Medical Biophysics
UNIVERSITY OF TORONTO

MEDICAL BIOPHYSICS

COURSE MODULES

2019 – 2020

***Note**: This document was last updated on November 28, 2019. Some information may have been altered since that time. To download the most up-to-date version, please visit: https://medbio.utoronto.ca/modulebooklet*

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Course Enrolment

To enroll in courses, students must request courses on ACORN/ROSI. Instructions are available at https://medbio.utoronto.ca/course-registration. 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).

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/PN5WH2J*

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.

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COURSE MODULES
2019 - 2020

Mandatory Modules	
Introductory Biostatistics	Sept. 6 – Sept. 13
Scientific Exposition and Ethics	Sept. 18 – Nov. 13

BIOLOGY	DATES	PHYSICS	DATES
Cancer Epigenetics	Nov. 7 – Dec. 19	Advanced Ultrasound	Mar. 4, 11 and Apr. 15
Cancer Immunotherapy	Jan. 8 – Mar. 25	Biological Imaging	Mar. 2 – May 4
Clinical & Experimental Radiobiology I & II	Apr. 20 – 24 and May 6	Biophysics of Focused Ultrasound	Nov 5 – Dec. 17
Development, Stem Cells and Cancer	Jan. 6 – Feb. 24	Cell and Molecular Biology for Physicists	Mar. 5 – Apr. 16
Radiation Biology and DNA Repair	Oct. 28 – Dec. 9	Introduction to Biophotonics	Mar. 6 – May 1
Tumor Microenvironment	Sept. 26 – Oct. 31	Magnetic Resonance Imaging – Overview	Mar. 3 – Apr. 28
		Medical Device Commercialization Essentials	Sept. 5 – Dec. 5
		Medical Device Innovation and Entrepreneurship	Sept. 5 – Dec. 5
		Overview of Medical Imaging	Sept. 18 – Oct. 30
		Ultrasound Overview	Jan. 10 – Feb. 28

PROJECTED COURSE MODULES*
2020 - 2021

Mandatory Modules	
Introductory Biostatistics	
Scientific Exposition and Ethics	

BIOLOGY	DATES	PHYSICS	DATES
Cell Signaling & Metabolism		Advanced Magnetic Resonance Imaging	
Clinical & Experimental Radiobiology I & II		Advanced Ultrasound	
Experimental Models for Cancer Research		Biological Imaging	
Predictive Oncology & Therapeutics		Biophysics of Focused Ultrasound, Thermal Biophysics	
Quantitative Cancer Genomics		Cell and Molecular Biology for Physicists	
Structural Biology & Proteomics		Introduction to Bio-Microscopies	
		Introduction to Biophotonics	
		Magnetic Resonance Imaging - Overview	
		Medical Device Commercialization Essentials	
		Medical Device Innovation and Entrepreneurship	
		Nanotechnology for Medicine	
		Overview of Medical Imaging	
		Ultrasound Overview	

*Projected course offerings subject to change.

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List of Modules 2019 - 2020

Fall 2019

Biophysics of Focused Ultrasound, Thermal Biophysics

Cancer Epigenetics

Introductory Biostatistics - MANDATORY

Medical Device Commercialization Essentials

Medical Device Innovation and Entrepreneurship

Overview of Medical Imaging

Radiation Biology & DNA Repair

Scientific Exposition and Ethics - MANDATORY

Tumor Microenvironment

Winter 2020

Advanced Ultrasound

Biological Imaging

Cancer Immunotherapy

Cell and Molecular Biology for Physicists - Introduction

Clinical & Experimental Radiobiology I & II

Development, Stem Cells and Cancer

Introduction to Biophotonics

Magnetic Resonance Imaging - Overview

Ultrasound Overview

NOTE: Should there be insufficient enrolment in a module listed above, it will be offered the following year.

Fall 2019		
Topic	**Biophysics of Focused Ultrasound, Thermal Biophysics**	
Coordinator	Dr. Meaghan O'Reilly	
Day & Time	Tuesdays, 12:30 – 2:30 PM	
Location	Sunnybrook Health Sciences Centre, 2075 Bayview Ave. C-Wing, C736A or S-Wing, S615	
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 effects 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 (100%)	
Schedule		
Date	**Instructor**	**Lecture**
November 5	Meaghan O'Reilly	Biology/Rationale/Nomenclature
November 12	Meaghan O'Reilly	Blood Flow/Modelling/Energy Delivery
November 19	Meaghan O'Reilly	Energy Delivery(Cont'd)/Thermometry/Treatment Monitoring
November 26	Meaghan O'Reilly	Non-Thermal Mechanisms of Ultrasound/Bioeffects
December 3	Meaghan O'Reilly	Cavitation/Cavitation Nucleating Agents
December 10	Meaghan O'Reilly	Treatment Monitoring for Non-Thermal Therapies
December 17	**Exam**	

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Fall 2019		
Topic	**Cancer Epigenetics**	
Coordinators	Dr. Daniel De Carvalho & Dr. Hansen He	
Day & Time	Thursdays, 9:00 am – 11:00 AM	
Location	Princess Margaret Cancer Research Tower, 101 College Street, Room 4-204 Alternate location (November 28 only) PMCRT, Rm. 14-203	
Recommended Prerequisites	NONE	
Module Goals	Epigenetic regulation is critical in cancer development and progression. Moreover, epigenetic modifications can be used as therapeutic targets as well as biomarkers in cancer. This course will introduce basic concept in epigenetics and the frontiers in cancer epigenetics. Each class will consist of a 15 and 45 minutes lecture reviewing the day's topic by the lecturer and students, respectively, followed by a one-hour student-led interactive discussion around the specific papers.	
Evaluation Method	Presentation and participation in discussion. 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). Lecturers will provide the lecture topic and a 15mins introduction, as well as suggest manuscripts to be discussed at least two weeks prior to the lecture date. The selected scientific manuscripts will need to be shared with all students at least one week before the lecture. Lecturers will be available in person or by email to provide an optional review of the students' proposed presentation and discussion plan. The lecturers are responsible for assigning the student's grade using an evaluation form common across all of the lectures.	
Schedule		
Date	**Instructor**	**Lecture**
November 7	Housheng Hansen He & Daniel De Carvalho	Course overview and setting expectations
November 14	Mathieu Lupien	Functional epigenetics
November 21	Housheng Hansen He	Frontier in RNA epigenetics
November 28 **Loc: Rm. 14-203, PMCRT**	Michael Hoffman	Machine Learning in Epigenomics
December 5	Cheryl Arrowsmith	Chemical biology approaches to cancer epigenetics
December 12	Miguel Ramalho-Santos	Epigenetics in developmental and cancer biology
December 19	Daniel De Carvalho	Epigenetics in immunotherapy

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Fall 2019		
Topic	**Introductory Biostatistics - MANDATORY**	
Coordinator	Dr. Jason Lerch	
Day & Time	Week of September 9, with optional tutorial September 6.	
Location	Various: see schedule below for dates and times Princess Margaret Cancer Centre, 610 University Avenue Princess Margaret Cancer Research Tower (PMCRT), 101 College Street University of Toronto, Medical Science Building (MS) 1 Kings College Circle Lash Miller Chemical Labs, (MS) 80 St. George St	
Recommended Prerequisites	Required module – no prerequisites	
Module Goals	This course will serve as a rapid introduction to probability and statistical thinking with methods drawn from frequentist as well as Bayesian statistics. 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. Short daily quizzes: 15% Short presentation: 10% Small group applied problem solving: 40% Final exam: 35%	
Schedule		
Date	**Location**	**Lecture**
September 6	9 AM – 12 noon: 610 University Ave, Room 7-605	Tutorial (optional): Introduction to the R environment.
September 9	9 AM – 12 noon: 610 University Ave, Room 7-605 12 noon – 3 PM: MS 3278	Introduction. Data organization, descriptive statistics, plotting, basic linear models.
September 10	9 AM – 12 noon: 610 University Ave, 6th floor Auditorium 12 noon – 3 PM: PMCRT, Room 4-204	Probability in all its glory. Multiple linear models, interactions, p values, multiple comparisons.
September 11	9 AM – 12 noon: 610 University Ave, 6th floor Auditorium 12 noon – 3 PM: MS 3278	Hypothesis testing, searching for truth, and the crisis of replicability
September 12	9 AM – 12 noon: 610 University Ave, 6th floor Auditorium 12 noon – 3 PM: 80 St. George St, Room LM161	Putting it all together – analyzing a biomedical dataset from beginning to end. Review

September 13	U of T Exam Centre, 255 McCaul Street, Rm. EX310	**Exam**

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Fall 2019	
Topic	**Medical Device Commercialization Essentials**
Coordinators	Drs. Graham Wright, Brian Courtney, & Ahmed Nasef
Day & Time	Thursdays at 6:15 PM – 8:00 PM (except the week of Nov.4th) Orientation will be held on Thursday September 5th 4:00-5:00 PM in Lecture Theatre M6-502.
Location	Sunnybrook Health Sciences Centre, 2075 Bayview Ave., Toronto 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	In the Medical Device Innovation & Entrepreneurship module, students present a systematic review of significant clinical challenges and propose the development of novel medical device solutions that address the gaps in these challenges. In this commercialization module, students are required to incorporate the analysis and critical review of the prospective novel medical device concept from assignment 1 into a high-level report or a business case proposal. Students are to assume that this high-level proposal will be reviewed by an industrial technology advisor (ITA) through Sunnybrook's technology transfer office. The ITA will assess the potential of financially supporting the commercialization of this technology and determine whether or not an adequate market opportunity exists to support the development of an innovation. The students should draft the business case proposal within this commercialization context. The business case proposal should include the following sections to demonstrate commercialization potential: technology

	overview, market opportunity, industry analysis, business model/value proposition, and associated preliminary IP and reimbursement strategies. Grading Scheme: Class participation (10%), Group Report (90%).

Schedule		
Date	**Instructor**	**Lecture**
September 5	Graham Wright	Orientation (4:00 – 5:00 PM)
September 12	William Mitchell, Gail Garland, and Brian Courtney	Medtech Start-up Strategy
September 26	Steve Pulver	Market Structure & Competitive Analysis Workshop
October 10	Stephen Dilbert	Reimbursement Strategy Workshop
October 17	Steve Leonard	Patenting Strategy Workshop
October 24	Jayson Parker	Regulatory Strategy Workshop
November 4	Joseph Fernbok	Ideation & Brainstorming Exercise
November 21	TBA	The Art of The Pitch
November 28	TBA	Funding Sources and Approaches in Medtech
December 5	**No class, Final Report due**	

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Fall 2019	
Topic	**Medical Device Innovation and Entrepreneurship**
Coordinators	Drs. Graham Wright; Brian Courtney; Ahmed Nasef
Day & Time	Thursdays at 5:00 – 6:00 PM (except the week of Monday, Nov. 4th) Orientation will be held in M6-502 on Sept 5th 4:00-5:00 PM
Location	Sunnybrook Health Sciences Centre, 2075 Bayview Ave., Toronto Lecture Theatre M6-502
Recommended Prerequisites	NONE
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	Students will be divided into teams. Each team will be given a strategic focus area within medicine with a well-defined and documented clinical challenge that imposes a significant medical burden. Students will be required to evaluate current treatment options and assess the potential to develop a novel medical device solution. Students will be evaluated based on: (i) in-class participation; and (ii) a presentation, which will include the following sections: • An assessment of the clinical need & underlying problem leading to the new device. Students are expected to perform medical literature reviews through online sources e.g. PubMed, Harrison's online, etc. • Market analysis including market size, segments, attractiveness, and competitive dynamics

	• Analysis of the different parties and stakeholders involved in delivering and financing care related to the clinical challenge (e.g. patients, physicians, hospitals, government officials/legislators, MOHLTC, nurse practitioners, etc.) • Analysis of treatment options and innovations available prior to the identified novel device that tried to address the identified clinical challenge. Students are expected to perform a comprehensive review of previous innovations outlining their strengths and weaknesses. • An overview of the medical device concept that has been developed to address the need including associated regulatory & reimbursement considerations. • A critical review of possible areas of improvement for the identified device Students will be evaluated on how well they have taken the lessons taught during the course and applied them. For all evaluations, students are required to demonstrate both that they have the evidence to support their claims as well as that they have added value by extending the analysis and using creativity. Grading Scheme: Class participation (10%), Group Presentation (90%).

Schedule

Date	Instructor	Lecture
September 5	Graham Wright	Orientation (4:00 – 5:00 PM)
September 12	William Mitchell, Gail Garland	Strategic Trends in the Medical Devices Industry
September 19	William Mitchell, Karen Cross, Chris O'Connor, Kieran Murphy	Clinical Needs Finding & Medical Technology in Entrepreneurship
September 26	Steve Pulver	Commercializing Your Research
October 3	Harold Wodlinger	Business Modelling in Medtech
October 10	Stephen Dilbert	Medical Devices Reimbursement Strategy
October 17	Steve Leonard	Technology Transfer & Intellectual Property Basics
October 24	Jayson Parker	Medical Devices Regulation Primer
November 4	Joseph Ferenbok	Ideation & Design Thinking Methods
November 7	TBA	Research & Development Strategy + **Group Presentations**
November 14	Harindra Wijeysundera	Clinical Strategy Fundamentals
November 21	TBA	The Elements of a Sound Business Case
November 28	Stefano Picone	Medtech Start-up FInancing
December 5	Marian Petelycky	Quality & Process Management

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Fall 2019		
Topic	**Overview of Medical Imaging**	
Coordinators	Dr. John G. Sled	
Day & Time	Wednesdays, 9:30 – 11:30 AM	
Location	Sunnybrook Research Institute, 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 18	TBA	Introduction to Medical Imaging: a brief history
September 25	John G. Sled	Linear Systems and Fourier Transform Theory I
October 2	John G. Sled	Linear Systems and Fourier Transform Theory II
October 9	John G. Sled	X-rays and Projections
October 16	John G. Sled	Tomography and Inverse problems
October 23	James Mainprize	X-ray CT lab (may need to be scheduled on multiple days to accommodate the number of lab groups)
October 30	**Exam**	

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Fall 2019		
Topic	**Radiation Biology & DNA Repair**	
Coordinators	Dr. Marianne Koritzinsky & Dr. Razq Hakem	
Day & Time	Mondays,10:00 AM – 12:00 PM	
Location	Princess Margaret Cancer Centre, 610 University Avenue, Room 7-605 *NOTE: see below for alternate location on Nov. 11 only.	
Recommended Prerequisites	NONE	
Module Goals	DNA repair is critical for maintaining genomic integrity and its defects increase cancer risk. In addition, mutations in genes involved in DNA damage signaling or repair have also been associated with other human diseases and syndromes. DNA damage can also be induced to treat cancer patients as is the case for radiotherapy and a number of genotoxic anti-cancer drugs widely used in the clinics. This module will focus on DNA damage repair mechanisms and the physiological response to DNA insults, including radio- and chemo- therapies.	
Evaluation Method	- Presentation/discussion of scientific papers assigned a week ahead of time by the lecturers. - Class participation in all lectures. - Students will be required to submit research proposals to address questions that have arisen out of the topics covered in the module. On Dec. 2, each student will be assigned by the coordinators a specific topic/lecture to cover with the research proposal. Oral Presentation: 45% Class Participation: 15% Research Proposal: 40%	
Schedule		
Date	**Instructor**	**Lecture**
October 28	Marianne Koritzinsky	Introduction to Radiation Biology
November 4 PMCRT Room 4-204	Razq Hakem	Preclinical models to study mechanisms of DNA double strand breaks repair and their role in cancer.
November 11* 610 University Ave, Room -702/703/704	Karim Mekhail	R-loops, DNA repair and genomic instability
November 18	Benjamin Lok	Clinical Radiotherapy Overview and Predictive Biomarkers in the Clinic
November 25	David Malkin	The role of p53 in cancer development
December 2	Stan Liu	Tumor microenvironment and radiation response
December 9	No lecture	Research proposals to be submitted before 4PM on Dec. 9th.

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Fall 2019		
Topic	**Scientific Exposition and Ethics – MANDATORY**	
Coordinators	Drs. David Malkin & Jim Woodgett	
Day & Time	Wednesdays (various times; see below)	
Location	Princess Margaret Cancer Centre, 610 University Avenue, 6th floor auditorium or Room 7-605 where indicated below	
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 18	Topisirovic	**6th floor Auditorium, 1:30 - 3:30 PM**. Biomedical Research: Ethos, Logos... and Pathos (on research misconduct)
September 25	Stephenson	**Rm 7-605, 2 - 4 PM**. Principles of Ethical Conduct and Protection of Research Subjects
October 2	Scherer	**6th floor Auditorium 1:30 - 3:30 PM**. Privacy and Confidentiality in the Genome Era (Data Sharing/Validation/Clinical Translation)
October 16	Malkin	**Room 7-605, 2 - 4 PM**. Authorship Responsibility in the Spirit of Collaboration and Intellectual Property Protection
October 23	Woodgett	**6th floor Auditorium, 1:30 - 3:30 PM**. Research Ethics: Responsibilities and Best Practices
October 30	Woodgett & Malkin	**6th floor Auditorium, 1:30 - 3:30 PM**. Problem-Based Discussion – class participation

November 6	Stefanovic	**6th floor Auditorium, 1:30 - 3:30 PM.** Principles of equity diversity and inclusion in research
November 13	**U of T Exam Centre, Room EX310. 11:00 AM – 1:00 PM**. Exam.	

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Fall 2019		
Topic	**Tumour Microenvironment**	
Coordinators	Drs. Rama Khokha & Bradly Wouters	
Day & Time	*Thursdays, 9:15 am – 11:15 AM, except for October 1 and 7.	
Location	Princess Margaret Cancer Centre, 610 University Avenue, Room 7-605	
Recommended Prerequisites	NONE	
Module Goals	The tumor microenvironment (TME) is a complex entity in human cancers. It is constituted by multiple structural and cellular aberrations that arise during tumorigenesis. How cellular and molecular features of TME underlie tumor development and progression, as well as how these characteristics form the basis for new biomarkers and cancer therapies will be covered in this topic. The class will be split into groups of ~5 students. The instructor will deliver a lecture, followed by a presentation (30-40 minutes) delivered by a selected student group. The presentation will be based on 3-4 papers that have been provided at least two weeks ahead of the class. A set of instructions will also be provided to groups ahead of time. The non-presenting groups will actively participate in the review/criticism of these presented papers, as well as be prepared to cover the next set of questions in this field. Depending on the number of students enrolled, there will be either 1 or 2 rounds of presentations. Some lecturers will use a variation of the above format for class participation.	
Evaluation Method	Attendance/Participation/Presentation (50%) Exam (50%); In class examination	
Schedule		
Date	**Instructor**	**Lecture**
September 26	Trevor McKee	Imaging
***October 1 (Tuesday)**	Brad Wouters	Hypoxia
***October 7 (Monday)**	Stanley Liu	Vasculature
October 10	Steven Chan	Mitochondria
October 17	Tracy McGaha	Immune cells
October 24	Aaron Schimmer	Metabolism
October 31	Exam	In class examination

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Winter 2020

Topic	**Advanced Ultrasound**	
Coordinator	Dr. David Goertz	
Day & Time	March 4 & 11, 2020, 9:30 AM – 5:00 PM	
Location	Sunnybrook Research Institute, 2075 Bayview Ave., Room S615	
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. The module will be offered in alternate years.	
Evaluation Method	Exam	
Schedule		
Date	**Instructor**	**Lecture**
March 4	David Goertz	Wave interactions with tissue, Cavitation.
March 11	David Goertz and Christine Demore	Transducers, Beamforming, contrast imaging, selected topics.
April 15 (TBC)	Exam	

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Winter 2020		
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 lectures will address: (1) knowledge gaps in a recent area of research where imaging proved beneficial; (2) methodological developments 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 funded grant application. Grantsmanship insights, strategies and pitfalls will be discussed. Through the module, students will generate and pitch their own project idea, participate in peer feedback, and craft their own short proposals.	
Evaluation Method	Students will prepare a short grant proposal of their own design related to imaging in biological research. Evaluation will be based on general participation (10%), idea pitches (20%), peer review and evaluation (20%), and a short written proposal (50%).	
Schedule		
Date	**Instructor**	**Lecture**
March 2	B. Nieman	Module Instruction 1, Lecture 1
March 9	Microscopy Theme	Lecture 2 & Grant Discussion, Module Instruction 2
March 16	Optics Theme	Lecture 3 & Grant Discussion, Module Instruction 3
March 23	B. Nieman & C. Macgowan	**Grant Pitches**
March 30	Ultrasound Theme	Lecture 4 & Grant Discussion
April 6	C. Macgowan (MRI Theme)	Lecture 5 & Grant Discussion
April 13	C. Macgowan & B. Nieman	**Peer Review of Grant Proposals**
April 20	**No class**	
April 27	**No class**	
May 4	**Final Grant Proposals Due, Module Feedback**	

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Winter 2020		
Topic	**Cancer Immunotherapy**	
Coordinator	Dr. Tracy McGaha	
Day & Time	Wednesdays, from 2-4 PM	
Location	TBA	
Recommended Prerequisites	NONE	
Module Goals	Immunotherapy has generated great excitement and has revolutionized clinical approaches to many diseases. While direct targeting of immune bottle-necks has shown promise in a range of clinical pathologies, it is now becoming clear that many other therapeutic approaches owe their efficacy partially through induction of immune reactions. The course will cover general approaches to cellular and biologics-mediated targeting of the immune response in a range of disease states; and clinical management of disease from an immunologic perspective including discussion of adverse reactions to immunotherapy.	
Evaluation Method	20% Attendance, 40% Midterm, 40% Final Exam	
Schedule – The lecturers and dates to be announced.		
Date	**Instructor**	**Lecture**
Jan 8, 2019	Christopher Paige	Introduction to Immunotherapy
Jan 15, 2019	Daniel de Carvalho	Intersection of chemotherapy and immunotherapy
Jan 22, 2019	Shane Harding	Radiotherapy as immunotherapy
Jan 29, 2019	Sam Sabil	Immuno-metabolism as a therapeutic target
Feb 5, 2019	Naoto Hirano	Tumor infiltrating lymphocyte and CAR T cell infusion therapy: Concepts and practical challenges
Feb 12, 2019	Adrian Sacher	Checkpoint inhibition therapy
Feb 19, 2019	Marcus Butler	Clinical considerations for immunotherapy (adverse responses and clinical management)
Feb 26, 2019	Eyal Grunebaum	Cellular immunotherapy, lessons from treating severe immune deficiencies
March 4, 2019	Thomas Eiwegger	Management of allergic disease
March 11, 2019	David Brooks	Immunotherapy of infectious disease

March 18, 2019	Dana Philpott	Bugs as drugs
March 25, 2019	Final Exam	

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Winter 2020		
Topic	**Cell and Molecular Biology for Physicists - Introduction**	
Coordinators	Drs. Margarete Akens and Arash Zarrine-Afsar	
Day & Time	Thursdays, 9:00 – 11:00 AM	
Location	PMCRT, 101 College Street, Room 4-204 Alternate location (March 26 only): PMCRT, Room 14-203	
Recommended Prerequisites	NONE	
Module Goals	This course introduces physical scientists to the basic concepts of anatomy, cell molecular and cancer biology. Methods in DNA, RNA, and protein technologies will also be discussed. 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 5	M. Akens	Cell and developmental biology
March 12	M. Akens	Basic anatomy and visualization techniques
March 19	T. Pugh	Cancer genomics and transcriptomics to guide patient care
March 26	A. Zarrine-Afsar	Methods in Molecular Biology
April 2	M. Rauth	Signal transduction
April 9	D. Hill	Interventional radiobiology and tumour microenvironment
April 16	**Evaluation (Classroom exam)**	

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Medical Biophysics
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Winter 2020

Topic	**Clinical & Experimental Radiobiology I & II**
Coordinator	Dr. Marianne Koritzinsky
Day & Time	April 20 - 24, 8:45 AM – 5:00 PM and May 6, 8:45 AM – 12:30 PM
Location	TBA
Recommended Prerequisites	The suggested textbook for this course is Basic Clinical Radiobiology, Fifth 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/Basic-Clinical-Radiobiology-Michael-Joiner/dp/1444179632 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 May 6th, 9 AM – 12 PM – location TBA

Schedule

MONDAY APRIL 20, 2020 - *Lectures/schedule is subject to change*

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 21, 2020

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
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 22, 2020

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 23, 2020

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 24, 2020

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
1:30-12:00	T13	Tutorial and Question period (25-27)	Andrew, Marianne, Alejandro
12:00-12:30		Concluding remarks	Marianne

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Winter 2020		
Topic	**Development, Stem Cells and Cancer**	
Coordinators	Dr. Norman Iscove	
Day & Time	Mondays, 2:30 – 4:30 PM	
Location	Princess Margaret Cancer Centre, 610 University Ave, Room 7-605	
Recommended Prerequisites	The course is tailored for students from physics/engineering backgrounds with minimal prior exposure to biology.	
Module Goals	This module will cover the nature, biology, medical applicability and cancer relevance of stem cells. The topics will be developed in a 6-session lecture series. Each topic, listed below, will be covered in 2 hr.	
Evaluation Method	Conceptual mastery within each topic will be tested by a single written examination will be given at the end of the lecture series, providing 100% of the final grade.	
Schedule		
Date	**Instructor**	**Lecture**
January 6	G. Keller	Principles of embryonic development applied to derivation of adult cells and tissues from embryonic stem cells
January 13	R. Khokha	Architecture, regulation and microenvironment in the mammary epithelial stem cell system.
January 20	N. Iscove	Stem cells, self-renewal and the origin of leukemia
January 27	J. Dick	Concepts of “stemness” in human normal and leukemic hemopoiesis.
February 3	C. O’Brien	Architecture, regulation and microenvironment in normal and malignant gastrointestinal stem cell systems.
February 10	L. Ailles	Detection and quantitation of cancer stem cells and microenvironmental impact in epithelial and mesenchymal cancers
February 17	Family Day – no class	
February 24	Written examination	

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Winter 2020	
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 15-710
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 research and clinical 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 three [(1)-(3)] areas.
Evaluation Method	Class participation (25%), and the oral exit exam (75%)

Schedule		
Date	**Instructor**	**Lecture**
March 6	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 will be 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 13	Lothar Lilge	Diagnostic techniques are explained based on the spectral information content of the biological tissue and/or biomarkers. These include diffuse reflectance, fluorescence and Raman spectroscopies. Extensions towards hyperspectral and Raman-based imaging techniques will be covered. Impact as exemplified by clinical studies and common clinical procedures will be assessed.
March 20	Alex Vitkin	Diagnostic imaging, including issues of resolution, contrast, turbidity, and imaging depth will be presented. High resolution diagnostics including

		optical coherence imaging, photoacoustics, optical projection tomography, confocal and multi-photon techniques; low(er) resolution approaches including diffuse optical imaging will be discussed.
March 27	Lothar Lilge	Photo-therapeutics based on non-thermal interactions (photo bio-modulation therapy, photodynamic therapy) will be covered. This lecture will emphasize the need for accurate dosimetry to maximize therapeutic efficacy.
April 3	Lothar Lilge	Photo-therapeutics based on temporally-controlled (rapidly pulsed) laser delivery, including photo-ablation and selective photothermolysis.
April 10	**No Class – Good Friday**	
April 17	Alex Vitkin	Selected advanced topics such as nanophotonics, molecular imaging, optical clearing and theragnostics
April 24	**No Class / review as needed**	
May 1	**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 2020		
Topic	**Magnetic Resonance Imaging - Overview**	
Coordinators	Dr. Jean Chen	
Day & Time	Tuesdays, 12:30 – 2:30 PM	
Location	Sunnybrook Research Institute, 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 the Overview of Medical Imaging module 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 3	Kamil Uludag	Basic MR Physics 1
March 10	Kamil Uludag	Basic MR Physics 1
March 17	Brian Nieman	Imaging Physics 1
March 24	Brian Nieman	Imaging Physics 2
March 31	Jean Chen	Laboratory
April 7	No lecture	
April 14	Jean Chen	Instrumentation
April 28	**Exam**	

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Winter 2020		
Topic	**Ultrasound Overview**	
Coordinators	Dr. Christine Demore	
Day & Time	January 10 & January 17, 2020, 9:30 AM – 5:00 PM	
Location	Sunnybrook Research Institute, 2075 Bayview Ave., 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. Individual oral exams will be held to evaluate understanding of taught concepts.	
Evaluation Method	Lab report (50%) and exam (50%)	
Schedule		
Date	**Instructor**	**Lecture**
January 10	Christine Demore	Beam profile and physics, ultrasound wave-tissue interactions, signal processing and beam forming
January 17	Christine Demore	Transducer and array design, flow detection and imaging, contrast imaging, and assorted topics
January 24 (TBC)	Lab with TAs (3 hours; times finalised during lectures)	
February 28 (TBC)	**Exam (1 hour; times finalized during lectures)**	

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