic alterations in cancer
February 21	Daniel De Carvalho	Cancer genomics and immunotherapy: Improving immunotherapy through the power of epigenetic modulation

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Winter 2019		
Topic	**Structural Biology & Proteomics**	
Coordinators	Drs. John Rubinstein & Mitsu Ikura	
Day & Time	Thursday, 9:00 am – 11:00 am	
Location	PMCRT, 101 College Street, Room 4-204 Mar 14 class will be held in room 14-203	
Recommended Prerequisites	NONE	
Module Goals	This course offers 6 lectures that are focused on the current hot topics in structural biology and proteomics. Three lectures are designated to discuss structural biology, in which you will learn (1) protein structure and dynamics, (2) structures of membrane proteins, and (3) structures of supermolecular assembly. These courses will discuss the recent development in structural elucidation of biological macromolecules. You will learn how various research tools such as X-ray crystallography, NMR spectroscopy, and electron microscopy are used to determine atomic-resolution structures of complicated biological macromolecules (i.e. proteins, nucleic acids, etc) and their complexes. In the other three lectures designated to proteomics research, you will study various applications of mass spectrometry-based proteomics. Mass spectrometry has become an indispensable tool for a variety of biomedical research. The lectures intend to cover (1) large-scale mapping protein-protein interactomes in genomes, (2) global characterization of post-translational modifications (such as protein phosphorylation and ubiquitination) in proteomes, and (3) development of biomarkers for diagnosis. These lectures are designed to help students to grasp the overview of the latest advancement in structural biology and proteomics, the very active research fields in biology.	
Evaluation Method	**Report or essay (to be confirmed)**	
Schedule		
Date	**Instructor**	**Lecture**
March 7	Avi Chakrabartty	An introduction to protein structure and folding
March 14	Avi Chakrabartty	An introduction to protein structure and folding
March 21	Arash Zarrine Afsar	Proteomics
March 28	John Rubinstein	Structural Biology
April 4	Brian Raught	Mass spectrometry-based techniques to map cell structures and identify protein-protein interactions
April 11	*No Lecture*	
April 18	Brian Raught	Mass spectrometry-based techniques to map cell structures and identify protein-protein interactions
April 25	John Rubinstein & Mitsu Ikura	Evaluation

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Winter 2019		
Topic	**Ultrasound Overview**	
Coordinators	Drs. Christine Demore & Brandon Helfield	
Day & Time	January 11 & January 18, 2019, 9:30 am – 5:00 pm	
Location	Sunnybrook Research Institute, Room SG22	
Recommended Prerequisites	The Overview of Medical Imaging or equivalent preparation	
Module Goals	Ultrasound is a high-resolution and rapid imaging modality that applies high- frequency acoustic waves to create images based on echoes that are generated by acoustic impedance heterogeneity between different materials in a sample. Ultrasound imaging has many clinical applications from monitoring fetus in pregnancy, to diagnostic imaging of breast, abdomen and vasculature, and guiding interventional tools in minimally-invasive procedures. This course will introduce the principles of ultrasound imaging, starting with a general overview of this imaging modality and its applications. It will cover ultrasound beam profiles and the basic physics of ultrasound, interaction of ultrasound waves with tissue transducers, signal processing and image formation and beam forming, transducer design, flow detection, contrast imaging, and assorted topics. The lectures will be given over two intensive days on consecutive weeks, followed by the practical laboratory to reinforce the taught concepts.	
Evaluation Method	Lab report (50%) and exam (50%)	
Schedule		
Date	**Instructor**	**Lecture**
January 11	Christine Demore &. Brandon Helfield	Beam profile and physics, ultrasound wave-tissue interactions, signal processing and beam forming
January 18	Christine Demore &. Brandon Helfield	Transducer and array design, flow detection and imaging, contrast imaging, and assorted topics
January 25	Lab with TAs (3 hours; times finalised during lectures)	
February 22	**Exam 9:30 am – 12:30 pm**	