McGill University

Faculty of Engineering

Proposal for the creation of a Department of Bioengineering

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Executive Summary

The document outlines a proposal for the creation of a Department of Bioengineering within McGill University's Faculty of Engineering. Bioengineering is the application of biological scientific knowledge and principles to the design of structures, devices, materials and processes that solve problems of importance to society. It also encompasses the application of existing engineering knowledge and processes to the solution of problems involving living organisms and systems. In the last 10 years, bioengineering has been one of the fastest areas of growth in research activity within McGill's Faculty of Engineering. The Department of Bioengineering, the first at a Canadian university, will administer the B.Eng. in Bioengineering program for which accreditation by the Canadian Engineering Accreditation Board (CEAB) will be sought. It will house researchers and students, facilitate interdisciplinary research and training and be engaged in graduate education in bioengineering. It is expected that the new undergraduate program, once approved by MELS, will admit fifty new e students each year, with a complement of six to eight professors. The Department's academic and non-academic staff will provide focus to the development of activities in Bioengineering and the success of one of McGill's Priority Research Areas.

The significant global growth of the field of bioengineering demands increased numbers of highly qualified personnel. This is especially true in Quebec with its many biotechnology, bioenvironmental, biopharmaceutical, and medical device companies, which range from start-ups to established companies, constituting ample receptor capacity for the graduates in bioengineering. The new Department of Bioengineering will complement the existing professional degree awarding departments in Engineering, the Department of Bioresource Engineering in the Faculty of Agricultural and Environmental Sciences and the Department of Biomedical Engineering in the Faculty of Medicine at McGill University. It will provide the broad-based fundamental approach of the Faculty of Engineering by covering both health- and non-health-related areas. It will therefore fulfill the missing piece to a comprehensive coverage of engineering in the life sciences at McGill, and establishing the University as a leader in this field at both local and international levels.

1. Introduction

Herein, the Faculty of Engineering at McGill University proposes the creation of a Department of Bioengineering. Bioengineering is one of the fastest growing areas of engineering with considerable commercial and societal value. It covers a wide range of subjects associated with the application of engineering principles to life sciences. Bioengineering is broad and interdisciplinary and includes biomaterials, biomedical devices and prostheses, tissue engineering and regenerative medicine, biosensors, drug delivery systems, monitoring and diagnostic devices, and imaging tools. It also includes many non-health-related applications, such as environmental systems, agriculture and the processing of biofuels. In addition, bioengineering concerns the application of knowledge from the life sciences to engineering problems – a synergistic benefit exemplified by the development of novel biomimetic building materials and structures, design of energy efficient biomimetic propulsion systems, biological technologies for environmental restoration, and the construction of neuromorphic intelligent machines and biologically-inspired robots. Of necessity, progress in bioengineering requires multidisciplinary team efforts in biophysics, physiology, biotechnology, chemical engineering, electrical engineering, mechanical engineering, materials engineering, biomedical engineering, biochemistry, bioinformatics, medical informatics and other fields.

1.1. Definition(s) of Bioengineering

Bioengineering is rooted in physics, mathematics, chemistry, biology, and the life sciences. It is the application of a systematic, quantitative, and integrative way of considering, and approaching the solutions to problems important to life sciences. As might be expected for a relatively new and highly multidisciplinary field, there are several definitions of 'bioengineering'. We provide some examples below.

In recognizing that no definition could completely eliminate overlap with other research disciplines or preclude variations in interpretation by different individuals and organizations, the NIH Bioengineering Consortium agreed on the following definition for Bioengineering research on biology, medicine, behavior, or health: *"Bioengineering integrates physical, chemical, or mathematical sciences and engineering principles for the study of biology, medicine, behavior, or health. It advances fundamental concepts, creates knowledge for the molecular to the organ systems levels, and develops innovative biologics, materials, processes, implants, devices, and informatics approaches for the prevention, diagnosis, and treatment of disease, for patient rehabilitation, and for improving health."*

The 105th U.S. Congress, on the other hand, in June 25, 1998 (in H.R. 4170 "A Bill to amend the Public Health Service Act to establish a National Center for Bioengineering Research") defined bioengineering as: *"Bioengineering is an interdisciplinary field that applies physical, chemical, and mathematical sciences and engineering principles to the study of biology, medicine, behavior, and health. It advances knowledge from the molecular to the organ systems level, and develops new and novel biologics, materials, processes, implants, devices, and*

informatics approaches for the prevention, diagnosis, and treatment of disease, for patient rehabilitation, and for improving health."

Indeed, life sciences are playing an increasingly large role in the everyday life of Canadians and some would argue that the country's economy is shifting to a "bio-based economy". BIOTECanada[1] defines the bio-based economy as follows:

Biotechnology is driving an economic shift to a broader "bio-based economy" which integrates biologic products and technologies, derived from renewable resources, into new sustainable production and manufacturing processes.

...

The concept of the bio-based economy goes beyond the traditional definition of biotechnology. The bio-based economy focuses on biological tools and products from renewable resources to create wealth and sustainability in the production of medical treatments, diagnostics, more-nutritional foods, energy, chemicals, and materials, while improving the quality of the environment.

1.2. Historical background and recent progress of bioengineering at McGill

It is proposed that the name of the new Department be *Bioengineering*. This name reflects the broad scope of research and teaching activities that the department will oversee. The name was selected based on an in-depth survey of departments with a similarly broad focus at institutions across North America (Appendix A). It was found that most of these departments are called either Bioengineering or Biomedical Engineering. The Biomedical departments tend to be older departments, created when the sole focus was on application of engineering principles to healthcare, particularly in the clinical context. The areas of activity of many of these departments have recently broadened greatly to encompass non-healthcare related areas of bioengineering.

Undergraduate and graduate education in engineering and the life sciences at McGill University until the present time has been nominally recognized only in two subsectors of bioengineering – Bioresource Engineering (formerly Agricultural Engineering) and Biomedical Engineering. The first graduates from the accredited undergraduate program in Agricultural Engineering appeared in 1971. This program was renamed B.Eng. in Bioresource Engineering in 2005 and is offered by the Department of Bioresource Engineering within the Faculty of Agricultural and Environmental Sciences. The undergraduate Bioresource Engineering program, as it stands now, permits students to concentrate in the following areas: BioEnvironmental Engineering, Soil and Water Engineering, Ecological Engineering, Food and Bioprocess Engineering, and Agricultural Engineering. The Department of Bioresource Engineering thus has an emphasis on areas which are complementary to the focus areas of the proposed bioengineering department.

[1] http://www.biotech.ca/en/what-biotech-is/bio-economy.aspx

The Master's and Ph.D. degrees in Biomedical Engineering, offered by the Department of Biomedical Engineering within the Faculty of Medicine, were approved by the Quebec Ministry of Education in 1993. Prior to that time, graduate students completed biomedical engineering related theses by registering in other Ph.D. programs in the traditional engineering and medical departments. The Department of Biomedical Engineering is focused on clinical aspects of health care technology. This department does not offer an undergraduate degree program.

In 2005, the Faculty of Engineering, in collaboration with the Department of Biomedical Engineering, created a minor program in Biomedical Engineering for undergraduate students in engineering. The development of the engineering minor program in Biomedical Engineering was motivated by the growing level of interest and research activity by the Faculty of Engineering in the area of bioengineering.

In parallel with these activities, the number of researchers within the Faculty of Engineering who are active in bioengineering research topics has been growing significantly. There are now approximately thirty professors across all of the Engineering departments who are engaged in this area, the majority of whom have been hired in the last ten years. Indeed, the creation of a unit within the Faculty of Engineering that would be dedicated to bioengineering has been under consideration for more than four years. In January 2007, a Faculty of Engineering task force on bioengineering, which included six members from the Faculty as well as representation from the Faculty of Medicine and the Faculty of Agricultural and Environmental Sciences was established. The task force reported in May 2007, making a number of recommendations. These included: i) the creation of a new accredited undergraduate engineering program in Bioengineering, ii) the creation of a Department or School of Bioengineering, and iii) the creation of a multi-faculty research institute with a focus in this area. The task force also stressed the highly interdisciplinary nature of this field and the importance of collaboration and communication between relevant units and personnel across the university.

The first of these recommendations has already been initiated. The Faculty of Engineering will be redesigning the proposed B.Eng. in Bioengineering program to meet the recommendations of CREPUQ's Commission d'évaluation des projets de programmes, as part of the process leading to its approval by MELS. This undergraduate program will be the first dedicated full program in the life sciences and engineering within the Faculty of Engineering and will be complementary to the existing Engineering programs as well as the Bioresource Engineering program, with little or no overlap beyond the usual training in core engineering fundamentals. The initial proposal was approved by Senate in May 2011with the expectation that it would be offered by a new department or school of Bioengineering. The second of the task force's recommendations is the topic of the current proposal. The third recommendation is also a significant component of the development of this strategic area within McGill, but lies outside the scope of the current proposal. However, it is addressed further in Section 5 of this document.

1.3. Motivation: The need for graduates in Bioengineering

Significant global growth of the field of bioengineering demands increased numbers of highly qualified personnel (HQP). For example, in its most recent occupational outlook, the U.S. Department of Labor states that among all engineering disciplines Biomedical engineers, which in their definition includes biomechanical and biomaterials engineering, should experience the fastest growth of employment over the next decade. The report also states "*Biomedical engineers are expected to have employment growth of 72 percent over the projections decade, much faster than the average* [about 12%] *for all occupations. The aging of the population and a growing focus on health issues will drive demand for better medical devices and equipment designed by biomedical engineers. Along with the demand for more sophisticated medical equipment and procedures, an increased concern for cost-effectiveness will boost demand for biomedical engineers, particularly in pharmaceutical manufacturing and related industries.*"[2] This will bring the total employment for biomedical engineers in the U.S. near to that of Chemical Engineers and higher than that of Petroleum Engineers. In addition, the report "Occupational employment projections to 2018"[3] projects the 10-year growth in employment of Biomedical Engineers to be 72%. The next highest growth rate for an engineering occupation is Software Engineering at 34%. The report lists "Bachelor degrees" as the most significant source of training for these new positions.

The need for HQP in bioengineering is especially true in Quebec, which boasts a large concentration of pharmaceutical, biotechnology, and bioengineering companies ranging from start-ups to established companies, constituting ample receptor capacity for graduates in bioengineering. Notwithstanding the recent closures of several pharmaceutical research offices in Montreal, Quebec has the fourth-highest number of biotechnology companies of any province or state in North America.[4] Canadian head offices of some thirty international pharmaceutical companies are in Quebec. The province is also host to almost half of the pharmaceutical companies in Canada, with the greater part of the Canadian basic and clinical research activity located in Montreal.[5] The life sciences company database[6] maintained by *BIOTECanada* lists over 150 Quebec area firms involved in biotechnology. Many of these biotechnology companies are in the health sector, where a total of sixty-seven companies employ over 2,300 people. Quebec obtains the largest share of Canadian biotech investment R&D (Statistics Canada, Canadian Trends in Biotechnology, 2nd ed., 2005) and ranks as the pharmaceutical R&D capital of Canada, with an estimated 13,000 health researchers in public research centres and a health sciences industry workforce of 25,000. *BIOTECanada* also notes that out of all provinces in

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[2] Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook, 2010-11 Edition*, Engineers, on the Internet at http://www.bls.gov/oco/ocos027.htm

[3] *Alan Lacey and Benjamin Wright* , "Occupational employment projections to 2018", Monthly Labor Review Online, Vol. 132, No. 11, November 2009

[4] "Life Sciences: Biotechnology Industry," Investissement Québec, http://www.investquebec.com/en/index.aspx?page=1874

[5] "Life Sciences: Pharmaceutical Industry," Investissement Québec, http://www.investquebec.com/en/index.aspx?page=398

[6] Canadian Life Sciences Database, BIOTECanada, http://www.canadianlifesciences.com/ca/index.php

Canada, Quebec has the highest percentage of GDP associated with the bio-based economy (as of 2007; 7.86% as compared with the country-wide average of 6.4% and 6.81% in Ontario).[7] The size of the bio-based economy in Canada overall is similar to that of the automotive industry, slightly lower than the oil and gas industry and about six times the size of the aerospace industry.

According to *Montréal InVivo,* the life sciences industry in Quebec employs over 40,500 people.[8] Medical devices and technologies are a large part of this industry, including over 600 companies and employing 15,000 people, the majority of which are to be found in the Montreal region.[9] In the specific area of medical devices, a recent *MDEIE* report[10] estimates employment at 5,200 in 2008 with 29% of these positions being held by university graduates. This same report notes (Tableau 9) that, according to company surveys, recruitment of personnel is considered to be a current and future challenge determining growth of the industry in Quebec.

By hosting the world-leading Montreal Neurological Institute (MNI) and being in close proximity to the National Research Council Biotechnology Research Institute, Canada's largest biotechnology research centre employing over 800 people, McGill University is uniquely positioned in Canada to advance the field of bioengineering. Undoubtedly, the emergence of the world-class pharmaceutical and biotechnology industry in Montreal and Quebec has been aided by the excellence of McGill's research and education in the medical and life sciences. However, as discoveries in the life sciences lead more and more towards commercial products, engineering becomes increasingly important. Thus, the Faculty of Engineering at McGill, along with engineering faculties at our sister institutions, have a critical role to play in the maintenance and growth of the bioengineering industry in Quebec and Canada. Indeed, while Quebec (and Canada) based universities do not have departments under the name of Bioengineering the other Montreal-area and Quebec universities are not standing still in this regard. For example, École Polytechnique de Montréal and École de technologie supérieure (ETS) are both expanding their research and teaching activities in this area. However, McGill should be a leader in this field at both local and international levels. Several of our major competitors in Europe and the USA (Appendix A) have created similar structures, which are now thriving, and it is clear that there is a great need for such a Department here in Canada, and that it should be based at McGill, in Montreal.

1.4. Reporting structure

In considering options for the management and delivery of the undergraduate Bioengineering program, a number of options are clearly available: i) The program could be delivered by an existing department which could hire additional staff as necessary, as was done for the recently created B.Eng. in Software Engineering; ii) The program could be delivered by a

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[7] http://www.biotech.ca/en/what-biotech-is/bio-economy.aspx
[8] http://www.montreal-invivo.com/en/research/technologies/human_capital.php
[9] http://www.montreal-invivo.com/en/research/technologies/scope.php
[10] « *L'industrie manufacturière québécoise du matériel médical - Une industrie aux multiples facettes* », report published by Quebec's ministère du Développement économique, de l'Innovation et de l'Exportation, 2010

new unit that is based within one faculty, which is what we propose here; iii) The program could be delivered by a newly established unit that reports to multiple faculties, as is done by the McGill School of the Environment. The first option is not appropriate for this topic, since it cuts across every existing department of the Faculty of Engineering (unlike the situation for Software Engineering which was clearly of principal concern to the Department of Electrical and Computer Engineering). The third option is clearly an attractive one for a highly multidisciplinary area such as this and has been considered carefully. However, given the established structure at McGill for the assignment of teaching duties (via department chairs) and the requirement by the Canadian Engineering Accreditation Board (CEAB) that accredited engineering programs be delivered and led by licensed engineers, it would be extremely challenging to deliver an accredited undergraduate engineering program from an inter-faculty unit. Therefore it is proposed that the new unit should reside within the Faculty of Engineering, reporting to the Dean of Engineering, and that it should be structured as an academic department. This will then be consistent with the other departments within the Faculty of Engineering that offer professional programs in Engineering. However, although it will reside in the Faculty of Engineering, the new department will coordinate closely with the Department of Biomedical Engineering and the Department of Bioresource Engineering, in addition to other related units in other faculties.

Therefore, at McGill University, bioengineering can be seen as a stool with three legs – each leg corresponding to a current concentration of particular expertise and focus in one of the faculties. The three pillars of Bioengineering at McGill are i) the broad-based fundamental approach of the Faculty of Engineering with a coverage of both health- and non-health-related areas, ii) the clinical health-care focus of the Department of Biomedical Engineering in the Faculty of Medicine, and iii) the biological, agricultural, ecological, and environmental focus of the Department of Bioresource Engineering in the Faculty of Agricultural and Environmental Sciences.

This Department of Bioengineering - unique in Canada - will administer the B.Eng. program in Bioengineering and will house researchers and students and facilitate interdisciplinary research and training in bioengineering.

2. Justifications and benefits for the discipline, the Faculty, University, academic staff and students

In its Strategic Research Plan of 2008, McGill University lists Bioengineering as an existing area of strength and of current and future investment. In recent years, the University has invested extensively in bioengineering as evidenced by the number of Canada Research Chair positions (Tiers 1 and 2) across numerous faculties, including Engineering, Science, Agricultural and Environmental Sciences, Medicine and Dentistry. Within the Faculty of Engineering, bioengineering has been one of the fastest areas of growth, and currently there are approximately thirty faculty members whose research is focused on bioengineering. A major portion of these are young and dynamic new hires (e.g. five have been hired since 2008) who are already

contributing significantly to the fields of biology, biotechnology and medicine. These researchers have been highly successful in generating operating and infrastructure funding for bioengineering research, amounting to approximately $24M since 2005. This level of funding has been generated from agencies such as NSERC (from virtually all possible grant programs e.g. Discovery Grants, Idea to Innovation, Collaborative Health and Strategic Research Networks), CIHR, FQRNT FRSQ, MDEIE, industrial sources, and US agencies.

In addition, and as to be expected in such an interdisciplinary domain, engineering faculty members with bioengineering interests have ongoing collaborations among faculty colleagues and with other McGill units, including the Departments of Biomedical Engineering, Physiology, Neurology and Neurosurgery, Experimental Medicine. and Physical and Occupational Therapy (amongst others) in the Faculty of Medicine, the Departments of Bioresource Engineering and Natural Resource Sciences in the Faculty of Agricultural and Environmental Sciences, several departments in the Faculty of Science (e.g., Biology, Physics, Chemistry, and the School of Computer Science), the McGill School of the Environment, the Institute of Parasitology, the Faculty of Dentistry, MNI, Réseau universitaire intégré de santé McGill (RUIS), and its primary teaching hospitals and research institutes, the MUHC Research Institutes at Montreal General and Royal Victoria Hospitals.

The influx of new faculty has also enhanced teaching programs in the Faculty of Engineering. Since 2003, many new graduate and undergraduate courses in the field of bioengineering have been created to complement existing courses: including CHEE 515 Materials Surfaces: A Biomimetic Approach, CHEE 561 Introduction to Soft Tissue Biophysics, CHEE 562 Engineering Principles in Physiological Systems, CHEE/MECH 563 Biofluids and Cardiovascular Mechanics, CHEE 591 Environmental Bioremediation, CIVE 500 Molecular Techniques for Environmental Biotechnology, ECSE 517 Neural Prosthetic Systems, MECH 547 Mechanics of biological materials, MECH 553 Design and Manufacture of Microdevices, and MIME 470 Engineering Biomaterials. The creation of the Minor in Biomedical Engineering (approved in fall 2005) allowed undergraduate students to gain exposure to topics in this field, which was previously provided only at the graduate level. This minor was added to other minors in the general bioengineering area – the Minor in Biotechnology and the Minor in Environmental Engineering. In 2009, the NSERC CREATE program in Integrated Sensor Systems was successfully established. This is hosted through McGill Institute for Advanced Materials, in which biosensors form a significant element. This growing strength in bioengineering within the Faculty of Engineering has recently culminated in the creation and university approval of the B.Eng. in Bioengineering, demonstrating the obvious importance of the subject to McGill.

The proposed Department of Bioengineering will galvanise this strength and will provide focus to the development of activities in this area. This will be achieved through 1) the improvement in the acquisition of resources, such as research laboratory space, 2) the cluster hiring of new faculty with expertise in bioengineering, and 3) the establishment of new graduate and undergraduate courses. Therefore, it will act as a focal point and provide leadership in the area of bioengineering for the Faculty and for McGill as a whole. It will administer the B.Eng. program, and will participate in the creation of new M.Eng. and Ph.D. graduate programs in

collaboration with existing units at McGill and house researchers and students and facilitate interdisciplinary research and training in bioengineering. The B.Eng. program will expand the existing high-quality training in traditional engineering disciplines and will increase the pool of potential HQP. Moreover, the multidisciplinary nature of the field will cross-fertilize research areas across McGill and create an attractive environment for graduate and post-doctoral students.

In terms of staff, initially (Summer/Fall 2012), three faculty members will be hired that will form the nucleus of the Department of Bioengineering. This will include an endowed chair in Bioengineering, who will lead the Department. In the following year, this number is expected to increase to six. A further two hires are planned by 2014. In terms of students, initially (Fall 2014/Winter 2015), the undergraduate program is expected to attract thirty new students. This is a similar number to that currently registered in the Minor in Biomedical Engineering. At steady-state, the number of new undergraduate students admitted each year is expected to be around fifty. In terms of graduate studies, seventy-five graduate students are expected to be trained annually (Section 5). This will be in addition to the more than one hundred graduate students who are already receiving training in bioengineering throughout the existing units in the Faculty.

The benefits of a newly created Department of Bioengineering will have upon the Faculty of Engineering and McGill can be summarised as follows:

1. Through the B.Eng. in Bioengineering, the new Department will attract a new group of students into the Faculty of Engineering, McGill University and into the engineering profession.

2. The new Department will bring greater focus and clarity to bioengineering faculty, researchers and graduate students who are currently spread across the Faculty of Engineering. By also working with other units at McGill via an interdisciplinary institute for bioengineering, it will help to build the platform for new research-oriented Master's and Ph.D. programs in Bioengineering, increasing the efficient usage and leveraging of resources.

3. The new Department will cement the growing trend of the Faculty of Engineering away from being a unit exclusively focused on the physical sciences towards a well-balanced unit including the life sciences.

4. Given McGill's current strength in bioengineering research and graduate engineering, and the high profile of McGill in the Canadian engineering profession, the creation of the department will also influence and assist the development of national standards for the certification of bioengineering undergraduates as professional engineers.

5. The Department of Bioengineering will facilitate a dedicated space for teaching and research in bioengineering.

6. The Department of Bioengineering will provide more visibility to the new undergraduate and graduate Bioengineering programs, as well as the bioengineering professors in Engineering to be hired.

3. Proposed teaching and research activities of the Department of Bioengineering;

3.1. Teaching

The department will offer undergraduate, graduate and postdoctoral training in bioengineering. It will administer the B.Eng. program in Bioengineering, and create M.Eng. and Ph.D. graduate programs in the field, in collaboration with other McGill units (Section 5)

With the aim of providing a professional program in Engineering, the B.Eng. in Bioengineering is designed to meet the accreditation standard of CEAB. It is intended to provide the broadest training in bioengineering of any program in Canada. The initial proposal was developed by a Faculty of Engineering Committee over two years and through a number of consultations within the departments in the Faculty of Engineering and McGill University. In January 2011, a Bioengineering Program Committee, composed of Engineering professors and a professor from the Department of Biomedical Engineering, in the Faculty of Medicine, was established. The mandate of the committee is to oversee all aspects of the undergraduate program in bioengineering. This includes: (a) ensuring that students are advised appropriately during their program; (b) periodic program review to ensure that the program and courses meet their objectives, and if not, to ensure that necessary revisions are made; (c) in collaboration with the Dean of Engineering, insure that the program has sufficient resources for effective implementation. Until the establishment of the Department of Bioengineering, the Associate Dean (Undergraduate Education) and/or the Bioengineering Chair has the responsibility of assigning staff to the teaching of the bioengineering specific (BIEN) courses.

The stated general objectives of the program are to a) provide students with the ability to apply sound engineering foundations and physical principles in order to solve problems of a biological nature; and b) prepare students for the broad area of bioengineering incorporating the professional and academic fields of biomaterials engineering, medical devices and prosthetics, biomechanics, and tissue engineering. The specific objectives are: i) through courses offered within the Faculty of Engineering, provide the student with core knowledge in the areas of (a) bioelectricity, (b) biomechanics, (c) biomaterials, (d) biochemical engineering, (e) bioinstrumentation, (f) biotransport, (g) bioenvironmental engineering, (h) biophysics; ii) through courses offered outside of the Faculty of Engineering, provide student with knowledge in the fundamental natural sciences; specifically, physics, chemistry, cell and molecular biology, and physiology; and iii) provide the students with a solid foundation in mathematics and computing necessary for bioengineering modeling, experimental design, and data analysis.

The B.Eng. in Bioengineering program, approved by Senate in May 2011,has been making its way through the external approval process, in order for it to be approved by MELS.

The plan is now to have the program in place for students, at least those entering the General Engineering year (Year 0), to be admitted into this new program for September 2014.

3.2. Research

The department will house researchers and students and facilitate interdisciplinary research and training in bioengineering. Bioengineering research is broad and interdisciplinary and includes biomaterials, biomedical devices and prostheses, tissue engineering and regenerative medicine, biosensors, drug delivery systems, monitoring and diagnostic devices, and imaging tools. Bioengineering also includes non-health-related work, for example, in the areas of environmental, agriculture and biofuels. The quality of the economy and the quality of life of individual citizens are inextricably bound together and are related to wellness and the health care system. Bioengineering will be a growing and critical component of health care advancement in this century, bringing many benefits to our communities including:

- Development of new biosensors and detectors to monitor the environment (air / water) and bodily processes or abnormalities (sepsis, glucose / cholesterol / urine) with much shorter delays (e.g. a few minutes at the doctor's office) rather than the delay normally associated with laboratory examinations and traditional cultures, thereby reducing reliance on and the need for costly centralized laboratories.
- A non-invasive treatment for chronic diseases through microencapsulation of a target cell (some trials are already underway) to regularly monitor blood sugar levels in diabetics, to treat liver failure and renal to control cholesterol. With this approach, expensive equipment (dialysis) or periodic injections of insulin, which are invasive and do not fully control fluctuations in blood levels, will be replaced by the ingestion of microcapsules during meals, thus providing an inexpensive and simple intervention for the patient.
- Therapies based on nanostructures, implantable chips and microfluidics to improve tissue regeneration and strengthening of bones and teeth, which will reduce health problems associated with aging and allow people with spinal cord injuries to regain their ability to lead a normal life. Neurological engineering solutions will create sensory implantable prostheses to restore sight, hearing and touch, and the normal function of artificial limbs.
- More accurate and effective diagnoses will be provided by computer modelling, and advanced signal processing of physiological systems will establish and monitor, assess and choose treatment or appropriate prostheses.
- Development of more advanced robotics, inspired by biological models, and creates new opportunities and commercial applications in fields as diverse as electronics and industrial sensing, aerospace, robotics and health care, and including remote surgery.
- New analytical and computational instruments for pharmaceutical research, leading to more rapid and reliable drug discovery
- Improved detection of environmental pathogens, resulting in fewer incidents of infection (e.g. MRSA infection in hospitals, food- and water-borne illnesses)

The following professors (with their research domains) who are already based in the Faculty of Engineering could potentially be Associate Members of the new Department, and contribute to the teaching of the new bachelor's degree program in bioengineering through courses that they offer in their own programs:

- T. Arbel, Associate Professor in Electrical and Computer Engineering, *medical imaging, image registration, image-guided neurosurgery.*
- F. Barthelat, Assistant Professor in Mechanical Engineering, *biomimetic materials and composites.*
- M. Cerruti, Assistant Professor in Materials Engineering, CRC Tier II awardee, *bioactive scaffolds for bone and cartilage regeneration.*
- V. Chodavarapu, Assistant Professor in Electrical and Computer Engineering, *CMOS biochemical sensors, neural implants.*
- J. Clark, Professor in Electrical and Computer Engineering, *cognitive modeling of visual attention mechanisms, human-computer interfaces.*
- S. Coulombe, Associate Professor in Chemical Engineering, CRC Tier II awardee, *plasma techniques for cell permeabilization*
- D. Frigon, Assistant Professor in Civil Engineering, *wastewater remediation*
- R. Gehr, Associate Professor in Civil Engineering, *environmental engineering, water and wastewater treatment processes.*
- P.L. Girard-Lauriault, Chemical Engineering, *tissue engineering*
- S. Ghoshal, Associate Professor in Civil Engineering, William Dawson Scholar, *bioremediation processes for polluted soil and groundwater*
- R. Hill, Associate Professor in Chemical Engineering, CRC II Awardee, *macromolecules on phospholipid-bilayer membranes, and studies of biologically active membranes (reinforced hydrogels) synthesized from cellulose*
- E. Jones, Assistant Professor in Chemical Engineering, *measurement and modeling of cardiovascular systems.*
- A. Kietzig, Assistant Professor in Chemical Engineering, *biomimetic surface engineering*
- A. Kirk, Professor in Electrical and Computer Engineering, James McGill Professor, *affinity biosensors based on nanophotonic structures.*
- R. Leask, Associate Professor in Chemical Engineering, William Dawson Scholar, *engineering analysis of cardiovascular pathology.*
- J. Liu, Assistant Professor in Civil Engineering, *environmental fate of pollutants, environmental impact of nanomaterials, and the removal of pollutants from water.*
- X. Liu, Assistant Professor in Mechanical Engineering, Chwang-Seto Faculty Scholar, *micro- and nano-robotic systems, design of MEMS devices and microfluidic devices for biochemical analysis, biological research (lab-on-a-chip), and clinical diagnosis.*
- Z. Mi, Assistant Professor in Electrical and Computer Engineering, Hydro-Quebec Nanoengineering Scholar and William Dawson Scholar, *nanotechnology for biosensing.*
- L. Mongeau, Professor in Mechanical Engineering, CRC Tier I awardee, *voice production, modeling of speech biomechanics, instrumented voice boxes*

- R. Mongrain, Associate Professor in Mechanical Engineering, William Dawson Scholar, *prosthetic heart valves, stents, biomaterials, CAD design of implants, heart biomechanics*
- S. Musallam, Assistant Professor in Electrical and Computer Engineering, CRC Tier II awardee, *brain-machine interfaces, micro-electrode arrays, neurophysiology, decoding of brain signals.*
- S. Nazhat, Associate Professor in Materials Engineering, Hatch Faculty Fellow, *polymer and composite biomaterials.*
- J. Nicell, Professor in Civil Engineering, James McGill Professor, *biological treatment of industrial waste, perception of odour.*
- M. Popovic, Associate Professor in Electrical and Computer Engineering, *microwave scanning of near-surface breast tissue, biological applications of computational electromagnetics*
- T. Quinn, Associate Professor in Chemical Engineering, CRC Tier I awardee, *growth and repair of cartilage.*
- A. Rey, Professor in Chemical Engineering, James McGill Professor, *biological membranes, biological polymer processing, and biomimetics.*
- S. Shrivastava, Associate Professor in Civil Engineering and Applied Mechanics, *biomechanics.*
- N. Tufenkji, Associate Professor in Chemical Engineering, CRC Tier II awardee, *transport and fate of microorganisms in aqueous systems.*
- S. Vengallatore, Associate Professor in Mechanical Engineering, CRC Tier II awardee, *medical diagnostics & intelligent drug delivery.*
- V. Yargeau, Associate Professor in Chemical Engineering, *bioremediation of wastewater*

4. Uniqueness of the Department of Bioengineering

It is apparent that in spite of the growing strength in bioengineering and the obvious importance of the subject, there is currently no focus to the developmental activities in the area; each unit in the Faculty has been proceeding according to their own plans and agendas. This has hampered the acquisition of resources, such as research laboratory space, and has led to a fractured approach to hiring new faculty and establishing new courses. The establishment of a Department of Bioengineering will act as a focal point and provide leadership in the area of bioengineering for the Faculty and for McGill as a whole.

In terms of teaching, currently, there is limited access for undergraduates to training in bioengineering in the Faculty of Engineering, primarily through the minors in Biomedical Engineering or Biotechnology. Current major programs in the Faculty of Engineering teach some aspects of Bioengineering within their core program, e.g. biochemical or biotechnology courses are offered in the B.Eng. program in Chemical Engineering or an environmental course in Civil Engineering. On the other hand, and aside from the common courses that offer fundamental knowledge in engineering, the B.Eng. programs in Electrical and Computer Engineering, Mechanical Engineering or Materials Engineering do not offer courses that are specifically

related to bioengineering as core requirements in their respective programs. However, all programs offer a limited number of bio-related technical complementary courses in their programs. Therefore, at present there is no program that offers the breadth of training that is required in Bioengineering, such as in the combination of areas of bioelectricity, biomechanics, biomaterials, biochemical engineering, bioinstrumentation, biotransport, bioenvironmental engineering, and biophysics. Outside of the Faculty of Engineering, undergraduate students can carry out a CEAB accredited B.Eng. Bioresource Engineering, but this has a particular focus on agricultural and environmental bioengineering. It is therefore apparent that there is a clear need for an accredited undergraduate degree program providing a fundamental training in the broad area of engineering in the life sciences.

The undergraduate program that will be housed in the Department of Bioengineering is designed to be accredited by CEAB and would be complementary to the B.Eng. programs in Engineering and in Bioresource Engineering, and would also provide a solid life sciences and engineering background for those wishing to continue in Bioengineering, Biomedical, or Bioresource Engineering at the graduate level. Initially, due to resource limitations and strict constraints imposed by accreditation requirements (e.g. courses with Engineering Science or Engineering Design components have to be taught by licensed professional engineers), the program will concentrate on providing a strong fundamental background as well as exposure to a limited set of advanced topics, dependent on the expertise currently available in the Faculty (e.g. biomaterials and biomechanics). In the future it is envisaged that the program will be expanded to include multiple tracks or concentrations, such as tracks focusing on biomedical engineering, biomaterials, biomechanics or environmental engineering. The program will be under the administration of the Department of Bioengineering, but would make use of expertise and resources that are spread throughout the other departments in the Faculty of Engineering and McGill.

5. Future outlook: Establishment of a multi-Faculty interdisciplinary McGill Institute for Bioengineering

McGill University highlights Bioengineering as an existing area of strength in its current (2008) and new Strategic Research Plans. Bioengineering is also a strategic research area in the Faculty of Engineering as reflected by its significant growth in recent years. Indeed, a number of departments highlight research themes that fall within facets of bioengineering, e.g. biomedical engineering and biotechnology and environmental engineering in the Department of Chemical Engineering; environmental engineering in the Department of Civil Engineering and Applied Mechanics; cardiovascular engineering, voice production, bone fracture and osteoporosis, mechanics of biological materials and biomimetics in the Department of Mechanical Engineering; biomaterials and tissue engineering in the Department of Mining and Materials Engineering; and biomechanics, biosignals processing, neural Engineering and neuromuscular systems, medical informatics, medical imaging and solid modelling in the Department of Electrical and Computer Engineering. As can be appreciated, the research topics are interdisciplinary and wide-ranging, reflecting broad contributions from every single department

in the Faculty. In addition to the various departments in Engineering, Bioengineering research takes place in several departments in Science (e.g. Biology, Physics, Computer Science, and Chemistry), Medicine (Biomedical Engineering, Physiology, Physical and Occupational Therapy), the McGill School of the Environment, Agricultural and Environmental Sciences, and Dentistry.

In order to further strengthen the presence and status of Bioengineering research within the Faculty of Engineering, collaboration between the various bioengineering researchers within the Faculty and within McGill must be enhanced. Therefore, the establishment of a multi-Faculty interdisciplinary McGill institute for bioengineering would integrate the various groups working in the area of Bioengineering. Institutes at McGill have traditionally been defined as units that are engaged in research as well as teaching at the graduate level. Students can be registered in an institute and staff members, appointed in departments can be cross-appointed to an institute, if the institute offers a graduate program. Faculty could also join the interdisciplinary institute for bioengineering as Associate Members or Affiliate Members. The institute could be modelled after ones at the University of Toronto, the École Polytechnique de Montréal, and Dalhousie University.

This institute would have the mandate of coordinating joint research projects and the acquisition and management of shared facilities in the field of bioengineering. It would also oversee the design and administration of interdisciplinary graduate degree programs (Masters and Ph.D.) in Bioengineering and would be under the direction of an executive committee appointed and overseen by the Deans of Engineering, Agricultural and Environmental Sciences, and Medicine, for example.

The institute would hold regular meetings and seminars, and could provide research laboratory space and centralized shared facilities. In addition, there are many benefits to the University that accrue upon the enabling of interdisciplinary research; benefits which make the required institutional changes worthwhile. One of the principal benefits is the increased access to research funding, which is increasingly being targeted to emerging technologies and areas of societal importance that span many disciplines.

The creation of an institute that will stimulate cross-faculty collaborations should be the focus of concerted efforts by all interested parties at McGill.

6. Resources

6.1. General principles

The creation of the Department of Bioengineering represents net growth for McGill University. The department will attract new undergraduate and graduate students, who would not otherwise have attended McGill, which will result in increased revenue to the university and Faculty of Engineering. Similarly the academic staff who will be appointed in to the department

will be new hires and will not simply be transferred from existing departments. The Office of the Provost has agreed to provide the necessary funding to the Faculty of Engineering in order to adequately fund the start-up and operations of the new department. Funding for the new department will not be taken from budgets of existing departments within the Faculty of Engineering.

6.2. Staff

6.2.1. Academic Staff

The new Department will support teaching and research activities in the area of bioengineering. It is estimated that a steady-state complement of six to eight professors will be needed to support the teaching load of the new program in bioengineering. These professors will handle the teaching of the BIEN courses in the program (Appendix B). The Department will begin with a complement of three new professors, including an endowed Chair in Bioengineering, who will be hired during summer 2012. This endowed Chair in Bioengineering will also serve as the Chair of the new department and direct the proposed program. The other two hires will be Tenure-Track professors at the Assistant or Associate Professor levels. The search committees for these positions will include a representative from one of the other non-engineering departments and the Faculties of Engineering and Medicine will engage in mutual consultations on all hires in this area to fortify the breadth of expertise and cover teaching needs with all available staff on campus. In 2012-2013 there will be another search to hire three more professors in bioengineering to increase the number of professors to six (all six slots have been confirmed by the Provost). Two additional Faculty slots in bioengineering will be sought in the 2013-2014 academic year. Thus, the expected staff complement of the new bioengineering department will be up to eight professors by the fall of 2014. In addition, a number of professors (e.g. between five and ten of the professors listed in section 4.2.) affiliated with other units in the Faculty, and from other Faculties, may also share in the teaching load. These professors, as with others from McGill will also have the opportunity to become Associate Members of the new department.

6.2.2. Non-academic staff

The student services for the new program will be handled initially (until the creation of the Department of Bioengineering) by clerical, managerial, and advisory staff of the McGill Engineering Student Centre (MESC). The Centre handles advising for all undergraduates in engineering programs at McGill, and also provides administrative support for student records for all engineering courses and programs.

The hiring plan for the new department includes one manager, one Administrative Assistant, and one technician. The Administrative Assistant was hired in January 2012, and we plan to hire the manager to provide support for the program set up phase, and a technician in the summer of 2012, in time for the arrival of the endowed Bioengineering chair-holder and the first two professors. In addition, a half-time technician will be hired when the full complement of

BIEN lab courses will be offered. Funding for these staff has been accounted for in the enrolment revenues.

6.3. Space

The Department will require office space to house new faculty members, administrative support staff, and graduate students. As well, laboratory space will be required for both research and undergraduate teaching. Space has been offered on a temporary basis by the Departments of Chemical Engineering and Mechanical Engineering. This will be sufficient for the first few years of operation, but in the long-term, permanent space will be required. McGill has identified the creation or renovation of space to house the broader domain of Bioengineering as a matter of high priority. This may consist either of the construction of a new building or the renovation of vacated space in the Royal Victoria Hospital or elsewhere. This space would host the future planned institute of Bioengineering and would provide a home for interdisciplinary teaching and research in this area, by also housing professors from the Department of Biomedical Engineering in the Faculty of Medicine, as well as professors from the Faculties of Dentistry and Science and possibly others.

6.4. Equipment/Laboratories

Laboratory equipment will be required for the laboratory based BIEN courses and the Office of the Provost has committed to provide start-up funds for its purchase.

7. Proposed schedule of implementation and plans for future developments

The table below provides the actions with expected implementation timelines.

Action	Timeline
Establishment of the Department of Bioengineering	Spring 2012
Endowed Chair in Bioengineering (academic staff-program director)	Search underway. Expected appointment by 1st August 2012
Two faculty positions in Bioengineering (academic staff)	Search underway. Expected appointment: August 2012
Administrative Assistant (non-academic staff)	Currently in place
Lab Manager/technician (non-academic staff	Expected appointment by August 2012.
Program Manager (non-academic staff)	Search to begin in January 2013. Expected appointment by fall 2013.
Approval and implementation of the B.Eng. in Bioengineering program.	Expected implementation 2014
Three faculty positions in Bioengineering (academic staff)	Search to begin in fall 2012
Two faculty positions in Bioengineering (academic staff)	Search to begin once program is approved
Technician at 50% time (non academic staff)	Search to begin when full complement of BIEN lab courses are offered
Undergraduate program CEAB Accreditation	Three years after admission of the first cohort

8. Consultations within McGill and dates

Within McGill University, the new Department shares interests in common with all other departments in the Faculty of Engineering, with the Department of Biomedical Engineering in the Faculty of Medicine, the Department of Bioresource Engineering in the Faculty of Agricultural and Environmental Sciences, the Department of Biology in the Faculty of Science, and the Faculty of Dentistry.

Discussions within the Faculty of Engineering as well as with the Department of Biomedical Engineering, the Department of Bioresource Engineering, the Department of Biology and the McGill School of Environment have been initiated through an invitation to two roundtable discussions; on December 15, 2011 and January 17, 2012. The invitation to the roundtable was also extended to the Deans of the Faculties of Science, Medicine, Dentistry and Agricultural and Environmental Sciences.

Consultations were carried out with the following units across McGill University:

Faculty/School	**Date of Response (Appendix C)**
Faculty of Engineering	Faculty Council approval 14 February 2012
Faculty of Science	16 January 2012
Faculty of Agricultural and Environmental Sciences	25 January 2012
Faculty of Dentistry	1 March 2012
McGill School of Environment	3 March 2012
Faculty of Medicine	19 March 2012

Appendix A: Survey of Bioengineering departments at other institutions

Within McGill

Within McGill University, the new Department shares interests in common with all other departments in the Faculty of Engineering, with the Department of Biomedical Engineering in the Faculty of Medicine, the Department of Bioresource Engineering in the Faculty of Agricultural and Environmental Sciences, the Department of Biology in the Faculty of Science, and the Faculty of Dentistry. The Department of Biomedical Engineering in the Faculty of Medicine is focused on clinical aspects of health care technology. This department does not offer any undergraduate degree programs. However, many of its courses are available to higher year undergraduates in engineering, particularly to those enrolled in the Biomedical Engineering minor. Through the B.Eng. in Bioengineering, the new Department will fill the lack at McGill of undergraduate education in bioengineering and provide a pool of potential candidates for the graduate programs in Biomedical Engineering and Bioresource Engineering.

The Department of Bioresource Engineering in the Faculty of Agricultural and Environmental Sciences has an emphasis on areas which are complementary to the focus areas of the new bioengineering department, such as Agro-Environmental Engineering – environmental management and conservation, geomatics, organic waste treatment; Soil and Water – water resources, hydrology, irrigation and drainage, GIS; Ecological Engineering – engineering design and management of complex ecological systems; Food and Bioprocessing - engineering of foods and food processes, properties of biological materials, fermentation, biotechnology, processing machinery; and Agricultural Engineering - machinery, robotics, structural design, GIS, remote sensing, and much more.

Therefore, the new Department of Bioengineering will complement the existing Biomedical, and Bioresource departments and provide McGill with the missing piece to a comprehensive coverage of engineering in the life sciences.

Within Québec and Canada

Quebec based universities do not have departments under the name of Bioengineering. While the **Université de Sherbrooke** and **École Polytechnique** de Montréal offer B.Eng. degrees related to the field of bioengineering, they are not offered under departments dedicated to bioengineering. The Université de Sherbrooke baccalauréat en génie biotechnologique is offered by the Department of Chemical Engineering and Biotechnological Engineering and the Department of Biology in the Faculty of Science. This program is narrowly focused on biotechnology, molecular biology and biochemical engineering. It does not cover biomaterials, bio-signal processing, biomechanics, or biomedical topics. The Biomedical Engineering Program (génie biomédical) offered by École Polytechnique de Montréal is offered through the Institut de génie biomédical, which is under the joint control of Poly and the Faculty of Medicine, Université de Montréal.

The following is a brief overview of similar entities elsewhere in Canada:

Dalhousie University: The Department of Biological Engineering is based within the Faculty of Engineering. It offers two undergraduate programs; Biological Engineering and Environmental Engineering. The focus of this department is on bio-systems, such as aquaculture, environment, and biotechnology. Dalhousie University also has a School of Biomedical Engineering, which is jointly run between the Faculty of Medicine and Faculty of engineering. It only offers graduate studies.

Guelph University: While the School of Engineering offers undergraduate programs in Biological and Biomedical Engineering, there are no departments.

McMaster University: The McMaster School of Biomedical Engineering is shared between the Faculties of Health Sciences and Engineering. This department does not offer an undergraduate program.

University of Alberta: The Department of Biomedical Engineering is based in the Faculty of Medicine. This department does not offer an undergraduate program.

University of British Columbia: While two departments with the Faculty of Applied Science offer major options in Biomedical Engineering; the Department of Electrical and Computer Engineering and the Department of Mechanical Engineering, there is no specific department of biomedical engineering.

University of Toronto: The Institute of Biomaterials and Biomedical Engineering offers graduate studies in Biomedical Engineering. This is jointly run by the Faculties of Applied Science and Engineering, Dentistry, and Medicine.

Bioengineering/Biomedical Engineering departments in the U.S.

The following is a brief overview of the structure of the top ten ranked US bioengineering/biomedical departments (ranked in the top 10 biomedical/bioengineering departments by US News and World report for 2010). It can be seen that there are many different approaches to organizing activities in bioengineering.

Boston University: Biomedical Engineering is a department within the College of Engineering. While the Biomedical department has links to the School of Medicine, the School of Medicine does not have any degree programs in Biomedical areas. The Biomedical department also has affiliations to local hospitals.

Duke: The Biomedical Engineering department is part of the Pratt School of Engineering. Duke has a medical school, which has a biomedical sciences graduate program, but no biomedical engineering programs.

Johns Hopkins University: Biomedical Engineering is a department within the School of Medicine and a program within the School of Engineering.

Georgia Institute of Technology (Georgia Tech): Biomedical Engineering is a joint unit in the College of Engineering at Georgia Tech and the School of Medicine at Emory University. Georgia Tech does not have a medical school of its own.

Massachusetts Institute of Technology: Biological Engineering is a department within MIT. MIT does not have a medical school. MIT's approach to biological engineering is very broad and is not restricted to biomedical or health-related engineering.

Rice University: Rice University does not have a medical school. Multiple departments (Bioengineering, Biochemistry & Cell Biology, Chemistry) collaborate with each other and with Texas hospitals in the Rice BioScience Research Collaborative.

University of California San Diego (USCD): Bioengineering at UCSD was established in 1966 as a joint program between the School of Medicine and the Department of Applied Mechanics and Engineering Science. In recognition of the unique features and requirements of bioengineering and the excellence of the bioengineering faculty and programs, the University of California established a new Department of Bioengineering in August 1994. This department is in the Jacobs School of Engineering.

University of Pennsylvania: The Bioengineering department is part of the Faculty of Engineering. The graduate programs in the School of Medicine are housed in Biomedical Graduate Studies, but do not involve any biomedical engineering.

Stanford University: The Department of Bioengineering is jointly supported by the Schools of Medicine and Engineering. The undergraduate degree program is offered by the School of Engineering. In the School of Medicine, only students in the PhD (or MD-PhD) program have a possibility to work in bioengineering.

University of Washington: The Bioengineering department is a joint unit in the College of Engineering and the School of Medicine. Many of the professors have joint or adjunct appointments with engineering or medical departments.

Bioengineering departments in other universities worldwide

The universities listed below from around the world have departments named "Bioengineering" and which are similar in focus to the department that is being proposed in McGill's Faculty of Engineering.

- Clemson University
- Imperial College, London
- Indian Institute of Technology, Kanpur (Biological Sciences and Bioengineering)

- Indian Institute of Technology, Bombay (Bioscience and Bioengineering)
- Nagaoka University of Technology
- National University of Singapore
- North Carolina A&T
- Oregon State University
- Osaka University (Mechanical Science and Bioengineering)
- Penn State University
- Politecnico di Milano
- San Diego State University
- SUNY Binghamton
- Temple University (*recently created department*)
- University of Aberdeen (Biomedical Physics and Bioengineering)
- University of California, Berkeley
- University of California, Los Angeles
- University of California, Riverside
- University of California, San Francisco (Bioengineering and Therapeutic Sciences)
- University College London (Medical Physics and Bioengineering)
- University of Colorado, Denver (*recently created department*)
- University of Illinois, Chicago
- University of Illinois, Urbana-Champagne
- University of Louisville
- University of Maryland
- University of Pennsylvania
- University of Pittsburgh
- University of Strathclyde
- University of Texas, Arlington
- University of Texas, Dallas (*recently created department*)
- University of Tokyo
- University of Toledo
- University of Utah

Appendix B: Proposed Bioengineering (BIEN) Courses in the B.Eng. in Bioengineering Program

BIEN 200 (4) *Introduction to Bioengineering*
Overview of the fundamental principles of biological engineering. Introduction to conservation laws. Introduction to engineering calculations; fundamentals of conservation principles; conservation of mass, energy, charge and momentum. Emphasis on the development of problem solving skills and methods. Examples from the chemical, biomedical, and pharmaceutical industries.

BIEN 210 (3) *Electrical Circuits for Bioengineers*
Review of Ohm's law and Kirchoff's laws. Introduction to electric network theory. Thevenin and Norton equivalents, Tellegen's theorem, Nodal and mesh analysis, linearity, superposition. Laplace Transforms. First and second order circuits. Bioelectricity in cells, equilibrium potential, active and passive transport, ion channels.

BIEN 290 (4) *Bioengineering Measurement Laboratory*
Laboratory safety. Conceptual understanding of measurement principles and instrumentation. Electric signals, equipment and circuits, as related to data acquisition and signal conditioning. Mechanical measurements of solid and thermofluid quantities. Optical sensing techniques. Measurements of biological and chemical properties. Statistical and uncertainty analyses.

BIEN 320 (3) *Molecular, Cellular, and Tissue Biomechanics*
Definition, history, and growth of biomechanics. Extracellular matrix structure and function. Mammalian cell architecture and function. Stress-strain relationships, viscoelasticity, poroelasticity, and biofloidic mechanics. Soft connective tissue mechanics. Skeletal tissue mechanics. Cellular and molecular biomechanics. Measurement and modelling of cell biomechanics. Mechanotransduction and mechanobiological effects on cells in cartilage and bone.

BIEN 340 (3) *Transport Processes in Biological Systems*
Fundamental principles of mass transport and its application to a variety of biological systems. Membrane permeability and diffusive transport. Convection. Transport across cell membranes. Ion channels. Active transport. Intra- and inter-cellular transport.

BIEN 350 (3) *Biosystems and Control*
Discrete- and continuous-time signals; basic system properties. Linear timeinvariant systems; convolution. Frequency domain analysis; filtering; sampling. Laplace and Fourier transforms; transfer functions; poles and zeros; transient and steady state response. Z-transforms. Dynamic behaviour and PID control of first- and second-order processes. Stability. Applications to biological systems.

BIEN 360 (3) *Probability and Statistics for Bioengineers*
Introduction to probability and statistics. Sampling, hypothesis testing, correlation, least-squares and non-linear regression, and analysis of variance. Data visualization. Bioinformatics.

BIEN 390 (3) *Bioengineering Laboratory*
Introduction to the fundamental principles of experimental design and statistical analysis as applied to Bioengineering research. Four laboratory modules: cell culturing, biomaterial synthesis and characterization, acoustics, and biomechanics. Application of statistics, probability and noise analysis to experimental data.

BIEN 470 (6) *Bioengineering Design Project*
A capstone group design project on an industrially relevant engineering problem of a biological nature. Student teams work in consultation with faculty and industrial consultants in the design of functional and practical systems, devices, or processes, taking into account safety, sustainability, management and economic considerations.

BIEN 471 (2) *Bioengineering Research Project*
Individual guided research project in Bioengineering.

Appendix C: Consultation Reports

Anne Broadhurst, Ms.

To: Showan Nazhat, Prof.
Subject: RE: Bioengineering consultation

-----Original Message-----
From: Martin Grant, Prof
Sent: Monday, January 16, 2012 9:18 AM
To: Andrew G Kirk, Prof
Cc: Laurie Hendren, Prof.
Subject: Bioengineering consultation

Andy,

Thanks for your request for comments on your proposal to open a new bioengineering department. We discussed it at a meeting of Departmental Chairs and Associate Deans last week.

As we wrote earlier, the Faculty of Science supports the new program. We will of course need resources to enact our own responsibilities in the program. In particular, our capacity is constrained by classroom size and our undergraduate laboratories; we need to work cooperatively to determine how many extra spots will be possible in Science classes, in advance of the actual requirements.

In terms of whether the best way to run this is with a new department, we have no opinion. We introduced new BSc programs in Earth Systems Science and in Neuroscience without introducing new Departments, but nevertheless we appointed a program Director, and re-organized academic advising. There are many ways to skin an academic cat.

Martin

--
Martin Grant, Dean of Science, Dawson Hall, McGill University,
853 Sherbrooke St W, Montreal QC H3A 2T6 Canada, 514-398-4211, Fax 3932, martin.grant@mcgill.ca,
http://www.physics.mcgill.ca/~grant/

Showan Nazhat, Prof.

From:	Shiv Prasher, Dr.
Sent:	Wednesday, January 25, 2012 10:06 AM
To:	Andrew G Kirk, Prof
Cc:	Showan Nazhat, Prof.; Chandra A. Madramootoo, Dr.; ENG-ACADEMICS@LISTS.MCGILL.CA
Subject:	Re: Cooperation between the Bioresource Engineering and Bioengineering programs at McGill
Attachments:	Memo to the Faculty of Engineering.docx

Dear Dean Kirk,

Thank you for giving the academic staff of Bioresource Engineering Department an opportunity to foster greater cooperation with the Faculty of Engineering. We want to be helpful and supportive to the new program in Bioengineering.

Please find attached a co-operation document that we have prepared in light of the two meetings that were held with you and your staff in December 2011 and January 2012.

We look forward to hearing from you at your earliest convenience.

Best wishes and kindest regards

Shiv

Shiv O. Prasher, Ph.D., P.Eng.
Past-President, CSBE/SCGAB
James McGill Professor and Chair
Department of Bioresource Engineering
Macdonald Campus of McGill University
21,111 Lakeshore Road
Ste-Anne-de-Bellevue, Quebec, Canada
H9X 3V9

Phone: 514-398-7775
Fax: 514-398-8387
Email: shiv.prasher@mcgill.ca
Web: http://www.mcgill.ca/bioeng/faculty-and-staff/shiv-o-prasher

On 2011-12-16, at 1:30 PM, Showan Nazhat, Prof. wrote:

Dear Shiv,

I am writing to thank you again for attending yesterday's roundtable discussion meeting in relation to the Notice of Motion to create a Department of Bioengineering in the Faculty of Engineering.

In following up on the discussion, I would be grateful if you and your colleagues could confirm the essential elements that you think must be addressed in the proposal. You can provide these comments in bullet points or as a short paragraph.

This is a great opportunity for the University and the support of you and everyone in your department is vital to its success.

Best regards,
Showan

Showan N Nazhat, Ph.D.
Associate Dean, Research and Graduate Education
Faculty of Engineering
McGill University
Rm 378, Macdonald Engineering Bui, 817 Sherbrooke Street West, Montreal, Qc, H3A 2K6
Tel: 1 514 398 6991 / Fax: 1 514 398 7379

Associate Professor and Gerald Hatch Faculty Fellow
Department of Mining and Materials Engineering
Rm 2090, Wong Building, 3610 University Street, Montreal, Qc, H3A 2B2
Tel: 1 514 398 5524 / Fax: 514-398-4492
E-mail: showan.nazhat@mcgill.ca

Cooperation between the Bioresource Engineering and Bioengineering Programs at McGill University

We are very pleased to participate in this exercise and want to assure you that our goal is to assist your Faculty in fostering excellent teaching and research in Bioengineering at McGill. Our goal is to be as helpful as we can, so that we will have two thriving, complementary undergraduate biological engineering programs at McGill University.

From the viewpoint of the Department of Bioresource Engineering, we feel that we can contribute to the initiative to grow biological engineering at McGill in the following ways:

1. Help teach the new program by making available some of the courses already offered by our departmental academic staff.

2. Attract students by ensuring that the full range of undergraduate program options in biological engineering and the full capacity to accommodate students in those programs are aggressively and professionally marketed online and in the print media by the Faculty of Engineering. This can be done by ensuring that B. Eng. (Bioresource Engineering) and the B. Eng. (Bioengineering) Programs are listed on the website of the Faculty of Engineering, together with other departments and programs that are offered in the Faculty. On our side, we will also include a link to the B. Eng. program in Bioengineering on our website.

3. Attract students by cooperatively presenting the full range of options in biological engineering to potential undergraduate students, and promoting McGill's capacity to accommodate a larger number of those students in mature and fully-accredited engineering programs. This can be done by clearly and unambiguously articulating the scope and content of each of the undergraduate biological engineering programs (B.Eng. Bioresource Engineering and B.Eng. Bioengineering) and ensuring that both programs are aggressively marketed by the recruitment staff of the Faculty of Engineering. This will minimize confusion and allow prospective students to consider all accredited engineering programs/departments at one place.

4. Support the creation of an inclusive and innovative inter-faculty administrative structure to facilitate and nurture interdisciplinary teaching and research in biological engineering at all levels. This could take the form of a School of Biological Engineering that spans the Faculties of Engineering, Agricultural and Environmental Sciences, and Medicine.

Shiv Prasher
Chair, Department of Bioresource Engineering

McGill

Dean, Faculty of Dentistry
McGill University
3640 University Street
Montreal, Quebec, Canada
H3A 2B2

Paul J. Allison
BDS, FDSRCS (Eng), PhD
E-mail: paul.allison@mcgill.ca
Tel: (514) 398-6758/7222
Fax: (514) 398-8900

Doyen, Faculté de médecine dentaire
Université McGill
3640, rue University
Montréal (Québec) Canada
H3A 2B2

March 1st, 2012

Dr. A. Kirk
Interim Dean, Faculty of Engineering
McGill University

Dear Andrew,

Upon your request, I asked Associate Dean Graduate Studies and Research Marc McKee to convene our researchers in the Faculty of Dentistry having an interest in bioengineering to discuss the new program you are developing.

Marc met with Drs. Barralet, Tran, and Komarova, and received written comments from Dr. Tabrizian. He provides the following summary of their discussions.

Although not unanimous, the majority felt the new bioengineering program would be good for McGill to have, and that it would fill a need for undergraduate students. It was also recognized that this is a critical moment for the field of bioengineering at McGill, meaning that good coordination between faculties and departments of McGill could develop this into something stronger than just a Faculty of Engineering initiative alone.

Everyone expressed some concern that a broader consultation and mandate to develop bioengineering at McGill had not included from the outset the various stakeholders outside of Engineering. However, most felt that it was not too late to miss a unique opportunity and to gather everyone's input (perhaps as a University Taskforce) to make bioengineering "bigger and better" and to capitalize on our strengths in this area across the University, perhaps as an Institute, with a "feeder" system (amongst others) coming from the proposed bioengineering undergraduate program. The following are some specific comments that were made that are not covered above, and relate to bioengineering "as a whole" at McGill, and not just to the proposed undergraduate program:

- *this will work for engineers who can then learn some biology, but how will our biologists learn engineering?*

- *there is much bioengineering that is biomedical, so how will this be explicitly developed? In fact there are very strong clinical links for this at McGill.*

- *not sure about the vitality of the Canadian job market for this after graduation.*

- *the proposed undergraduate program is not disciplinary enough and does not have enough "bio" and is very engineering oriented.*

- *the progam should have private sector speakers and co-op programs*

- *there is a danger that it will become the public face of bioengineering at McGill, and as it stands is not broad enough.*

Therefore while agreeing with the initiative in principle, there are clearly some reservations concerning the developmental process and the content of the program you are proposing. The Faculty therefore supports the initiative with these caveats and looks forward to being involved as it moves forward.

Yours sincerely

Paul Allison

Showan Nazhat, Prof.

From: Marilyn Scott, Prof.
Sent: Saturday, March 03, 2012 1:48 PM
To: Showan Nazhat, Prof.
Cc: Andrew G Kirk, Prof; Anne Broadhurst, Ms.
Subject: RE: Proposal for a Department of Bioengineering

Showan, thanks for your email, and my apologies for not getting back to you sooner. In principle, I think the concept of a Department of Bioengineering makes sense.

I provide reflections on two components.

Given the experience of the McGill School of Environment, I suggest that the recruitment of professors be distributed among tenure-track Assistant Professors, Associate Professors and Full Professors. In particular, this would establish a range of experience within the new unit, and it would also allow the pre-tenure faculty to focus on their research / teaching without being overwhelmed by the service component that comes with starting new programs and academic units.

With regard to marketing, it will be important to clearly distinguish this department and associated programs from the Biomedical Engineering program and the Bioresource Engineering program (and perhaps others), both of which can be argued as subsets of Bioengineering.

Marilyn E. Scott

Marilyn E. Scott, PhD
marilyn.scott@mcgill.ca
Director, McGill School of Environment (MSE)
3534 University Avenue
Montreal, QC H3Z 2A7, Canada
Phone 514-398-2670; FAX 514-398-1643

and
Associate Professor, Institute of Parasitology
Macdonald Campus of McGill University
21,111 Lakeshore Road
Ste-Anne de Bellevue, QC H9X 3V9, Canada
Phone 514-398-7996; FAX 514-398-7857

From: Showan Nazhat, Prof.
Sent: Tuesday, February 28, 2012 12:57 PM
To: Marilyn Scott, Prof.
Cc: Andrew G Kirk, Prof; Anne Broadhurst, Ms.
Subject: FW: Proposal for a Department of Bioengineering

Dear Professor Scott,

I am writing with a gentle reminder that we have not yet received a report from your School on the proposal for the creation of a Department in Bioengineering, which we had circulated before Christmas. The proposal was passed (attached and unchanged) by the Faculty of Engineering Council on February 14th. The next step

will be for Faculty of Engineering to take it to APC. In order to do that, we need to demonstrate that we have consulted with all of the affected units at McGill, and as a result I would appreciate a short report from your School. If you feel that you would like to propose any revisions, there is still time, but not much, so we'd appreciate hearing back from you within the next week if possible.

Best regards,
Showan

Showan N Nazhat, Ph.D.
Associate Dean, Research and Graduate Education
Faculty of Engineering
McGill University
Rm 378, Macdonald Engineering Bui, 817 Sherbrooke Street West, Montreal, Qc, H3A 2K6
Tel: 1 514 398 6991 / Fax: 1 514 398 7379

Associate Professor and Gerald Hatch Faculty Fellow
Department of Mining and Materials Engineering
Rm 2090, Wong Building, 3610 University Street, Montreal, Qc, H3A 2B2
Tel: 1 514 398 5524 / Fax: 514-398-4492
E-mail: showan.nazhat@mcgill.ca

From: Andrew G Kirk, Prof
Sent: Thursday, December 22, 2011 1:54 PM
To: Henrietta Galiana, Prof.; Shiv Prasher, Dr.; Graham Bell, Prof.; Marilyn Scott, Prof.
Cc: Anne Broadhurst, Ms.; Showan Nazhat, Prof.
Subject: Proposal for a Department of Bioengineering

Dear Mimi, Shiv, Graham and Marilyn

As promised, I am forwarding to you the current proposal for the creation of a department of Bioengineering within the Faculty of Engineering. This proposal is the outcome of a process that was initiated in 2007 with the formation of the Faculty of Engineering Taskforce on Bioengineering, which made a number of recommendations. These included: i) the creation of a new accredited undergraduate engineering program in Bioengineering, ii) the creation of a Department or School of Bioengineering to deliver the program, and iii) the creation of a multi-faculty research institute with a focus in this area. The first of these recommendations has already been initiated. A proposal for a B.Eng. in Bioengineering was approved by the University in May 2011 and is currently being reviewed by CREPUQ's Commission d'évaluation des projets de programmes. This undergraduate program will be the first dedicated full program in the life sciences and engineering within the Faculty of Engineering and will be complementary to the existing Engineering programs as well as the Bioresource Engineering program, with little or no overlap beyond the usual training in core engineering fundamentals. This program was approved by Senate with the expectation that it would be offered by a new department or school of Bioengineering once one was created. The second of these recommendations is the topic of the attached proposal, in which detailed arguments are made for the creation of this department. The third recommendation, for a new institute in this field, is also a significant component of the development of this strategic area within McGill, but lies outside the scope of the current proposal. However, I fully support the concept and it is addressed further in Section 5 of the attached proposal. The task force also stressed the highly interdisciplinary nature of this field and the importance of collaboration and communication between relevant units and personnel across the university, which I believe is reflected in the attached proposal.

As you know, a roundtable discussion on this topic was held on December 15th and I would like to thank all of you who provided input either there or afterwards. Wherever practical, the input that was received has been incorporated into the attached proposal. There will be a second roundtable discussion at 2.00 to 4.00 pm on Tuesday January 17, 2012 (Engineering Macdonald room 388), to which you are all invited to send representatives if you wish.

The proposal will be the subject of discussion at Faculty of Engineering Council early in the new year. At the same time, I would also invite feedback from all of you and we will endeavour to incorporate your suggestions received into a revised

document that we intend to submit to the Academic Policy Committee for eventual consideration by Senate. If you would like to meet with me to discuss any issues in detail, please do let me know and I will be happy to arrange it. In addition to the proposal, I also attach the Notice of Motion that was presented to the Engineering Faculty Council and some slides that were presented at the December 15th roundtable. I have also sent this to all the Deans at McGill in order to obtain formal consultation reports.

I believe this proposal represents a very exciting opportunity for the Faculty of Engineering, and for McGill, to achieve net growth and to significantly raise our profile in this very important strategic area. I hope that you will support this endeavour.

I would also like to take this opportunity to wish you a relaxing holiday and much success in 2012

Andy

Andrew Kirk

Interim Dean
James McGill Professor

Faculty of Engineering, McGill University
Macdonald Engineering Building, 817 Sherbrooke Street West
Montreal, Quebec H3A 2K6, Canada
Tel: +1 (514) 398-7251 Fax: +1 (514) 398-7379
Email: andrew.kirk@mcgill.ca

McGill

David Eidelman, M.D., C.M.

Vice-Principal, Health Affairs
Dean
Faculty of Medicine
McGill University
3605 de la Montagne Street
Montreal, Quebec
Canada H3G 2M1

Vice-principal, Santé et affaires médicales
Doyen
Faculté de médecine
Université McGill
3605, rue de la Montagne
Montréal, Québec
Canada H3G 2M1

Tel: (514) 398-3524
Fax: (514) 398-8568
david.h.eidelman@mcgill.ca

March 19, 2012

dean's office

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Dr. Andrew Kirk
Interim Dean
Faculty of Engineering
McGill University
McDonald Engineering Building
Room 382

Dear Dean Kirk,

I am writing in regard to the proposal for the establishment of a Department of Bioengineering. Based on our discussions, which indicated our joint interest in the eventual establishment of an interdisciplinary, multi-faculty institute for graduate studies and research in biological engineering, the Faculty of Medicine is happy to express its support for the establishment of a new Department of Bioengineering in the Faculty of Engineering as outlined in your proposal.

Sincerely,

David Eidelman, M.D., C.M.