Professional Engineers
Ontario

FINAL REPORT
OF THE
BIOENGINEERING SUB-GROUP
OF THE
ENGINEERING DISCIPLINES TASK FORCE (EDTG)

Report Date: November 15, 16, 2001

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1. BACKGROUND, AUTHORITY AND COMPOSITION OF THE SUBGROUP

1.1 Background

Recent trends in technology have driven a rapid expansion in the field of bioengineering.

As biotechnology moves from the science of discovery to that of application, the role of the engineer becomes clearer. With discoveries in science unlocking the structure of DNA, leading to the Human Genome project mapping out the genetic code of the human species, the world has moved to a new era. It is now possible to design biological components with predictable behaviour for use by humans. Furthermore, biological tools have been developed that permit the control of biological processes. Like the electrical engineer who has learned to monitor and direct the flow of electrons, the bioengineer is beginning to do the same thing with biomolecules, cells and other biological components.

In established engineering fields, these same technological advancements are reshaping the practice of engineering. Food, bioprocess, agricultural and forest engineering are all areas that are being affected by the advancements in biotechnology. Current practice would not necessarily include these fields under the banner of bioengineering, but with the expansion of biotechnology they are becoming inextricably linked to the practice of bioengineering and will undoubtedly become areas of specialization for bioengineers.

In this role, bioengineers will integrate their knowledge of engineering principles with biology to address problems requiring biological solutions or where biological systems are used for the benefit of society

With its mandate to regulate engineering practice in Ontario, PEO is well placed to assist the transition of bioengineering from its present state, where practitioners have virtually all come through classic engineering and applied science programs, to the future, where fully accredited undergraduate degree programs will fill the bioengineering needs in industry and society. Along with this mandate comes the responsibility of ensuring the adherence to ethical practices in this area.

This report has been compiled as a definitive step down the road toward defining the practice and educational requirements associated with bioengineering. This step is being undertaken while knowing that the rapid growth and diversity in bioengineering will undoubtedly result in unanticipated changes to the field. In spite of this uncertainty, the need still exists to begin the definition process. It is within this context that this report, representing the current opinion of the committee members, has been compiled.

1.1 1.2 Authority

To act on this responsibility, the PEO Council, by a motion at its meeting in February 2000, established the Bioengineering Subgroup of the Engineering Disciplines Task Group (EDTG) to investigate the practice and regulation of bioengineering in Ontario.

The inaugural meeting of the Bioengineering Subgroup of the EDTG was held on March 15, 2000. Regular meetings were held on a monthly basis until May 2001.

1.3 Objectives

The Bioengineering Subgroup of the EDTG believes that its short-term objectives, as outlined by Council, will be sufficient to enable the PEO to move toward the regulation of the practice of bioengineering in Ontario.

Short-term objectives for the Bioengineering Subgroup of the EDTG were outlined in the Draft Terms of Reference, February 18, 2000 (Appendix A) and included:

(a) Define a Core Body of Knowledge, and translate this into a Board Sheet that is to be used by the Academic Requirements Committee for licensure.

(b) Define the Areas of Practice that require the skills of a bioengineer.

(c) Recommend policy initiatives to recognize and position PEO to respond to issues and changes occurring in the field of bioengineering.

1.4 Composition

Membership of the Bioengineering Subgroup of the EDTG includes representation from many of the diverse facets of bioengineering today.

PEO was represented by President/Past President Peter DeVita P.Eng., Deputy Registrar, Admissions Norm Williams, Ph.D., P.Eng., and Councillor Max Perera P.Eng.

Technical membership included:

- Walter Bilanski, Ph.D., P.Eng., University of Guelph Biological Engineering, for bioresource and food applications;
- Katherine Crewe, P.Eng., Vice President, Operations, Cryoceth;
- Levente Diosady, Ph.D., P.Eng., University of Toronto, Department of Chemical Engineering, for food applications;
- Bruno DiStefano, P.Eng., President, Nuptek Systems Ltd.;
- Monique Frize, Ph.D., P.Eng., University of Ottawa and Carleton University, for biomedical applications;
- Lal Kushwaha, Ph.D., P.Eng., University of Saskatchewan Department of Agricultural and Bioresource Engineering;
- Begonia Lojk, P.Eng., Canadian Council of Professional Engineers;
- Joseph Molto, Ph.D., Director, Paleo-DNA Laboratory, Lakehead University;
- Argyrios Margaritis, Ph.D., P.Eng., University of Western Ontario Department of Chemical and Biochemical Engineering;
- Stephen Naumann, Ph.D., P.Eng., Director, Rehabilitation Engineering Department, Bloorview MacMillan Research Centre;

- John Runciman, Ph.D., P.Eng., University of Guelph Biological Engineering, for biomedical applications;
- Michael Sefton, Sc.D., P.Eng., Director, Institute of Biomaterials and Biomedical Engineering, University of Toronto; and
- Ady Solomon, Ph.D., P.Eng., University of Toronto, Department of Mechanical and Industrial Engineering.

Additional technical assistance was obtained from the following people:

- Valerie Davidson, Ph.D., P.Eng., University of Guelph Biological Engineering, for food applications;
- Andrew Daugulis, Ph.D., P.Eng., Department of Chemical Engineering, Queen's University, for biochemical applications;
- Heather Sheardown, Ph.D., P.Eng., Department of Chemical Engineering, McMaster University, for biochemical applications; and
- John Ogilvie, Ph.D., P.Eng., University of Guelph Biological Engineering, for bioresource applications.

2. BIOENGINEERING SUBGROUP ACTIVITIES

2.1 Meetings

The Subgroup met 10 times as a whole. Members who could not attend in person participated via teleconference. Work of the Subgroup was facilitated with the use of email. PEO Council was updated on the group's activities on June 28, 2000, and February 16, 2001.

2.2 Presentations

The Subgroup had the benefit of presentations from and discussion with eminent practitioners in the field:

- *Dr. Burleigh Trevor Deutsch, Biotech Canada*

Dr. Deutsch reviewed the current status of Biotech in Canada, covering such things as growth, employment, funding and development of engineers with a focus on ethics.

- *Dr. G. Surgeoner, President, Ontario Agri-Food Technologies*

Dr. Surgeoner discussed advances in the science to date and the future. Such advances lead to commercialization, which is where engineers become involved. The committee had questions surrounding what is expected of an engineer in this field.

- *Dr. Walter Kushnir, Biotechnology Secretariat, Ministry of Energy, Science and Technology (MEST)*

This meeting was the result of a meeting between PEO and the Honourable Jim Wilson, Minister, MEST. Dr. Kushnir talked about the activities at the Biotech Secretariat.

2.3 Meeting with the Minister

Then PEO President Peter DeVita, P.Eng., PEO Director of Professional Affairs Johnny Zuccon, P.Eng., PEO Manager of Government Relations John Gamble, P.Eng., and Councillor Max Perera, P.Eng., met with the Honourable Jim Wilson, Minister, MEST, on March 22, 2000 to brief him about PEO's initiative on bioengineering. See Appendix B for details.

2.4 Communications

Engineering Dimensions covered the establishment of the Bioengineering Subgroup in its March/April 2000 issue article on Council's February 17-18, 2000 meeting. Follow-up stories on the Subgroup's progress appeared in the July/August 2000 and March/April 2001 issues. *Engineering Dimensions*' May/June 2001 issue was devoted to the theme of bioengineering, with feature stories highlighting different kinds of bioengineering practice, the need for licensing of engineers working in bioengineering, and the Subgroup's work to define the new discipline. The work of the Subgroup was also mentioned in the 2000-2001 PEO Annual Report. Externally, the 2001 Engineering Week supplement, which appeared in the *National Post*, *Ottawa Citizen*, *London Free Press* and *Windsor Star* (combined circulation over 500,000), featured an article entitled "Licensing bioengineering". The front-page article by then President-elect Gordon Sterling, P.Eng., in the January 25, 2001 issue of *The North Bay Nugget* also mentions PEO's ongoing work to define and regulate emerging areas, including bioengineering, as does President-elect Richard Braddock's article on the front page of the January 24, 2002 issue of the *Nugget*.

3. DEFINITIONAL ISSUES

3.1 Clarification of Terms

The Bioengineering Subgroup recognized early that terminology was an important issue. There are many different groups active in the field of bioengineering. They bring with them a diverse collection of terms and definitions. Proper communication between these groups can only be achieved through a common language.

3.2 Suggested Definitions

To this end, the group arrived at the following definitions:

- *Bioengineering*

  An umbrella term meaning the integration of engineering science and the biological sciences for the benefit of society. Encompassed by the term Bioengineering are the subgroups or disciplines described by Biochemical/Food Engineering, Biomedical Engineering and Bioresource Engineering.

- *Biochemical/Food Engineering*

  Biochemical/Food Engineering is the application of engineering principles to the processing and manipulation of materials of biological origin and/or the application of biological techniques to the processing of materials (e.g. production and processing of pharmaceuticals by conventional and genetically modified techniques, microbial, animal and plant cell culture, fermentation, bioreactors, and enzyme process engineering).

- *Biomedical Engineering*

  The branch of bioengineering that deals with health and medicine (e.g. electronic and mechanical devices used on biological materials, animals and humans, medical implants and instruments, prosthetics, orthotics, ergonomics and bioinstrumentation).

- *Bioresource Engineering*

  The branch of bioengineering that deals with engineering design and analysis to develop processes, machines and systems that influence, control, or utilize biological materials and organisms for the benefit of society (e.g. culture, harvesting and processing of plants, raising of animals for food use and biological resources).

3.3 Recommendation

The Subgroup recommends the adoption of the definitions attributed to the words Bioengineering, Biochemical/Food Engineering, Biomedical Engineering and Bioresource Engineering, as outlined in section 3.2.

4. CORE BODY OF KNOWLEDGE

4.1 Introduction

In Canada, individuals typically enter a field of engineering practice through one of three paths. The first path is that of an accredited university engineering program. This path prepares an engineering graduate to enter a traditional field of practice with a well established body of knowledge. The second path occurs when an engineering graduate finds that, because of new scientific or technical knowledge, a new and distinct body of knowledge evolves and the engineering graduate crosses over into the new area of practice from the engineering graduate's traditional area of practice. This migration allows the graduate to practise in an area different than the one in which the graduate was formally trained. The final path is one where a domestic or foreign-trained individual seeks licensure with a foreign-obtained and/or non-accredited academic background.

Those who follow the last two paths can approach PEO for licensing as professional engineers, but the process creates challenges for PEO. To fulfil its mandate of regulating professional engineering practice in Ontario, PEO must first ensure that applicants have acceptable academic qualifications, or have acquired equivalent knowledge of the subjects considered to be necessary for practise as professional engineers. PEO must then ensure that the applicants have work experience that enables them to demonstrate that they have applied the theory they learned in obtaining their academic qualifications. To facilitate this process, establishing a core body of knowledge for competent practice in the area of an applicant's experience in an emerging field is essential. Also, necessary is the identification and definition of the areas of practice within the new discipline in which licensure is required in the public interest. The Subgroup was established to define a Core Body of Knowledge and exclusive areas of practice for bioengineering.

What follows has been generated to respond to the first two objectives set up for the Subgroup. The information is broken into two distinct sections. The first section includes the definitions of the Core Bodies of Knowledge for Bioengineering in general and then proposed matching undergraduate syllabi that PEO's Academic Requirements Committee can use for licensing purposes. The final section defines areas of practice for Biochemical/Food, Biomedical and Bioresource Engineering.

4.2 Core Body of Knowledge, Bioengineering

The Bioengineering Subgroup adopted as a given that the current education curriculum of an undergraduate "Bioengineer", as defined by the Canadian Engineering Accreditation Board, must meet all of the following minimum educational requirements:

- mathematics, 195 academic units (AU);
- basic science, 225 AU;
- engineering science and engineering design, 900 AU;

- complementary studies, 225 AU; and
- programme minimum of 1800 AU.

The Subgroup proposes the following additional curriculum requirements:

- a minimum total of 20 per cent "biological" content in the combined basic science and engineering science and engineering design components of the curriculum;
- a course or the equivalent in bioethics; and
- a fourth-year project/thesis in bioengineering.

It is the Subgroup's position that the use of the terms **Biochemical/Food Engineer, Biomedical Engineer** and **Bioresource Engineer** should be reserved for individuals or academic programmes with a selection of the courses or equivalent experience listed in the following sections.

4.3 Core Body of Knowledge, Biochemical/Food Engineering

It is the Subgroup's position that the use of the terms **Biochemical Engineer** or **Food Engineer** should be reserved for individuals with some of the courses or equivalent experience listed below.

- *Recommended syllabus for an undergraduate programme in Biochemical/Food Engineering*

  Note: the terms "optional" and "required" are specific to the Board Sheet formulation shown in this table and must be used in conjunction with the corresponding number of courses needed in each section. Thus, any university program may choose to make courses listed here as optional "required" or "core" for its programme, while other universities may list the course as an elective. Hence, not every student needs to have taken every professional course listed below, i.e. taking 10 of the 13 listed in Professional Courses, SECTION A is sufficient.

Terms: req —required for specific discipline
opt —optional for specific discipline
n/a —not applicable

Basic Studies	
14 courses necessary in this section	
Course Listing	
Mathematics	req
Advanced Mathematics	req
Probability and Statistics	req
Computer (Programming and Algorithms)	req
Statics and Dynamics/Mechanics of Materials	req
Electric Circuits and Power	req
Thermodynamics	req
Physics	req
Chemistry	req
Material Science	opt
Fluid Mechanics	req
Selected Topics in Electricity and Magnetism	opt
Organic Chemistry	req
Biology	opt
Biochemistry	req
Microbiology	req
Molecular Biology	opt

Professional Courses , SECTION A	
10 courses are necessary in this section	
Course Listing	
Bioengineering Design Project/Thesis	req
Biomaterials (structure and properties)	req
Numerical Methods/Network Theory	req
Control and Monitoring	req
Heat Engineering (Heat Transfer)	req
Food or Industrial Microbiology	req
Waste Management and Environment	req
Chemical Reaction Engineering	opt
Biotransport Phenomena	opt
Biopharmaceuticals	opt
Thermal Process Engineering	opt
Dehydration Process Engineering	opt
Environmental Engineering	opt

Professional Courses , SECTION B	
Six courses are necessary in this section	
Course Listing	
Reactor Engineering	opt
Principles of Instrumentation (Bioinstrumentation)	opt
Machine Design	opt
Systems Engineering and Materials Handling	opt
Applied Plant, Animal or Human Physiology	opt
Food Emulsions	opt
Food Chemistry	opt
Plant Biochemistry	opt
Biochemical Engineering	opt

COMPLEMENTARY STUDIES	
Three courses necessary in this section	
Course Listing	
Engineering Economics	req
Engineer and Society/Bioethics	req
Engineering Communications	opt
Project Management	opt
Safety, Ethics and Law	opt

4.4 Core Body of Knowledge, Biomedical Engineering

It is the Subgroup's position that use of the term **Biomedical Engineer** should be reserved for individuals with some of the courses or equivalent experience listed below.

- *Recommended syllabus for an undergraduate programme in Biomedical Engineering*

  Note: the terms "optional" and "required" are specific to the Board Sheet formulation shown in this table and must be used in conjunction with the corresponding number of courses needed in each section. Thus, any university programme may choose to make courses listed here as optional "required" or "core" for its programme, while other universities may list the course as an elective. Hence, not every student needs to have taken every professional course listed below, i.e. taking six of the seven listed in Professional Courses, SECTION A is sufficient.

terms: req - required for specific discipline
opt - optional for specific discipline
n/a - not applicable

<u>Basic Studies</u>	
11 courses necessary in this section	
Course Listing	
Mathematics	req
Advanced Mathematics	req
Probability and Statistics	req
Computer (Programming and Algorithms)	req
Statics and Dynamics/Mechanics of Materials	req
Electric Circuits	req
Thermodynamics	opt
Physics	opt
Chemistry	opt
Material Science	opt
Fluid Mechanics	opt
Selected Topics in Electricity and Magnetism	opt
Organic Chemistry	opt
Biology	opt
Biochemistry	opt
Microbiology	opt
Molecular Biology	opt

Professional Courses , SECTION A	
Six courses necessary in this section	
Course Listing	
Cellular or System Biology	req
Bioengineering Design Project/Thesis	req
Biomechanics	opt
Biomaterials (structure and properties)	opt
Bioinstrumentation	opt
Control Theory	opt
Biomedical Imaging	opt

Professional Courses , SECTION B	
Three courses necessary in this section	
Course Listing	
Chemical Reaction Engineering	opt
Transport Phenomena	opt
Reactor Engineering	opt
Heat Transfer	opt
Numerical Methods/Network Theory	opt
Ergonomics/Industrial Hygiene	opt
Tissue Mechanics	opt
Robotics	opt
Signal Processing	opt
Applied Optics/Photonics	opt
Analogue/Digital Electronics and Instrumentation	opt
Artificial Intelligence Applied to Medicine	
Cell & Tissue Engineering	opt
Microengineering in a Biological World	opt
Computational Biology	opt
Functional Genomics	opt

COMPLEMENTARY STUDIES	
Three courses necessary in this section	
Course Listing	
Engineering Economics	req
Engineer and Society/Bioethics	req
Engineering Communications	opt
Project Management	opt
Safety, Ethics and Law	opt

4.5 Core Body of Knowledge, Bioresource Engineering

It is the Subgroup's position that the use of the term **Bioresource Engineer** should be reserved for individuals with some of the courses or equivalent experience listed below.

- *Recommended syllabus for an undergraduate programme in Bioresource Engineering*

  Note: the terms "optional" and "required" are specific to the Board Sheet formulation shown in this table and must be used in conjunction with the corresponding number of courses needed in each section. Thus, any university programme may choose to make courses listed here as optional "required" or "core" for its programme, while other universities may list the course as an elective. Hence, not every student needs to have taken every professional course listed below, i.e. taking seven of the eight listed in Professional Courses, SECTION A is sufficient.

terms: req —required for specific discipline
opt —optional for specific discipline
n/a —not applicable

Basic Studies	
12 courses necessary in this section	
Course Listing	
Mathematics	req
Advanced Mathematics	req
Probability and Statistics	req
Computing (Programming and Algorithms)	req
Statics and Dynamics/Mechanics of Materials	req
Electric Circuits and Power	req
Thermodynamics	req
Material Science	req
Fluid Mechanics	req
Selected Topics in Electricity and Magnetism	opt
Organic Chemistry	req
Biology	req
Biochemistry	opt
Microbiology	opt
Geology	opt

Professional Courses , SECTION A	
7 courses necessary in this section	
Course Listing	
Applied Plant an Animal Physiology	req
Bioengineering Design Project / Thesis	req
Biomaterials (structure and properties)	req
Principles of Bioinstrumentation	req
Process Modelling	req
Heat Engineering (Heat Transfer)	req
Chemistry and Microbiology of Foods	opt
Soil Physics or Mechanics	opt

Professional Courses , SECTION B	
Five courses necessary in this section	
Course Listing	
Process Control	opt
Structural Analysis & Design in Steel, Wood and Concrete	opt
Machine Analysis and Design	opt
Power Units for Agriculture, Biosystems and Food Industries	opt
Hydrology	opt
Irrigation, Drainage and Erosion Control	opt
Unit Operations (value-added processing)	opt
Waste Management and External Environment	opt
Internal Environment Engineering	opt
Aquaculture Engineering	opt
Physical Properties of Biological Materials and Food Products	opt

COMPLEMENTARY STUDIES	
three courses necessary in this section	
Course Listing	
Engineering Economics	req
Engineering in Society/Bioethics	req
Engineering Communications	opt
Project Management	opt
Safety, Ethics and Law	opt

4.6 Recommendations

(a) The Subgroup recommends the adoption of the Core Body of Knowledge and syllabi for Bioengineering, Biochemical/Food Engineering, Biomedical Engineering and Bioresource Engineering as outlined in sections 4.2-4.5.

(b) The Subgroup also recommends that Council refer this report to the Academic Requirements Committee and the Experience Requirements Committee to develop the Board Sheets used in the Licensure process.

4.7 Additional Observations

Based on the findings documented in the report entitled *Engineering Work in Canada* prepared for the CCPE (Appendix C) and a submission by the Canadian Agri-Food Research Council (Appendix D), the Subgroup recognized the importance of key technical skills, such as project management, statistical process control theory and applications, biology-based processes (fermentation, separation, purification and preservation) and irradiation technology. Accordingly, the Subgroup suggests the inclusion where possible of these areas in developing the undergraduate or graduate programmes.

5. AREAS OF PRACTICE

This section focuses on what bioengineers do with their Core Body of Knowledge. This section therefore has an industry or ”practice” perspective.

5.1 Areas of Practice—Biochemical/Food Engineering

Biochemical/Food Engineering is the application of engineering principles to the processing and manipulation of materials of biological origin and/or the application of biological techniques to the processing of materials. Within this area of expertise, there are two recognized specializations. Food engineering is the application of engineering principles to the large-scale preservation, processing and distribution of food. Biochemical engineering is the application of engineering principles to biology, biochemistry and microbiology for the production of useful materials, including environmental applications where the key products are clean air and water.

Areas of concentration for Food and Biochemical Engineering would include the design, development, analysis, support, operation, interpretation and safety of systems for:

- the management of efficient, and environmentally sustainable systems for processing and manipulating biological materials and/or non-biological materials, using biological techniques;
- cleaning, upgrading and refining physical, chemical and/or microbial components of biological material and the preservation/stabilization of biological products, including food items;
- manipulation, processing and manufacturing of biological products, including foods and beverages;
- packaging and distributing biological products, including food items;
- processing of materials of biological origin to produce pharmaceuticals, enzymes, nutraceuticals and other valuable chemicals;
- microbial production, separation and purification of pharmaceuticals, enzymes, nutraceuticals and other valuable chemicals;
- using microbes or enzymes to produce pharmaceuticals, enzymes, nutraceuticals and food ingredients, and other valuable chemicals; or
- using biological material for the manipulation/processing of non-biological material

5.2 Areas of Practice—Biomedical Engineering

Biomedical Engineering is the branch of bioengineering that deals with health and medicine. Bioengineering integrates engineering science, design and the biological sciences for the design and analysis of processes, products and services for the benefit of society.

Areas of concentration would include the design, development, analysis, support, operation and interpretation of systems for:

- medical or human factors modelling and simulation;
- medical instrumentation and medical devices used in a clinical setting;
- implantable medical devices and biomaterials;
- aids and prostheses for the physically challenged;
- diagnostic medical devices, kits, tools and related software;
- modelling and simulation;
- quantitative information related to biomechanical, physiological and pathophysiological processes;
- bioinstrumention;
- bioreactors for large-scale production of cells for use in medicine;
- integrated systems for heath care management and the management of technology within the healthcare environment;
- integration of biomedical sensors with medical devices and diagnostics; or
- artificial intelligence applied to medicine.

5.3 Areas of Practice—Bioresource Engineering

Bioresource Engineering integrates engineering science and design and applied biological sciences to solve problems involving biological systems and the natural environment. It deals with engineering design and analysis to develop processes, machines, and systems that influence, control, or use biological materials and organisms for the benefit of society.

Areas of concentration would include the design, development, analysis, support, operation and integration of systems for:

- managing and protecting resources through creating safer, more efficient, and environmentally sustainable production systems for plants and animals;
- the machinery and systems for agriculture, horticulture, aquaculture and forestry;
- the structural systems for livestock, laboratory animals, horticulture, controlled-environment chambers; storage of agricultural and food products; instrumentation, monitors and controls; standards and safety;
- added-value processing of agricultural crops for use as food, feed, fibre, energy, nutraceuticals and pharmaceuticals; primary processing of waste materials for land application; quality control in processing operations; computer image analysis and engineering in support of biotechnology;
- handling systems for granular and fibrous materials; energy conservation and utilization;
- soil and water conservation; water management for agricultural use, irrigation and drainage; soil remediation; or
- utilization of waste materials in plant-soil systems.

5.4 Recommendations

The Subgroup recommends that PEO adopt the Areas of Practice described in sections 5.1-5.3 for Biochemical/Food Engineering, Biomedical Engineering and Bioresource Engineering.

6. ETHICAL ASPECTS

There are aspects of bioengineering and its related technologies that may be perceived with suspicion by the general population. This caution is natural and is a reflection of the complexity and unpredictable nature of biological organisms so central to bioengineering. In addition, unlike the majority of engineering practice, which tends to affect groups, there are significant portions of bioengineering that are specifically focused on the individual. Food, drugs and health care are all areas touched by bioengineering that are personal in perspective. Hence, the technological, moral and ethical impact of the practice of bioengineering on the public requires great diligence.

Our society has placed significant faith in practitioners and regulators of the practice of engineering. Simultaneously, engineers have carved out a role as experts in the application of technology and guardians of public welfare in this area. As engineering practitioners, the additional technological, ethical and moral burden that is, and is perceived to be, associated with bioengineering must be carefully considered to ensure our societal role is not compromised.

The discussion of ethics as it relates to bioengineering must occur within the context of the engineering Code of Ethics (section 77 of Regulation 941/90 under the Professional Engineers Act). As spelled out in this code, all practising engineers should strive for a high level of professional integrity, personal honour and diligence in holding the public welfare paramount.

To move ahead with this complex and at times heated issue, the Subgroup considered bioethics from two perspectives, one dealing with societal perception and the other with technical realities.

6.1 Societal Perception

In the developing field of bioengineering, some techniques or products might be ethically or morally unacceptable to members of the population. These controversial practices might even challenge personal or religious beliefs fundamental to their own existence. In this environment, the question of right or wrong, ethical or unethical, becomes difficult or impossible to define. What might be acceptable to one person might be unacceptable to another. In either case, it comes down to personal acceptance. Will a person, for example, accept an organ transplant from a genetically altered cow or pig? What is the population’s response likely to be in the face of creating a new creature or plant form?

An engineer working within this environment is challenged with the responsibility of ensuring people have the necessary information to make their own decisions. As such, bioengineers must be more sensitive to the acceptability of proposed new products. Engineers must at all times avoid making decisions in ignorance of what the population will accept.

6.2 Technical Realities

In addition to what people might believe, every new bioengineering technique or product brings with it quantifiable benefits and disadvantages. There are upsides when serving the public and corresponding downsides to be avoided as we seek to protect that same public. Engineers working in this environment must be conscious of both the expected and unexpected outcomes of their work. In either case, practising bioengineers must exercise explicit and proactive thought on the potential consequences of their work.

For example, a species of corn was genetically altered to be herbicide resistant. The idea was that a field could then be totally sprayed to kill the weeds without concern for the corn, since the corn was designed so that the herbicide would have no effect on it. Unfortunately, the corn cross-bred with local weeds, creating a strain of herbicide resistant weeds.

The eventual outcome of this corn manipulation was unexpectedly negative. Could this possibility have been foreseen? Perhaps, but it is difficult to know for sure. On a positive note, we now know about that unintended effect. If this experience prevents the same mistake from being made in future, the final outcome will not have been entirely negative. The key is that engineers must use due diligence to ensure that all reasonable precautions are taken to minimize negative outcomes.

In this respect, software engineering has a parallel in software “bugs”. These annoying software glitches are often unintended side effects of the way the software code is written. At a basic level, genetic structure and genetic manipulation share some commonality with software. The only way a software engineer knows for sure (or close to) that bugs are eliminated is to test all components of the code extensively and then the entire software package. Similarly, the idea of testing under a controlled environment is key to good bioethical practice.

6.3 Core Body of Knowledge, Bioethics

The following list is meant as a guide for what bioengineers should know on bioethics. It is presented in course syllabus format for simplicity:

- general concepts that define ethics;
- ethical theories (describe main ones, such as Mills, Locke, etc.);
- codes of ethics for engineers (PEO, IEEE-EMBS, etc.);
- ethical approaches to handling conflict of interest, plagiarism, intellectual property;
- ethical approaches to handling confidentiality, privacy, and secrecy;
- ethical considerations relating to human and animal experimentation (rights, procedures, ethics committees, etc.);
- how to assess the impact of technology on people and society;
- rights and responsibilities of engineers, including duty to report (whistleblowing); and
- particular bioethics issues, e.g. stem cell research, cloning and genetic engineering, reproductive technologies, xenotransplantation and organ transplants, etc.

7. SUMMARY OF RECOMMENDATIONS

7.1 Definitions

The Subgroup recommends the adoption of the definitions attributed to the words Bioengineering, Biochemical/Food Engineering, Biomedical Engineering and Bioresource Engineering, as outlined in section 3.2.

7.2 Core Body of Knowledge

(a) The Subgroup recommends the adoption of the Core Body of Knowledge and syllabi for Bioengineering, Biochemical/Food Engineering, Biomedical Engineering and Bioresource Engineering as outlined in sections 4.2-4.5.

(b) The Subgroup also recommends that Council refer this report to the Academic Requirements Committee and the Experience Requirements Committee to develop the Board Sheets used in the Licensure process.

7.3 Areas of Practice

The Subgroup recommends that PEO adopt the Areas of Practice described in sections 5.1-5.3 for Biochemical/Food Engineering, Biomedical Engineering and Bioresource Engineering.

8. POLICY INITIATIVES

8.1 Motions to Council

To give effect to the work of the Subgroup, the following course of action is suggested:

(a) That PEO Council pass a motion to receive the Subgroup report for review by Councillors before it is debated.

(b) That Council pass a motion at the subsequent Council meeting as follows:

Be it resolved that:

1. PEO Council endorse the recommendations of the Bioengineering Subgroup pertaining to the definitions of the terms Bioengineering, Biochemical/Food Engineering, Biomedical Engineering and Bioresource Engineering;
2. PEO Council recognize the Core Body of Knowledge (CBOK) as described in the Subgroup report;
3. PEO Council endorse the areas of practice as described in the Subgroup report;
4. PEO Council refer the report to the Academic Requirements Committee and the Experience Requirements Committee to develop Board Sheets;
5. PEO Council refer the report to the Council of Ontario Deans of Engineering (CODE) for consideration and distribution to appropriate parties or departments that might have an interest in creating or adopting the report for bioengineering programs;
6. PEO Council refer the Report to the Government Affairs Committee with specific instructions to develop a Demand-Side Legislation strategy for Council to consider. This exercise should be done in consultation/partnership with the Ministry of Energy, Science and Technology (and the Minister's renewed blessing);
7. Council refer the Report to the Canadian Council of Professional Engineers for distribution to its Canadian Engineering Accreditation Board, Canadian Engineering Qualifications Board and all interested stakeholders, as applicable;
8. PEO Council stand down the Subgroup.

8.2 Follow-up Action

This report contains a large number of course titles. Many of these are common titles familiar to individuals knowledgeable in the field. Other titles are less well known. To reduce any confusion surrounding these courses and their inclusion here, course syllabi should be written to clarify those not common to other areas of engineering.

APPENDIX A. TERMS OF REFERENCE, EDTG—BIOENGINEERING SUBGROUP, FEBRUARY 18, 2000

1. Introduction

The Engineering Disciplines Task Group (EDTG) was established in response to the recommendations contained in the Report of the Task Group on Emerging and Multidisciplinary Groups of November 1996. The EDTG's initial focus was to recommend to Council solutions to the different issues in the area of software engineering practice and to identify issues pertinent to PEO. The software engineering group has completed deliberations and is in the process of preparing a report to Council.

Over the last two decades we have seen a significant growth in R&D and applications in the field of bioengineering to improvements in agriculture, medicine and pharmaceutical products. Almost daily we hear of genetically modified foods, molecular bioengineering of protein, bio engineered skin grafts, ultrasonic scanners and medical imaging.

Six universities in Canada have been accredited to provide undergraduate programs in bio resource engineering, biological engineering, bio systems engineering and biochemical engineering. Two of these six universities are Guelph and Western. These programs are unique because of their emphasis on the biological sciences, and their close relationship to the traditional engineering disciplines such as electrical, mechanical and chemical.

There is also the Institute of Biomaterials and Biomedical Engineering, University of Toronto organised into three research teams - Diagnostic, health-rehabilitation engineering and tissue engineering. There are about 120 students in the Institute engaged in collaborative graduate programs.

Graduates of these programs are readily absorbed by companies operating in the bioengineering field. Professional engineering licensure is not a requirement for employment and as a result the licensure rate of bio-engineers is low. The work that is carried out in these areas under the bio-engineering umbrella definitely affects the health and welfare of the public.

The PEO Council recognizes that the time has come for creating a bioengineering discipline encompassing all the bio specialties. Persons who are practicing in these areas will have the opportunity to become professional engineers within a discipline that may address their professional goals. This should attract recent graduates passing out of existing programs, and could give rise to new engineering programs such as in biomedical engineering.

2. Objective

The Subgroup's long-term objectives are to recommend to PEO Council policies and procedures that,

(a) contribute to the protection of the public interests in matters relating to bio-engineering;
(b) ensure PEO's ability to regulate the practice of professional engineering in this area.

The short term objectives effectively define the mandate of the Subgroup and are as follows:

(a) to define a Core Body of Knowledge, and translate this into a Board Sheet that is to be used by the Academic Requirements Committee for licensure;
(b) to define the areas of practice which require the skills of a bioengineer;
(c) to recommend policy initiatives to recognize and position PEO to respond to issues and changes occurring in the field of bioengineering;

In carrying out its mandated tasks the Subgroup may make relevant recommendations to Council on any matter, but not limited to, the foregoing.

3. Action Plan

Given that one of the Bioengineering Subgroup's prime mandates is to define a Core Body of Knowledge and translate it into a Board sheet to be used by the ARC for licensure, it would be appropriate to review the curricula for the existing bio programs.

It is desirable to liaise with the CEAB and the other provinces so that we can begin a dialogue that could result in National standards. Further, the participation of CODE so that Deans who are interested can appropriately respond with new programs in Bioengineering is important.

The engineering profession needs to attract and work with scientists and applied scientists in this field. Such expertise will be required to teach the first generation of Bio-Engineers. Hence, adding one or more of such scientists on this Subgroup is highly desired. This is a new departure for PEO in how it forms task forces and task groups.

Finally, we need to systematically define the areas of practice, which require the skills of a Bioengineer, within the context of public interest. A compilation of policy initiatives and strategies for issue management in the area of bioengineering written into a report to PEO Council would be a fitting closure to this assignment. This can take two specific forms:

1. Recommendations for the Enforcement Committee so that they can apply Common Law techniques. This will mean defining how to recognize the work of a Bioengineer in the work place.
2. Recommendations for the creation of Demand-side legislation or additions to current legislation. This can be done in partnership with the Government Affairs Committee, which can compile a list of current legislation that impacts Biotechnology and Engineering.

4. Procedure

PEO staff will provide necessary advice and support to the Subgroup, including secretarial and liaison with other committees/task groups internal to PEO.

The Subgroup is encouraged to use electronic means for communication purposes where possible.

The Subgroup shall operate on a consensual basis. In contributing to the deliberations of the Subgroup, the Chair and Members are expected to draw upon their own networks, contacts and experience.

The Chair shall write a Final Report. The recommendations contained in the Final Report shall reflect consensus among all members. Dissenting views may be placed on record under individual member's names.

The Subgroup may provide suggested solutions and recommendations to Council should there be an identified need for action.

5. Resources

The Subgroup will be provided with the resources required to carry out this task assigned by the Council.

Funding for the Subgroup will be covered as part of the EDTG budget.

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A. Margaritis, Ph.D., P.Eng.
Joseph Molto, Ph.D.
Steve Nauman, Director of Rehabilitation Department, Bloorview MacMillan Centre
John Runciman, Ph.D., P.Eng.
Michael Sefton, Ph.D., P.Eng.,Director, Institute of Biomaterials and Biomedical Engineering
Ady Solomon, Ph.D., P.Eng.

Councillors: Peter DeVita, P.Eng.
Maximus Perera, P.Eng.

CCPE: Begonia Lojk, P.Eng.

PEO Staff: Roger Barker, P.Eng.; Norman Williams, Ph.D, P.Eng. ; Johnny Zuccon, P.Eng.; Connie Mucklestone

5. Timing

Executive Committee approval of the Terms of Reference:	March 13, 2000
Modified Terms of Reference to be presented to Council:	March 24, 2000
PEO Workshop presentation to Council on "What is Bioengineering?"	June 1, 2, 2000
Interim Report to Council	June, 2000
Core Body of Knowledge report (Board Sheet) to Council	Sept., 2000
Scope of Practice concepts for Enforcement Committee	January 2001
Suggestions for Demand-side Legislation for Government Affairs Committee	February, 2001
Final Report and Recommendations to Council	March, 2001

6. Authority

Passed by a resolution of Council meeting on February 18, 2000.

APPENDIX B

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Memorandum

To: Bioengineering Task Group

cc: Government Affairs Committee

From: John Gamble, P.Eng.

Date: April 3, 2000

Subject: Meeting with Minister Wilson

Representatives of PEO met with the Honourable Jim Wilson, and his staff at the Ministry of Energy, Science and Technology (MEST) to discuss the anticipated growth of biotechnology in Ontario on March 22, 2000. The meeting agenda is attached for reference. Attendance was as follows:

PEO: Peter DeVita, P.Eng., President-elect
Max Perera, P.Eng., Councillor
Johnny Zuccon, P.Eng., Director Professional Affairs
John Gamble, P.Eng., Manager Government Relations

MEST: The Honourable Jim Wilson, Minister
Lloyd Robertson, Special Assistant to the Minister
Peter Molner, Ontario Biotechnology Secretariat
Varsha Dourado, Ontario Biotechnology Secretariat

The meeting went very well. While the Minister did not feel biotechnology was the sole domain of engineers, he did acknowledge the important role that professional engineers can play in the field of biotechnology. He applauded the current efforts of PEO to ensure that it can continue to fulfill its regulatory mandate as new technologies arise.

The Minister encouraged staff with the Ontario Biotechnology Secretariat to work with PEO towards the mutual objectives of promoting a strong Ontario-based biotechnology sector and considering an appropriate regulatory regime to ensure the public interest.

Mr. Molnar and Ms. Dourodo of the Ontario Biotechnology Secretariat indicate that they would be pleased to work with PEO and are interested in meeting with PEO's Bioengineering Task Group.