



UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

Report No. 3280

To: Faculty Council

**From: Professor J. Paul Santerre, Director
Institute of Biomaterials and Biomedical Engineering**

Date: February 3, 2011 for March 8, 2011 Meeting

**Item: Proposal to create a Clinical Engineering Concentration in the
IBBME PhD Program**

The attached proposal has been developed in compliance with the University of Toronto's Quality Assurance Process (UTQAP) regarding major modifications to existing graduate and undergraduate programs.

Background:

A change to the existing IBBME PhD program is being proposed, namely, to add a clinical engineering concentration. This change entails the addition of an option in the PhD program to allow the reclassification of MHSc clinical engineering graduate students into the PhD program, an additional half-course requirement for graduate students without a clinical engineering background, a required joint engineering-health scientist supervisory arrangement and the requirement to conduct research within a clinical healthcare environment.

Consultation:

The proposal has been reviewed by the Faculties of Medicine and Dentistry, and the Engineering Graduate Education and Research Committee.

Proposal/Motion:

The proposal will be considered as a Special Motion at Faculty Council which will require 2/3 majority of members present for approval and must be circulated to Faculty Council members at least 14 days in advance.

“THAT the Faculty approves the creation of a Clinical Engineering Concentration in the existing IBBME PhD program as described in the attached Major Modification Proposal.”

University of Toronto

Major Modification Proposal

This template should be used to bring forward all proposals for major modifications to existing graduate and undergraduate programs for governance approval under the University of Toronto's Quality Assurance Process. It is designed to ensure that all evaluation criteria established by the Quality Council are addressed in bringing forward a proposal for a new program.

Section 1

Version Date:	February 16, 2011
Institutional Contact:	Jane E. Harrison, Director, Academic Programs and Policy, Office of the Vice Provost, Academic Programs <i>jane.harrison@utoronto.ca</i>
Faculty / Academic Division:	Applied Science & Engineering (FASE)
Department / Unit (if applicable) where the program will be housed:	Institute of Biomaterials & Biomedical Engineering
Program being modified:	PhD in Biomedical Engineering
Effective date:	September 2011

Section 2 *(please feel free to remove the instructions as you complete the template if you wish)*

1. Executive Summary

Please provide a brief summary of the change(s) being proposed outlining the implications of and rationale for and the change.

This is a proposal to create a concentration in clinical engineering within the existing IBBME PhD. Students in the concentration will complete the normal requirements of the PhD with the following changes: graduate students without a clinical engineering background will normally be required to complete an additional specified half course; students in the concentration require joint engineering-health scientist supervision; all students in the concentration must conduct research within a clinical healthcare environment. In addition, this proposal seeks to add an option in the PhD program to allow the transfer of MHS c clinical engineering graduate students into the PhD program and this concentration. We expect an initial enrolment in the concentration of 3 to 5 students.

Clinical engineering has become a unique sub-specialty of biomedical engineering given its specific emphasis on enhancing patient safety, quality of care and quality of life. As evidence of its maturing identity, certification in clinical engineering was introduced in Canada in 2010 by the American College of Clinical Engineers. Increasingly, there is an emerging need for research clinical engineers within hospital research institutes, universities and medical device industry to lead research and innovation. The demand for clinical engineering scientists will heighten in the years to come with the nascent biodesign teaching curricula across North America, the sprouting of interdisciplinary research institutes such as the newly formed Ontario Brain Institute, and the international growth of clinical engineering research at major research-intensive hospitals (e.g., UHN, Massachusetts General). Over a third of IBBME's current clinical engineering students and recent alumni (last 2 graduating classes) have expressed an interest in pursuing a PhD with a clinical engineering concentration. Already 6% of IBBME's MHS c Clinical Engineering class

are moving on to the PhD. Likewise, over half of current faculty supervising clinical engineering graduate students have indicated interest in engaging such students in doctoral level research. The proposed change reflects IBBME's on-going commitment to graduate students, that is, to respond to the growing graduate student interest in clinical engineering research and to pro-actively prepare for the expanding demand for clinical engineering scientists. Fortuitously, the proposed change is well-aligned to IBBME's 2009-2014 academic plan, a key priority of which is "to expand the graduate curriculum in order to provide a greater innovative/biodesign/entrepreneurship training experience, with an emphasis on the PhD level".

2. Rationale

- *Outline the rationale for the proposed change(s) and the fit with the unit's and division's academic plans*

Since 1984, the Institute of Biomaterials & Biomedical Engineering (IBBME) has offered a Master of Health Science (MHSc) in Clinical Engineering, which remains the only research-intensive clinical engineering program in North America. In each of the last 4 years, enrolment in the MHSc program has more than tripled the annual average in its first 20 years of existence. The program now receives in excess of 50 applicants for approximately 15-20 positions. The quality of the candidates remains unequivocally high, as witnessed by the escalating number of external scholarship holders (27% of currently enrolled students) and student-authored journal publications (about 33% of the class are publishing). The number of faculty who are directly financially supporting clinical engineering graduate students has also stepped up accordingly (100% of the current roster of 20 clinical engineering supervisors).

In recent years, the global community has witnessed a rapid expansion of the medical device sector (currently pegged as a \$90 billion market, not including stem cell technologies and other engineered biological therapeutics and diagnostics). In the US, the health care industry consumes 10% of the gross domestic product. Health care is projected as one of the world's largest and fastest-growing industries, reaching 19.6% of the the US GDP by 2016. Engineering principles are applied in hospitals, nursing homes, diagnostic laboratories, pharmacies, medical device manufacturing, rehabilitations services and many other areas to yield expenditure in the US alone of \$2.1 Trillion (2006 figures). In light of these forecasts, it is not surprising that the profession of clinical engineering has also gained significant attention nationwide; the certification of clinical engineers is being introduced in Canada in November of 2010 as part of the American College of Clinical Engineering's international certification process. An IBBME faculty member, Dr. Tony Easty, is chairing the certification committee for Canada. As healthcare becomes increasingly technology-dependent, the need for clinical engineering scientists and clinically-savvy engineers is only expected to grow for the foreseeable future.

IBBME's Ph.D. program does not currently provide a transfer option for clinical engineering graduate students from the MHSc. There is an increasing number of excellent students who wish to specifically focus on applied science and engineering research, fundamentally to enhance patient safety and the delivery, integration and management of contemporary, technology-mediated healthcare. Given the rich intensity of clinically applied research among the University of Toronto's teaching hospitals (eight of whom have approximately 45 senior research scientists appointed into IBBME), there exists tremendous opportunity for IBBME to lead the formation of clinical engineering scientists. Currently, there are no PhD programs with a clinical engineering concentration in North America.

Fit with IBBME's academic plan

The present proposal aligns with a key priority in IBBME's 2009-2014 academic plan which is "to expand the graduate curriculum in order to provide a greater innovative/biodesign/entrepreneurship training experience, with an emphasis on the PhD level, within the framework of IBBME's GTA network and with international collaborators." This initiative is recognized in the language of the Faculty of Applied Science and Engineering's research academic plan where the current PhD program for IBBME is located. FASE's

research plan recognizes “The challenges facing our healthcare system place financial strain on government resources and are pushing the frontiers of biomolecular science and patient-specific therapies and diagnostics. Integration of engineering practices with medical sciences, as well as the existing collaboration between Engineering, the Faculty of Medicine, and the University affiliated hospitals, helps us identify and study more efficient diagnostic strategies and better disease-monitoring leading to an enhanced quality of life.” The establishment of this clinical engineering concentration in IBBME’s PhD program is also in line with the core values of the Faculty of Medicine’s current and on-going strategic planning which emphasizes “Integration, collaboration and partnerships” as well as an emphasis on knowledge translation and social responsibility. As described below this proposal speaks to all of these themes, given that the program involves the participation of the Institute in partnership with Toronto hospitals, and is focussed on translational research with an emphasis on active patient involvement, thereby integrating technology with society. Dentistry’s current academic plan is focused on using its interdisciplinary strength to capitalize on strategic alliances in order to establish new partnerships and build an environment of growth that will lead to the translation of knowledge in the clinic. Towards these goals they have recently established a Clinical Studies Centre and have retained several of the Institute’s faculty members in teaching their graduate courses. Hence, the proposed concentration in Clinical Engineering is well aligned with their agenda. Both the Faculties of Medicine and Dentistry have been provided the proposal for their review and no issues have been raised to the initiative.

3. Description of the proposed major change (s)

- Describe what changes are being proposed. In particular, please address the following as applicable:
 - Requirements that differ substantially from those existing at the time of the previous cyclical program review
 - Significant changes to learning outcomes
 - Significant changes to the faculty engaged in delivering the program and/or to essential physical resources as may occur, for example, where there have been changes to the existing mode of delivery (e.g. different campus, on-line delivery, inter-institutional collaboration)
- As an Appendix, please provide full, revised calendar copy. In the interest of clarity it is recommended that the attached template be used to show original requirements, proposed changes and final clean copy with all proposed changes accepted.

IBBME proposes to modify IBBME’s existing PhD program with an opportunity for students to take on a clinical engineering concentration. The degree nomenclature will remain a “PhD in Biomedical Engineering”. Clinical engineering students who have expressed interest in pursuing a PhD have vetted this nomenclature and IBBME has confirmed with the American College of Clinical Engineers that our doctoral graduates would be eligible for certification. Doctoral students opting for the clinical engineering concentration will be expected to take a plurality of clinical engineering courses from IBBME’s existing graduate course offerings, and will have specific supervisory and research environment requirements as outlined below. The concentration will adhere to the level of research excellence, critical thought, originality and research output of IBBME’s PhD program. The specific proposed changes are to:

- Formalize a transfer option for graduate students enrolled in the MHSc program, whereby a student may transfer to the PhD program under conditions stipulated below and in accordance with the SGS regulations for transfers. This option currently exists only for students enrolled in the MASc program in IBBME.
- Introduce an additional clinical engineering course requirement as detailed below, above and beyond the existing PhD requirement, for students without a degree in clinical engineering.
- Add a multi-disciplinary supervision requirement for students pursuing the clinical engineering PhD concentration; their PhD research would normally be jointly supervised by faculty from engineering and the health sciences. The IBBME-appointed (primary) supervisor will assist the student in arranging joint supervision and will be the primary person responsible for guiding the student through the SGS

regulations and timelines.

- Add the requirement that the research must be carried out, at least in part, in a clinical environment, broadly understood to be any setting where a person is receiving care, for example, including, but not limited to a hospital-based laboratory, an assisted living centre, nursing home or outpatient clinic, where human subjects will be engaged.

Admission requirements

Students applying to IBBME's PhD program may apply to the concentration in Clinical Engineering option if they satisfy the following requirements:

- Undergraduate degree in engineering (to maintain eligibility for certification as a Clinical Engineer)
- Master's degree in clinical engineering or other clinically-related engineering field

To transfer from the MHSc to the PhD program, the following requirements must be met:

- completion of 3.0 full-course equivalents within the MHSc curriculum
- transfer exam consisting of an oral defense of a written PhD proposal before a committee of 3 SGS-appointed faculty members (at least one of whom will be a clinically-appointed faculty member) within 12 months of initial registration

Direct admission from a bachelor's may be considered in exceptional cases.

Program requirements (Please also refer to the revised Calendar Entry in the Appendix)

Supervisory requirement - Students taking the concentration in Clinical Engineering would normally be co-supervised by both engineering and health science faculty. The primary supervisor must be IBBME-appointed, however the co-supervisor could be from a clinical unit other than IBBME, however must be appointed to SGS. IBBME's PhD program currently allows for co-supervision from non-IBBME SGS appointed faculty.

Research environment requirement – Students must conduct their research in a clinical environment.

Existing IBBME PhD requirements - These include 1.0 full-course equivalent (FCE), successful completion of a thesis, participation in two seminar courses, passing a qualifying examination within 12 months of registration, annual supervisory committee meetings and oral defense of the thesis (departmental and senate oral).

Clinical Engineering course requirement - Normally, if the student does not have a formal degree in Clinical Engineering, one additional course in clinical engineering is required.

- 0.5 FCE from one of the IBBME clinical engineering courses (BME 1405, BME 1439, BME 1436 or BME4444)*

* A student who possesses protracted professional clinical engineering experience (5 or more years) will be exempt from this requirement.

All course requirements must be fulfilled with graduate level courses.

Program length

The proposed change will not impact the established program length for IBBME's PhD program, namely, 4 years (full-time) from a Master's degree or 5 years (full-time) for direct entry or transfer students. It is anticipated that the additional 0.5 FCE required of those without a clinical engineering master's degree would not prolong the residency in the program.

Mode of delivery

Only standard delivery as a full-time program will be implemented. The rationale is that the inherent nature of research in which these students will engage necessarily dictates continuity of work over a few years. In particular, human participants will be engaged in the vast majority of cases. Such research is bound by timelines of research ethics approval. Further, recruited research participants can only be retained for limited periods of time. Finally, the rapid cycle of clinical engineering advances in many areas would tend to favour the publication of research that is more current and timely.

Assessment of teaching and learning

Assessment of student achievement will be consistent with the current procedures within the IBBME PhD program. Namely, after completion of the qualifying exam, students will continue to meet with their supervisory committee at least once every 12 months until recommendation for the Departmental Oral Examination is made. At each meeting, the committee provides a written assessment of the student's progress along with recommended considerations or changes, as appropriate.

4. Impact of the change

- *Outline the expected impact on continuing students, if any, and how they will be accommodated*
- *Describe impact on other programs, divisions describing consultation with affected units.*

Impact on teaching

Over 30 faculty including scientists and clinician scientists in the affiliated hospitals presently contribute to the didactic components of the clinical engineering curriculum (courses and observerships). These include BME1405 & BME 1439 (Clinical engineering instrumentation I and II), BME 1436 (Clinical Engineering surgery) and BME4444 (Clinical engineering internship). The additional students in these courses as a result of the clinical engineering concentration will be incremental at first, as most of the initial candidates to be either current Clinical Engineering graduate students or alumni. Impact on teaching will be re-assessed as the concentration develops. Additionally, IBBME's most recent Academic Plan identifies a potential new hire in the area of Biodesign who will contribute to teaching in the clinical engineering concentration.

Impact on continuing students

The proposed change will have no impact on continuing students within IBBME's PhD program.

Impact on other programs

There are no other programs of this nature anywhere on campus or in Canada. Currently the only PhD program on campus with an Engineering emphasis which comes close to what is being proposed is IBBME's own PhD program. The introduction of the clinical concentration will be a further magnet for some of the country's and the world's best biomedical engineering students. The number of students applying to the current program already exceeds the number of funded positions among professors in IBBME so it is not anticipated that there

will be any recruitment impact. A similar scenario occurred in 2006 when IBBME's MHS program expanded from 6-8 graduate student spots to 30 spots. In the previous transformation in 2006, the draw did not deplete the MASc pool since the MASc-PhD program has continued to expand throughout the Ontario Graduate Incentive years of 2006-2010.

5. Resources:

- Describe any resource implication on the change(s) including but not limited to faculty complement, space, libraries, enrolment/admissions,

Space

As in the existing MHS program, lab and office space for graduate students in the clinical engineering PhD concentration will be made available through the affiliated hospital facilities of the supervising faculty.

Administration

The clinical engineering concentration will be administered through the existing graduate program office within IBBME. IBBME's Associate Director will continue to oversee all PhD admissions. Day-to-day program administration will be facilitated by the clinical engineering graduate coordinator and program assistant. These human resources will be able to support the program's initiation. Staffing levels will be revisited as necessary as the program evolves.

Faculty

A plurality (53%) of faculty who are either supervising or have recently supervised a clinical engineering graduate student responded positively about supervising and funding PhD students with a clinical engineering concentration. The quality of our current roster of clinical engineering supervisors, their competency to supervise students in related areas of research, and their ability to promote innovation and foster an appropriate intellectual climate are demonstrated in the attached summary of key faculty. This list includes several named and CRC chairs (Drs Chau, Easty, Mihailidis, Popovic, Shojanian just to name a few - www.ibbme.utoronto.ca). The current faculty roster includes 7 Full Professors, 5 Associate Professors and 9 Assistant Professors. It is anticipated that in the initial years, additional PhD students will be supervised by the key faculty featured in the attachment (typically 1 student/faculty member).

Tuition

- Tuition (existing PhD tuition + related ancillary fees as appropriate). Rationale: Tuition fees remain fixed for PhD programs across the University

Funding

IBBME currently has a roster of 20 SGS-appointed core and cross-appointed faculty who are supervising and funding clinical engineering graduate students. Over half have expressed interest in funding clinical engineering PhD students. These faculty members are already conducting research at the interface between engineering and health care, are well-funded (over \$10 million in active grants) with established research programs, and would be well-positioned to mentor doctoral students pursuing a clinical engineering thesis.

The proposed clinical engineering concentration would be philosophically aligned to an NSERC CREATE program in rehabilitation engineering (CARE, 2009-2015) that is housed at IBBME. Students pursuing the clinical engineering concentration would be eligible for support through CARE, at \$19,500 per annum, for

the first two years of study. The CARE program has the capacity to support up to 14 PhD students at this level in any given year. Given the caliber (average admission GPA of 3.62/4.0 in final 2 years of study for current first year class) and scholarship track record of students (27% hold external scholarships) entering the clinical engineering MHS program, it is anticipated that a healthy contingent of clinical engineering PhD students will also be competitive for national scholarships through NSERC or CIHR.

The Dean of Applied Science and Engineering has allocated the required 2011-12 portion of FASE's new 40 PhD positions to this program.

Enrolment

Initially, IBBME expects between three to five students to choose the clinical engineering concentration, with increasing numbers in future years. A steady state enrolment of about 20 students will be attained within the first seven years of the introduction of the clinical engineering concentration. This estimate is based on the potential capacity within our MHS program (53% of active clinical engineering supervisors have indicated their interest in funding and mentoring PhD students with a clinical engineering concentration) and interest among recent students (35% among those recently surveyed responded affirmatively about pursuing a PhD with a clinical engineering concentration).

Source of applicant pool

The proposed clinical engineering concentration would attract three types of students. The first would be students holding an MHS in Clinical Engineering or students currently enrolled in the MHS in Clinical Engineering program at the University of Toronto. The latter would have the option of reclassifying into the PhD program as outlined above. The second group of students would be those coming from a doctoral stream master's program, such as IBBME's MASc in biomedical engineering (i.e., students without an MHS in Clinical Engineering). The third would be candidates with a Bachelor's in Engineering and an exceptional academic record in their last 2 years of study, who have also accumulated 5 years or more of clinical engineering experience either in the medical device industry or hospital setting.

6. Governance Process:

<i>Levels of Approval Required</i>
Dean's Office Sign Off
Faculty/Divisional Council
Submission to Provost's Office
AP&P – reported annually
Ontario Quality Council - reported annually

Appendix A:

Original Calendar Copy	Proposed Changes (Additions highlighted)	New Calendar Copy
<p>Doctor of Philosophy</p> <p>Minimum Admission Requirements</p> <ul style="list-style-type: none"> Graduate in dentistry, engineering, medicine, or one of the physical or biological sciences with an appropriate master's degree. Direct admission may be considered in exceptional cases. <p>Program Requirements</p> <ul style="list-style-type: none"> Normally at least 1.0 full-course equivalent (FCE) and successful completion of a thesis, representing an original investigation in biomedical engineering. Within 12 months of registration, students must pass a qualifying examination covering the broad field of biomedical engineering appropriate to their background. Students will continue to meet with their supervisory committee at least once every 12 months until recommendation for the Departmental Oral Examination is made. On the recommendation of the supervisory committee and special approval from their department Graduate Chair or Coordinator, candidates have the opportunity to waive the Departmental Oral Examination and proceed directly to the 	<p>Doctor of Philosophy</p> <p>Minimum Admission Requirements</p> <ul style="list-style-type: none"> Graduate in dentistry, engineering, medicine, or one of the physical or biological sciences with an appropriate master's degree. Direct admission may be considered in exceptional cases. Transfer from the MHSc is available for highly qualified students interested in the Clinical Engineering concentration. <p>Program Requirements</p> <ul style="list-style-type: none"> Normally at least 1.0 full-course equivalent (FCE) and successful completion of a thesis, representing an original investigation in biomedical engineering. Within 12 months of registration, students must pass a qualifying examination covering the broad field of biomedical engineering appropriate to their background. Students will continue to meet with their supervisory committee at least once every 12 months until recommendation for the Departmental Oral Examination is made. On the recommendation of the supervisory committee and special approval from their department Graduate Chair 	<p>Doctor of Philosophy</p> <p>Minimum Admission Requirements</p> <ul style="list-style-type: none"> Graduate in dentistry, engineering, medicine, or one of the physical or biological sciences with an appropriate master's degree. Direct admission may be considered in exceptional cases. Transfer from the MHSc is available for highly qualified students interested in the Clinical Engineering concentration. <p>Program Requirements</p> <ul style="list-style-type: none"> Normally at least 1.0 full-course equivalent (FCE) and successful completion of a thesis, representing an original investigation in biomedical engineering. Within 12 months of registration, students must pass a qualifying examination covering the broad field of biomedical engineering appropriate to their background. Students will continue to meet with their supervisory committee at least once every 12 months until recommendation for the Departmental Oral Examination is made. On the recommendation of the supervisory committee and special approval from their department Graduate Chair

<p>University of Toronto Final Oral Examination.</p> <ul style="list-style-type: none"> • Engineering and physical science students are required to take a life sciences course, such as JPB 1022H (or an equivalent); while life science students are required to take a physical sciences course, such as JPB 1055H (or an equivalent). • Students pursue a thesis topic relevant to Biomedical Engineering and are expected to take BME 1450H Bioengineering Science. • Students participate in two seminar courses: one of BME 1010H or BME 1011H Graduate Seminar series, and JDE 1000H Ethics in Research. <p>Normal Program Length</p> <ul style="list-style-type: none"> • 4 years (full-time PhD); 5 years (direct-entry PhD and transfer from MHSc) 	<p>or Coordinator, candidates have the opportunity to waive the Departmental Oral Examination and proceed directly to the University of Toronto Final Oral Examination.</p> <ul style="list-style-type: none"> • Engineering and physical science students are required to take a life sciences course, such as JPB 1022H (or an equivalent); while life science students are required to take a physical sciences course, such as JPB 1055H (or an equivalent). • Students pursue a thesis topic relevant to Biomedical Engineering and are expected to take BME 1450H Bioengineering Science. • Students participate in two seminar courses: one of BME 1010H or BME 1011H Graduate Seminar series, and JDE 1000H Ethics in Research. • Students may pursue a clinical engineering concentration where they would normally be co-supervised by both engineering and health science faculty, conduct research in a clinical environment, and normally would be expected to take a clinical engineering course (BME1405, BME1439, BME1436 or BME4444) in addition to the above course requirements. <p>Normal Program Length</p> <ul style="list-style-type: none"> • 4 years (full-time PhD); 5 	<p>or Coordinator, candidates have the opportunity to waive the Departmental Oral Examination and proceed directly to the University of Toronto Final Oral Examination.</p> <ul style="list-style-type: none"> • Engineering and physical science students are required to take a life sciences course, such as JPB 1022H (or an equivalent); while life science students are required to take a physical sciences course, such as JPB 1055H (or an equivalent). • Students pursue a thesis topic relevant to Biomedical Engineering and are expected to take BME 1450H Bioengineering Science. • Students participate in two seminar courses: one of BME 1010H or BME 1011H Graduate Seminar series, and JDE 1000H Ethics in Research. • Students may pursue a clinical engineering concentration where they would normally be co-supervised by both engineering and health science faculty, conduct research in a clinical environment, and normally would be expected to take a clinical engineering course (BME1405, BME1439, BME1436 or BME4444) in addition to the above requirements. <p>Normal Program Length</p> <ul style="list-style-type: none"> • 4 years (full-time PhD); 5
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	<p>years (direct-entry PhD)</p> <p>Program Note</p> <ul style="list-style-type: none"> • Students wanting to pursue the clinical engineering concentration in the PhD program must be eligible for clinical engineering certification. 	<p>years (direct-entry PhD)</p> <p>Program Note</p> <ul style="list-style-type: none"> • Students wanting to pursue the clinical engineering concentration in the PhD program must be eligible for clinical engineering certification.
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Developed: January 31, 2011
Revised: February 16, 2011

IBBME Core and Cross-appointed Faculty in the Engineering in a Clinical Setting Theme

1. Amon, Cristina*
2. Andrysek, Jan*
3. Benhabib, Beno*
4. Biddiss, Elaine*
5. Black, Sandra*²
6. Borschel, Gregory
7. Brock, Kristy*²
8. Cafazzo, Joe*
9. Caldarone, Christopher
10. Chau, Tom*¹
11. Cheung, Angela
12. Coates, Allan*
13. Drake, James
14. Easty, Tony*²
15. Eizenman, Moshe
16. Fernie, Geoff*
17. Goldenberg, Andrew
18. Grantcharov, Teodor*
19. Gross, Allan
20. Hynynen, Kullervo¹
21. Jaffray, David
22. Johnston, Wayne²
23. Keshavjee, Shaf²
24. Lapinsky, Stephen
25. Mandelis, Andreas¹
26. Mihailidis, Alex*²
27. Milgram, Paul
28. Popovic, Milos*²
29. Pritzker, Ken
30. Schweizer, Tom*
31. Shojania, Kaveh¹
32. Steele, Catriona*
33. Steinman, David
34. Strauss, Bradley*
35. Trbovich, Patricia*
36. Weersink, Robert*
37. Wright, Graham*²
38. Yee, Albert

*currently supervising clinical engineering graduate students

¹Canada Research Chair

²Named Research Chair

Profiles of selected faculty in the Engineering in a Clinical Setting Theme of IBBME

Full Professors

Name	Cristina Amon
Graduate Training	26 PhD, 25 Masters
Career Research Funding	\$55.5 million
Journal Articles	94
Academic Rank	Dean, Faculty of Applied Science and Engineering
Graduate Appointments	IBBME, MIE, SGS
Research Chairs	National Council of Deans of Engineering and Applied Science (NCDEAS) of Canada, Research Committee Chair
Areas of Research	Fluid Dynamics & Heat Transfer, Nano-scale Thermal Transport, Heat and Mass Transfer Enhancement, Phase Change Heat Transfer, Concurrent Thermal Design, High-Performance Electronics Cooling Technologies, Transport in Methanol Fuel Cells and SOFCs, Hemodynamics and Mass Transport in Biological Systems, Aortic Aneurysms and Intravenous Blood Oxygenators
Selected Awards	Engineers Canada Award for the Support of Women in the Engineering Profession, 2010; Most Important Hispanic in Technology Award, 2010; ASME Heat Transfer Memorial Award, 2009; Canadian Academy of Engineering, Fellow, 2009; Massey College, University of Toronto, Senior Fellow, 2009; Women Engineer Inaugural Award, ASME Electronics and Photonics Packaging Division, 2008; Named One of America's Most Important Hispanics in Technology and Business, Hispanic Engineer and Information Technology Magazine, 2005, 2006.

Name	Allan Coates
Graduate Training	3 PhD, 3 Masters
Career Research Funding	\$3.7 million
Journal Articles	148
Academic Rank	Professor
Graduate Appointments	IBBME, Physiology
Research Chairs	
Areas of Research	adapting new technologies in the aerosol field to patient care; nebulizer systems for the treatment of cystic fibrosis (CF); role of exercise and exercise testing in cystic fibrosis; lung gene delivery systems
Selected Awards	Medical Research Council of Canada – Fellowship, Kinsmen Mary Ivany Memorial Canadian Cystic Fibrosis Foundation Scholarship, Senior Research Scientist Award- The Montreal Children's Hospital Research Institute

Name	Milos Popovic
Graduate Training	30 +
Career Research Funding	
Journal Articles	64
Academic Rank	Professor
Graduate Appointments	IBBME, MIE, ECE, GDRS
Research Chairs	Toronto Rehab Chair in Spinal Cord Injury Research
Areas of Research	Neuroprostheses for grasping, standing, walking and sitting; modeling of locomotion, standing, grasping, and reaching functions
Selected Awards	Engineering Medal for Research and Development, Ontario Society of Professional Engineers and Professional Engineers of Ontario; Technology Transfer Award

Name	James Drake
Graduate Training	
Career Research Funding	\$1.2 million
Journal Articles	201
Academic Rank	Professor
Graduate Appointments	IBBME, IMS
Research Chairs	
Areas of Research	Neuroendoscopy; Complex Shunt Problems; Computer Assisted Surgery
Selected Awards	"Doctor of the Year", Annual Herbie Fund Mistletoe Ball, CNS American Syringomyelia Alliance Project Fellowship Award, Donald D. Matson Award

Name	David Steinman
Graduate Training	7 Masters, 6 PhD
Career Research Funding	\$3.5 million
Journal Articles	71
Academic Rank	Professor
Graduate Appointments	MIE, IBBME
Research Chairs	
Areas of Research	The overarching theme of my research is the integration of medical imaging and computational modeling to elucidate the role of hemodynamic forces in the development, diagnosis and treatment of cardiovascular diseases. This program can be broken down along two complementary lines of research. The first, image-based modeling, exploits medical imaging data to construct patient-specific computational fluid dynamics (CFD) models. The second, virtual imaging, uses computational models to simulate the impact of complex anatomy, flow and motion on medical images.
Selected Awards	Career Investigator Award – Heart and Stroke Foundation, Premier's Research Excellence Award

Name	Kenneth Pritzker
Graduate Training	12 Masters, 3 PhD
Career Research Funding	\$7.4 million
Journal Articles	229
Academic Rank	Professor
Graduate Appointments	Lab Medicine & Pathobiology, SGS, Surgery, Clinical Biochemistry, IBBME
Research Chairs	
Areas of Research	Biomaterialization: Normal and Pathological; Pathogenesis of Degenerative Joint Diseases; Pathogenesis of Crystal Deposits in Tissues; Connective Tissues as Biomaterials; Novel Biomaterials; Biomedical Applications of Fullerenes; Connective Tissue Neoplasia
Selected Awards	

Name	Paul Milgram
Graduate Training	27 Masters, 16 PhD,
Career Research Funding	\$2.6 million
Journal Articles	21
Academic Rank	Professor
Graduate Appointments	MIE, IBBME
Research Chairs	
Areas of Research	Human factors applications in medicine, mixed reality (MR) displays, human-machine interfaces for remote control, Visualizations of 3D data, manipulation of 3D data, Human factors applications in air traffic control, models of visual attention
Selected Awards	

Name	Kullervo Hynynen
Graduate Training	33 Masters, 32 PhD
Career Research Funding	NA
Journal Articles	260
Academic Rank	Professor
Graduate Appointments	Medical Biophysics, IBBME
Research Chairs	Canada Research Chair in Imaging Systems and Image-Guided Therapy (Tier 1)
Areas of Research	
Selected Awards	Fellow of the Acoustical Society of America, Robinson Award Lecture, North American Hyperthermia Society

Name	Andreas Mandelis
Graduate Training	21 Masters, 16 PhD
Career Research Funding	\$8.1 million
Journal Articles	284
Academic Rank	Professor
Graduate Appointments	MIE, ECE, IBBME
Research Chairs	Canada Research Chair (Tier I) in Diffusion-Wave Sciences and Technologies
Areas of Research	Fundamental physical processes as they impact instrumentation science and signal generation in the fields of thermophysics, non-radiative and radiative phenomena in electronic, optical and biomedical materials, thermal-wave and diffusion-wave phenomena in electronic and photonic media. More recent interests include building the foundations of biothermophotonic and bioacoustophotonic transport phenomena in hard (dental) and soft tissues.
Selected Awards	010 Killam Research Fellowship, 2009 Canadian Association of Physicists (CAP) Medal for Outstanding Achievement in Industrial and Applied Physics, Senior Prize of the International Photoacoustic and Photothermal Association.

Name	Graham Wright
Graduate Training	13 PhD, 5 Masters
Career Research Funding	\$69.5 million
Journal Articles	91
Academic Rank	Professor
Graduate Appointments	IBBME, Medical Biophysics
Research Chairs	Canada Research Chair (Tier 1) in Imaging for Cardiovascular Therapeutics
Areas of Research	Cardiovascular imaging, with an emphasis on Magnetic Resonance Imaging (MRI)
Selected Awards	Cum Laude Award, Research Trainee Prize, 89th Scientific Assembly and Annual Meeting of Radiological Society of North America (RSNA), Lauterbur Award, Walter Berdon Award for Basic Science Paper in Pediatric Radiology, Premier's Research Excellence Award

Name	Beno Benhabib
Graduate Training	21 PhD, 66 Masters
Career Research Funding	\$4 million
Journal Articles	113
Academic Rank	Professor
Graduate Appointments	MIE, ECE, IBBME
Research Chairs	
Areas of Research	Autonomous Robotic Systems
Selected Awards	

Name	Sandra Black
Graduate Training	15 PhD, 6 Masters
Career Research Funding	\$30.6 million
Journal Articles	276
Academic Rank	Professor
Graduate Appointments	Medicine, GDRS, IMS
Research Chairs	Brill Chair in Neurology
Areas of Research	neurological degeneration and regenerative processes at the integrative level; cognitive sequelae of stroke and stroke recovery; differential diagnosis and monitoring of dementia utilizing concurrent clinical, neuropsychological and neuroimaging measures
Selected Awards	University of Toronto Department of Medicine Mentorship Award, SRI Merit Pool Award, Deborah Ivy Christiani Brill Chair in Neurology, The Acenberg Award

Name	Geoff Fernie
Graduate Training	11 PhD, 19 Masters
Career Research Funding	\$55.65 million
Journal Articles	86
Academic Rank	Professor
Graduate Appointments	IBBME, MIE, SGS, OSOT, GDRS, IMS, Physical Therapy
Research Chairs	
Areas of Research	Development of Technology to Assist Older People; People with Disabilities to live independently at home and reduce the burden of care on formal and informal caregivers; Accessible environments; Hand Hygiene
Selected Awards	Inducted into the Terry Fox Hall of Fame, MEDEC Annual Award for Medical Achievement, Dr Jonas Salk Award, inducted as a fellow to the Canadian Academy of Health Sciences

Name	Allan Gross
Graduate Training	1 PhD
Career Research Funding	Not Indicated
Journal Articles	186
Academic Rank	Professor
Graduate Appointments	Surgery
Research Chairs	
Areas of Research	rthopaedic surgeon specializing in lower extremity reconstruction, with a particular interest in revision arthroplasty of the hip and knee.
Selected Awards	The Genzyme International Cartilage Repair Society (ICRS) Cartilage Research Life Time Award, Order of Ontario, The Canadian Orthopaedic Association President's Award for Excellence in Recognition of Outstanding Contributions to Orthopaedic Surgery

Name	David Jaffray
Graduate Training	10 Masters, 10 PhD
Career Research Funding	\$137 million
Journal Articles	169
Academic Rank	Professor
Graduate Appointments	IBBME, Medical Biophysics, Radiation Oncology
Research Chairs	
Areas of Research	Contribution to our understanding of the physics factors limiting the performance of megavoltage radiography systems; The development of portal imaging systems for use in radiation therapy; The development of kilovoltage cone-beam CT for image guided RT
Selected Awards	Innovation Award 2007, Inventor of the Year Award-University Health Network, Canada's Top 40 Under 40 Award

Name	Wayne Johnston
Graduate Training	24 Masters, 7 PhD
Career Research Funding	\$2.6 million
Journal Articles	318
Academic Rank	Full Professor
Graduate Appointments	IBBME, Surgery, IMS, SGS
Research Chairs	R. Fraser Elliott Chair in Vascular Surgery
Areas of Research	Abdominal aortic aneurysm repair. Hemodynamics and Doppler ultrasound research
Selected Awards	

Associate Professors

Name	Kristy Brock
Graduate Training	2 PhD, 3 Masters
Career Research Funding	\$1.8 million
Journal Articles	53
Academic Rank	Associate Professor
Graduate Appointments	Radiation Oncology, Medical Biophysics, MedSci, IBBME
Research Chairs	Cancer Care Ontario Research Chair
Areas of Research	Radiation Therapy, Image Guidance, Image Analysis, Biomechanical Models, Deformable Registration
Selected Awards	Radiation Physics Research Productivity Award; Research Leadership Award; Outstanding Research Potential; Most Influential Research Publication; Accuray Award

Name	Christopher Caldarone
Graduate Training	
Career Research Funding	\$3 million
Journal Articles	89
Academic Rank	Associate Professor
Graduate Appointments	Surgery, IBBME
Research Chairs	
Areas of Research	Apoptosis-related mitochondrial dysfunction after neonatal cardiac surgery; Remote ischemic preconditioning;
Selected Awards	

Name	Tom Chau
Graduate Training	14 PhD, 34 Masters
Career Research Funding	\$6.5 million
Journal Articles	93
Academic Rank	Associate Professor
Graduate Appointments	IBBME, GDRS, MIE, Nursing
Research Chairs	
Areas of Research	pediatric rehabilitation engineering; physiological access technologies including near-infrared spectroscopy, infrared thermography, mechanomyography and transcranial Doppler ultrasound
Selected Awards	Globe & Mail's 25 Transformation Canadians, Da Vinci Award (National MS Society, US), Top 40 Under 40, Maclean's Magazine 2006 Honour Roll, Perkin's Prize, Forchheimer Prize, Engineering Medal (PEO).

Name	Angela Cheung
Graduate Training	11 Masters, 4 PhD
Career Research Funding	\$4.4 million
Journal Articles	104
Academic Rank	Associate Professor
Graduate Appointments	IMS, IBBME, Medicine, HPME, DLSPH
Research Chairs	
Areas of Research	Postmenopausal Health (Osteoporosis, Cardiovascular Health, & Prevention of Cancers); Clinical and Functional Outcomes, Quality of Life, and Health Services Research; Innovations in Diagnostic Tests on Bone; Cost-effectiveness Analyses, Medical Decision Making, and Health Policy Issues related to Women's Health
Selected Awards	Canadian Who's Who, Who's Who of Canadian Women, Canadian Institutes of Health Research/OWHC Senior Investigator Award, Archie Sopman Diabetes Research and Education Award

Name	Tony Easty
Graduate Training	1 PhD, 12 Masters
Career Research Funding	\$5.7 million
Journal Articles	25
Academic Rank	Associate Professor
Graduate Appointments	IBBME, ECE
Research Chairs	Baxter Chair in Health Technology
Areas of Research	Human factors engineering, safety in healthcare, safe medication delivery, workflow practices in healthcare, medical device design and development
Selected Awards	ExCEL Award for Excellence in Clinical Engineering Leadership, Outstanding Young Canadian Biomedical Engineer

Name	Moshe Eizenman
Graduate Training	23 Masters, 5 PhD
Career Research Funding	\$1.6 million
Journal Articles	37
Academic Rank	Associate Professor
Graduate Appointments	IBBME, ECE, Ophthalmology
Research Chairs	
Areas of Research	Eye trackers, eye movements, visual fields plotting, array signal processing, adaptive filters, visually evoked potentials
Selected Awards	

Name	Stephen Lapinsky
Graduate Training	1 Masters
Career Research Funding	\$850,000
Journal Articles	78
Academic Rank	Associate Professor
Graduate Appointments	Medicine, IBBME
Research Chairs	
Areas of Research	Severe acute respirator syndrome in pandemic planning; critical care management of obstetrical patients, technology application of medicine, mechanical ventilation, continuous renal replacement therapy in critical care
Selected Awards	Canadian Healthcare Manager "Who's who in Healthcare 2001" Technology Award, Jubilee Award

Name	Catriona Steele
Graduate Training	3 PhD, 4 Masters
Career Research Funding	\$1.1 million
Journal Articles	40
Academic Rank	Associate Professor
Graduate Appointments	SPL, SGS, GDRS, IBBME
Research Chairs	
Areas of Research	Dysphagia;
Selected Awards	<i>Celebrating Education Excellence Award,</i>

Assistant Professors

Name	Jan Andrysek
Graduate Training	3 Masters
Career Research Funding	\$680,000
Journal Articles	12
Academic Rank	Researcher
Graduate Appointments	IBBME
Research Chairs	
Areas of Research	Rehabilitation engineering, prosthetics, orthotics, human gait, gait analysis techniques, biomechanical modeling of gait, assistive devices.
Selected Awards	Clifford Chadderton Award for Prosthetics and Orthotics Research, The University of Toronto Patent Award

Name	Elaine Biddiss
Graduate Training	4 Masters
Career Research Funding	\$150,000
Journal Articles	14
Academic Rank	Associate Professor
Graduate Appointments	GDRS, IBBME
Research Chairs	
Areas of Research	rehabilitation engineering; assistive technologies; promotion of physical activity for disabled children; healthcare environments; physiological measurement; multi-modal feedback; prosthetics
Selected Awards	Forchheimer Prize; Norman F. Moody Award; Perkins Prize

Name	Gregory Borschel
Graduate Training	1 PhD
Career Research Funding	\$623,000
Journal Articles	30
Academic Rank	Assistant Professor
Graduate Appointments	Surgery
Research Chairs	
Areas of Research	pediatric hand, nerve, and microsurgery
Selected Awards	

Name	Joseph Cafazzo
Graduate Training	3 PhD, 12 Masters
Career Research Funding	\$2.2 million
Journal Articles	28
Academic Rank	Assistant Professor
Graduate Appointments	HPME, IBBME, Medicine
Research Chairs	
Areas of Research	human factors, clinical engineering, and health informatics
Selected Awards	MOHLTC Career Scientist Award, ASGE Award of Distinction, 1998 RSNA Cum Laude Award

Name	Teodor Grantcharov
Graduate Training	2 PhD, 4 Masters
Career Research Funding	\$ 423,000
Journal Articles	58
Academic Rank	Assistant Professor of Surgery
Graduate Appointments	MedSci
Research Chairs	
Areas of Research	Surgical education, surgical simulation, assessment of technical skills, minimally invasive surgery
Selected Awards	Honorary Medal of the Danish Surgical Society, 2008 PAIRO Trust Travel Award for Clinical Educators, The Edith and Olfert Dines Hansen's Research Award, AstraZeneca's Annual Award for Young Danish Gastroenterologist

Name	Tom Schweizer
Graduate Training	
Career Research Funding	
Journal Articles	
Academic Rank	Assistant Professor
Graduate Appointments	IBBME, Neurosurgery
Research Chairs	
Areas of Research	Cognitive neuroscience, cerebellum, stroke, focal brain lesions, neuroimaging, real-world functional outcome, neurorehabilitation, knowledge translation
Selected Awards	

Name	Bradley Strauss
Graduate Training	4 Masters
Career Research Funding	\$3.9 million
Journal Articles	129
Academic Rank	Assistant Professor
Graduate Appointments	Medicine, IBBME, MedSci, CMP
Research Chairs	
Areas of Research	Clinical studies with new interventional devices; Coronary Imaging and Interventional Procedures; In vivo models of fibrointimal hyperplasia and pharmacologic interventions; Vascular smooth muscle cell behaviour in culture; Chronic Total Occlusions: Pathophysiology, Animal Models, Novel Therapies; Venous Bypass Graft Disease
Selected Awards	Frank Berkman Memorial Lectureship, Research Scholar of Heart and Stroke Foundation of Canada, Hewlett Packard Cardiology Award, Wyeth Research Award

Name	Patricia Trbovich
Graduate Training	2 Masters
Career Research Funding	\$298,000
Journal Articles	9
Academic Rank	Assistant Professor
Graduate Appointments	IBBME
Research Chairs	
Areas of Research	understanding and addressing problems of attention, interruption, multi-tasking, and overload in the healthcare workplace
Selected Awards	OGS

Name	Robert Weersink
Graduate Training	4 Masters
Career Research Funding	\$640,000
Journal Articles	24
Academic Rank	Lecturer
Graduate Appointments	IBBME
Research Chairs	
Areas of Research	
Selected Awards	

Name	Albert Yee
Graduate Training	7 Masters, 2 PhD
Career Research Funding	\$2.5 million
Journal Articles	44
Academic Rank	Assistant Professor
Graduate Appointments	IMS, Surgery, IBBME
Research Chairs	
Areas of Research	Preclinical models of spinal surgery; Vertebral metastases; Intervertebral disc cell metabolism
Selected Awards	Sunnybrook Research Institute Merit Pool Award