Where engineering & medicine meet

By Michael Mastromatteo

Engineers, particularly biomedical engineers, are becoming more prominent in health care settings. Many see engineers as leading the effort to develop new technology and digital information to improve and enhance medical treatments and therapy. How should this practice be regulated? Are practitioners appropriately educated for their leadership responsibilities? These are among the issues for the profession to consider.

The convergence of engineering with biology and other life sciences continues to present tremendous opportunity for engineers to make innovative contributions in the health field.

Although the link between engineering and life sciences is of relatively long standing, new research and recent innovations are bringing new prominence to an engineering presence in hospital or health care settings. In the last 25 years, engineers have moved from the background to the forefront in the ever-evolving health care field.

The growing list of applications for biomedical engineering is evidence of this shift. Biomedical engineering is an interdisciplinary field combining engineering, physics, chemistry and mathematics to find solutions for problems in physiology, biology and medicine. Biomedical engineers enhance patient care by bringing an engineering approach and methods to health care technology. They help develop novel rehabilitation and treatment techniques, devise new instruments that expand traditional surgical capability, and allow extremely disabled patients new hope for an improved quality of life. As well, biomedical engineers develop improvements to diagnostic imaging equipment and other tests that allow doctors to extract new and more precise kinds of information.

And, in a development that bodes well for the future, engineering educators and practising biomedical engineers both report a high level of interest among today's engineering students to apply their skills and learning in the health care area.

In a recent survey of future trends, the U.S. Department of Labor predicts that an aging North American population and efforts to control runaway health costs will spur ongoing interest in the contributions of biomedical engineers.

It's expected the demand for more sophisticated medical equipment and procedures and an increased emphasis on cost-effectiveness throughout national health care systems will only add to the demand for biomedical engineers, most notably in pharmaceutical manufacturing and related industries.

Advances in digital information are also providing engineers new ways to support health care and medicine. Engineering regulators may need to pay close attention to developments to help the profession steer a course through tricky emerging discipline regulatory waters.

In a June 2005 statement on biotechnology, the Canadian Council of Professional Engineers (CCPE) suggested the engineering profession offer its regulatory and technical expertise to the development of national policies for regulation and accreditation. The CCPE statement recognizes the need for a framework to regulate biotechnology that includes social, ethical, health, economic and environmental factors within a broad public safety context.

Gerry Margaritis, P.Eng., a professor of biochemical engineering at the University of Western Ontario, and co-chair of PEO's 2001 Bioengineering Subcommittee of the Engineering Disciplines Task Group, agrees the growing interplay between engineering and medicine will have repercussions for both professions, especially in the education of future practitioners.

"Some revisions and adjustments to both disciplines may be required to optimize the total educational and training experience of the participants, given the time limitations and the tremendous amount of work required in seven years to get both degrees (engineering and medicine)," Margaritis says. "This is especially important as we embark in the new frontiers of nanomedicine and nanoengineering."

Margaritis, in fact, supports establishing a supervisory council of engineers and doctors to respond to the anticipated changes. "I recommend the establishment of a joint engineering-medicine regulatory council under the leadership of PEO/CCPE and the Canadian Medical Association. This will need a lot of thinking, planning and good will from both disciplines," he says.

In support, Margaritis refers to a recent article from the University of Western Ontario in the *Canadian Medical Association Journal* (CMAJ), which outlines the benefits of a combined MD/bachelor of engineering science degree. By applying engineering principles to current medical problems, the degree itself underscores the growing relationship between the two disciplines, he says. "Many engineering concepts such as transfer phenomena, thermodynamics and mechanical vibrations are studied in a more medical context than would be possible in a traditional engineering or physical science program," the CMAJ article says. "In addition, the simultaneous acquisition of engineering and clinical skills provides unique insights into ways that technology can be used to improve health care."

But behind the optimistic forecasts and regulatory challenges are real success stories on the human level. Following are brief sketches of selected engineers, bioengineers, and educators whose work serves to shed a positive light on engineering as an enabling, problem-solving and, ultimately, people-centred profession.

"Some people might not think that this is leading-edge work, but we certainly think so, because there is a need that's not being met, and existing technology was not doing anything for these kinds of patients."

Tom Chau, P.Eng.

Engineer Tom Chau of Bloorview Kids Rehab in Toronto works with a young patient.

In some ways, Ross Ethier, director of the Institute of Biomaterials and Biomedical Engineering at the University of Toronto, represents the salutary vitality that exists between engineering and medicine. Although the institute has been in existence for more than 40 years, it has found many new outlets for its interdisciplinary problem solving, especially with the advent of digital information gathering.

Ethier has combined a scientific, mathematical aptitude with a curiosity about the "boundaries of disciplines," to emerge as a leader in the sphere of "biofluid mechanics."

Working with the ophthalmology and vision sciences department of U of T's faculty of medicine, Ethier is helping develop new ways of treating glaucoma. While traditional treatments centre on reducing pressure through medication or laser surgery, there remain too many unanswered questions about the progress of the disease in some patients. Ethier and his team concentrate on the movement of fluids in the eye and other factors at the molecular level that prevent drainage, and threaten the optic nerve. In a best-case scenario, his research would lead to some form of intervention that would allow for proper drainage of fluid.

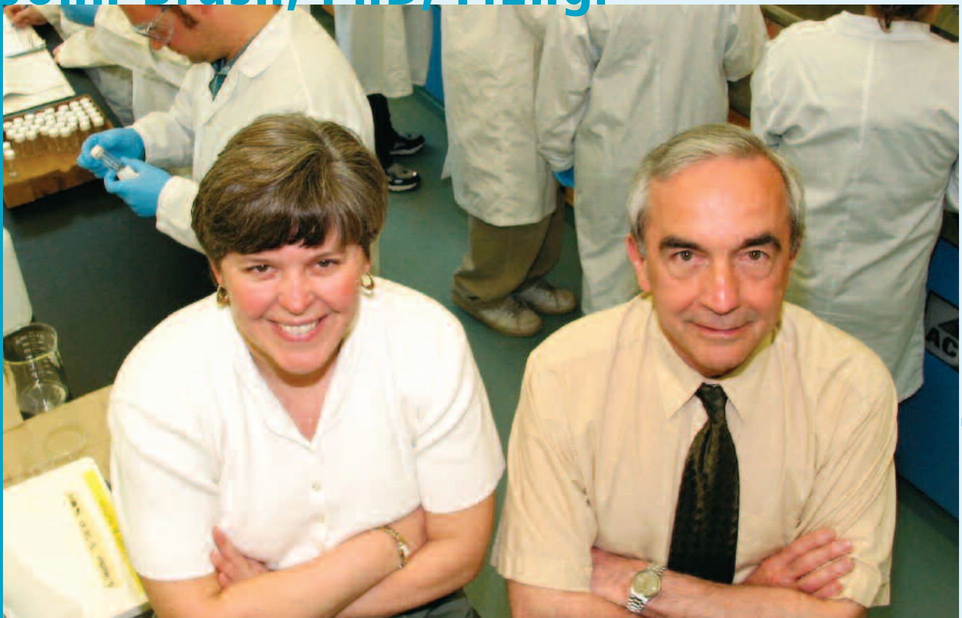
Ethier's second area of research is the application of biofluid mechanics to the cardiovascular system in the treatment of cardiac and arterial disease.

Not overly surprised biomedical engineers are starting to make such inroads in researching new forms of medical treatment, he believes the interdisciplinary nature of medicine and health care lends itself to innovation and development of new ideas and approaches.

He says the huge volume of data now available to researchers is trans-

"I have found it very satisfying to apply my knowledge and expertise to an area as important as human health and health care."

John Brash, PhD, P.Eng.



John Brash, director of the McMaster University school of biomedical engineering, with colleague Heather Sheardown, PhD, P.Eng., of the chemical engineering department.

Tom

Eng., Emily Seto, P.Eng., Levente Diosady, P.Eng., Molly Shoichet, PhD

Tom Chau gives credit to his parents for encouraging him to use his engineering skills and knowledge to make a difference in the lives of people with disabilities.

The Canada Research Chair in pediatric rehabilitation engineering at Bloorview Kids Rehab in Toronto, Chau leads a team of researchers in developing programs and devices that enable people with severe disabilities to communicate with caregivers and the environment in general.

His work helps patients, especially children, make use of whatever limited mobility and sensation they have to provide information to those around them. Through the use of muscle movement recording sensors to control prosthetic arms, throat bands to monitor choking or difficulty swallowing, or special computers that let children create messages by blinking an eye or moving a finger, Chau is breaking new ground in helping special patients experience and interact more with the world around them.

"Some people might not think that this is leading-edge work, but we certainly think so, because there is a need that's not being met, and existing technology was not doing anything for these kinds of patients," Chau told *Engineering Dimensions*. "There are a lot of novel ideas we are exploring, particularly in addressing the problem of access to communication with the environment. I think we were the first to consider using physiological signals and we've had some preliminary success that has been very encouraging."

A recipient of an Ontario Professional Engineers Engineering Medal in the Young Engineer category in November 2005, Chau combines work at Bloorview with teaching duties at the University of Toronto's Institute of Biomaterials and Biomedical Engineering. He believes there is ample ground for engineers to make ongoing contributions to health care. "Health care has become such an interdisciplinary practice and there is room now for all of these other disciplines that conventionally were not associated with health care to make real contributions." He gives credit to a host of other players in applying new treatments and techniques, but says engineers still have a central role to play in the process.

forming health care from a qualitative to a quantitative science. "And traditionally, who are the best people to deal with large volumes of data and information? They are the engineers," Ethier said.

Ross Ethier, PhD, P.Eng.

Ross Ethier, director of the Institute of Biomaterials and Biomedical Engineering at the University of Toronto.

As the first-ever director of the McMaster University school of biomedical engineering (MSBME) in Hamilton, John Brash has a unique vantage point to reflect on the contributions of engineering to health care and medicine.

The MSBME is rare in combining the university's faculties of health sciences and engineering into a single entity–and in its own way symbolizes the developing synergy between the two disciplines.

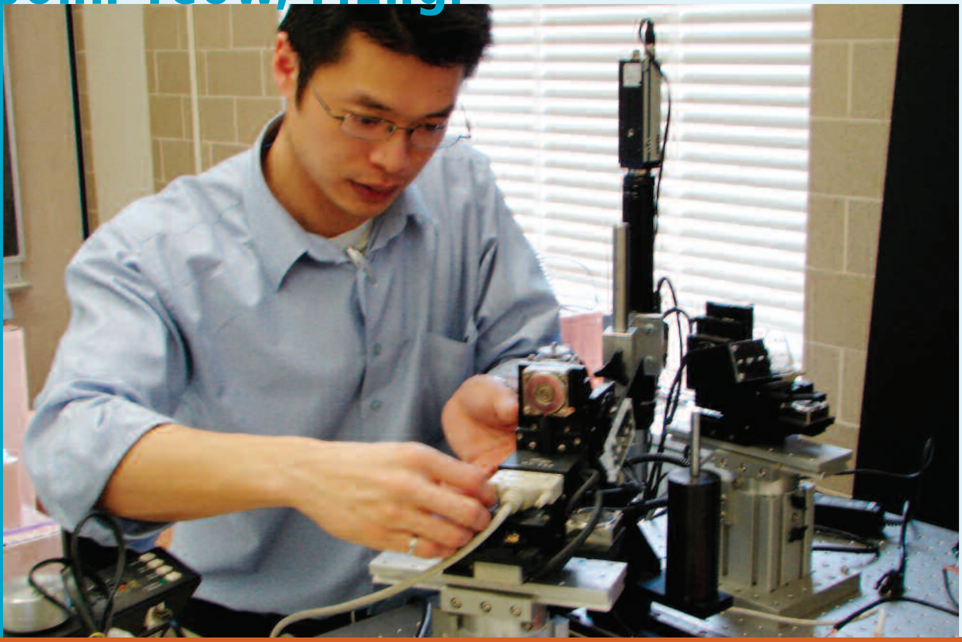
Brash joined McMaster as a professor in the departments of chemical engineering and pathology and molecular medicine. This experiential diversity is reflected in his chief interests, which involve the search for biomaterials in the development of medical devices, and the interaction of these devices with blood cells, proteins and related biological fluids.

"I have found it very satisfying to apply my knowledge and expertise to an area as important as human health and health care," Brash told *Engineering Dimensions*. "Engineering and technology have made huge contributions in this area. Think about hip and knee implants, cataract surgery–among the most successful of all surgeries–medical imaging and implants in the circulatory system, such as heart valves, stents and grafts. All of these are contributions of biomedical engineering [and] the future will see much more in the way of nanotechnology applications, tissue engineering, regenerative medicine and medical robotics."

n Chau, P.Eng., Ross Ethier, P.Eng., John Brash, P.Eng.

“Engineers have lots of expertise and technical knowledge to offer in solving the many challenges faced by physicians, oncologists and pathologists.”

John Yeow, P.Eng.



John Yeow with a robotic micromanipulator setup used for microassembly of micro/nanodevices.

Emily Seto’s involvement in engineering and health care comes by way of her work as a member of the medical device human factors group at the University Health Network, an amalgamation of teaching and research hospitals affiliated with the University of Toronto.

Seto elected the biomedical option in her engineering science studies at U of T, and eventually became involved in medical imaging research. Following up on a master’s degree thesis about finding ways to minimize patient head motion on functional magnetic resonance images, Seto remains deeply involved in patient safety and human factors issues associated with medical devices and information systems.

“The human factors work that we do is in the health care domain,” Seto told *Engineering Dimensions*. “I think human factors is an extension of my interests and experience, as it is a tool to try to make medical systems safer, more efficient and more effective.”

Seto is a strong defender of using the biomedical engineer’s input to bring a human factors approach to health care delivery and, ultimately, to the benefit of patients themselves.

“It’s interesting how health care is sometimes one of the last areas to reap the benefits of advances in processes and technology,” Seto said. “I think there are enormous improvements that can be achieved in health care using engineering and human factors principles that have already made substantial advances in areas such as aeronautics.”

Her work emphasizes the positive admixture of professionals working together to improve and enhance something as basic, yet complex, as health care and medical treatment. “Engineering often crosses over into other disciplines,”

“Engineers are always in the health and safety business.”

Levente Diosady, P.Eng.

Food engineer Levente Diosady is working to improve the diets of children in developing countries.

Any discussion of engineers' contributions to medicine and health care is bound to turn to nanotechnology. Cited by some as one of the most significant scientific breakthroughs in recent times, nanotechnology is already making an appreciable contribution to medicine. And again, engineers are often the enabling force.

John Yeow, of systems design engineering at the University of Waterloo, is harnessing nanotechnology to design more efficient and "patient-friendly" endoscopes, which will enable doctors to gain a better view of a patient's stomach and intestines.

The nanotech-based endoscope combines microsystem technology (10 to 20 microns) to provide greater imaging resolution and clarity. Yeow aimed to consult with surgeons about the limitations of existing equipment and to seek innovative ways around the identified problems. As a former consultant for the Princess Margaret Hospital in Toronto, Yeow is familiar with the functionality of various medical instruments and has devoted an engineer's touch in devising enhancements.

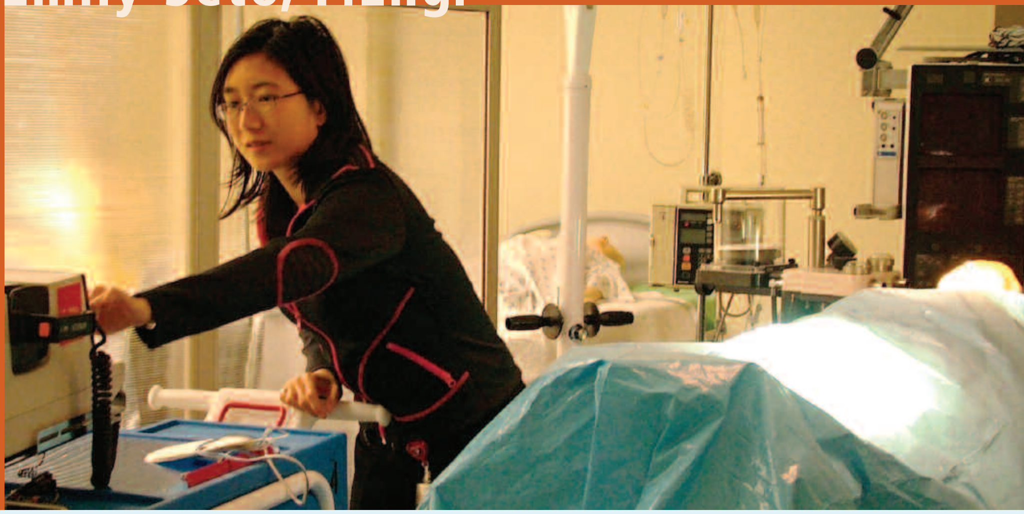
"There have been intense research interests within the academic community and industry in developing knowledge in nanotechnology science," Yeow said. "Now we are starting to observe much more activity in the development of functional devices with the incorporation of nanotechnology. Nanotechnology-based biomedical devices are gaining lots of attention because they have the potential to enhance performance by reducing power requirements, increasing sensitivity, lifetime and portability. We are still a long way from nanotech 'bots' that can function independently, but the future is bright."

Yeow also hopes to exploit nanotechnology to reduce the size, improve the efficiency and develop new applications for x-rays used in radiation oncology.

"I didn't have an interest in biomedical engineering in my undergraduate years," he says. "However, I realize that the multidisciplinary engineering-medical field is a fertile ground for innovations. Engineers have lots of expertise and technical knowledge to offer in solving the many challenges faced by physicians, oncologists and pathologists. The work domains of engineering and medicine are complex and sophisticated. The integration process of both domains will create new challenges and, at the same time, new opportunities. It requires a new breed of professionals who are well trained and experienced in both domains."

she says. "In health care, usually a team of people is required to complete a project, including a variety of clinicians, engineers, physicists, vendors and others. Sometimes the projects are designed to directly help clinicians, but the end goal is always to help the patients."

Emily Seto, P.Eng.



Biomedical engineer Emily Seto adjusts patient imaging equipment at the University Health Network facility in Toronto.

It might be a stretch to consider Levente Diosady a biomedical engineer, but there's no doubt his work and research impact on a basic area of human health. Diosady is a University of Toronto-based food engineer whose work with food fortification and preservation technology is contributing to combating malnutrition and mineral deficiencies in the developing world.

A past recipient of an Ontario Professional Engineers Engineering Medal for Research and Development, Diosady is fortifying food salt with nutrients like Vitamin A, iron and iodine to improve the diets of children in India, Kenya, and other African nations.

The lack of certain vitamins and minerals can lead to anemia, blindness, stunted growth and decreased resistance to infection and disease. Diosady has added iron, iodine and vitamins to salt as a complex, yet inexpensive, way to introduce essential nutrients to people's diets. In addition to solving the chemical and technological obstacles in combining salt with other nutrients, his research involves overcoming the cost, cultural, climatic and, even, social factors that might hinder the wide distribution of fortified salt as a dietary supplement.

Results of trials in Africa and elsewhere are proving positive. In Ghana, for example, tests involving 5000 subjects over an eight-month period revealed that use of double-fortified salt led to a significant decrease in iodine deficiency and anemia. Similar, though not as dramatic, results are anticipated in larger trials in India and various countries in Africa.

Diosady had little trouble associating work as a food engineer to a health imperative. "Engineers are always in the health and safety business," he said. "Sometimes, however, their attention has to be refocused on thinking of ways technology can be harnessed to tackle a problem like malnutrition. In some ways, engineers have always been of service to particular clients. But in the case of disease prevention, the client can be thought of as an entire society."

Molly Shoichet, PhD, Tom Chau, P.Eng., Ross Ethier, P.Eng., John Brasl

The traditional view of engineer as bridge builder might have some metaphorical significance to Molly Shoichet, a professor of chemical engineering at the University of Toronto, and holder of a Canada Research Chair in tissue engineering.

With apologies to classical civil engineering sensibility, Shoichet's work aims to build artificial bridges in fractures in the spinal cord that can act as a channel for new nerve cells. Although "reversing" the impact of spinal cord injury might be overly ambitious, her work focuses on promoting tissue regeneration and limiting the debilitating effects of spinal damage.

As Shoichet recently told the Natural Sciences and Engineering Research Council newsletter, "what is most exciting about this work is that we determined that some of the new nerve cells or axons that were growing in [lab] rats were drawing from the brain. The reason that is so exciting is that you can get tissue growing. But you also want to get the right tissue. And, in this case, it's the cells in the brain that are regenerating their axons."

Part of Shoichet's work involves the splicing of special tubes onto severed spinal cords of paraplegic rats. The tubes, which had been treated with neural growth factors, led to the growth of some new nerve tissue. Although this didn't result in dramatic new mobility on the part of the test subjects, the test showed the new spinal cord nerve tissue enabled some enhanced function.

Shoichet is considered one of Canada's leading "biotech entrepreneurs" who is looking to bring research on tissue regeneration to the next level. She was recently named director of the new bioengineering minor program at the University of Toronto. The minor is designed to enrich the undergraduate engineering experience and to help prepare students for careers in medical diagnostics, pharmaceuticals, agriculture and other interdisciplinary areas.

"The brain and the spinal cord are like the final frontier of science and knowledge," Shoichet told *Engineering Dimensions*. "There are many tissues and organs that require very creative regenerative strategies, but given the complexity of the brain and the spinal cord, I would agree that it is the biggest problem, and coming up with the strategies to overcome it requires multi-disciplinary teams."

Although not a professional engineer, Shoichet readily admits to taking an engineering approach to her neuroscience work.

Evolution in biomedical engineering

By Michael Mastromatteo

Timothy Zakutney, P.Eng., is manager of biomedical engineering in the cardiovascular devices division of the University of Ottawa Heart Institute. As the current treasurer of the Canadian Medical and Biological Engineering Society (CMBES), and a system development consultant with expertise in software systems for a number of university and health care programs, Zakutney has a unique perspective on the contributions of engineers to the wider health care arena.

Engineering Dimensions interviewed Timothy Zakutney recently.

Engineering Dimensions: How did you become involved with the Canadian Medical and Biological Engineering Society in the first place?

Zakutney: My first introduction to CMBES was during my graduate school years. The CMBES membership is comprised of all professionals associated with medicine, medical devices, and health care delivery. CMBES is an advocate not only for the biomedical engineering profession focused on research and development, but also clinical engineering, the profession that applies engineering and management principles to medical device technology in the health care setting. The best description would be to say that the society promotes all aspects of medical engineering from "bench to bedside."

Engineering Dimensions: Although CMBES was established back in 1965, it seems to represent the growing inter-relationship between engineering and medicine/health care. Would you agree the inter-relationship has become more important in the last few years and that health care professionals are looking for more input from biomedical engineers?

Zakutney: Engineers have always played, and will continue to play, a key role in materializing the innovative ideas, techniques and procedures that are spawned in the hospital and academic organizations. In fact, what we find is that as engineering specialties expand and develop, in particular, computer and software engineering, this role is being harnessed by the medical technology field. With the growing emphasis on wireless technologies, tele-home monitoring, tele-medicine and electronic patient and health records, these relatively new professions are making tremendous contributions to health care. In reality, engineering has always played a prominent role in health care, although perhaps not formally under the label as a biomedical engineer as today. Potentially, all engineering professions can be considered biomedical engineers as each specialty has something to offer health and patient care.

Engineering Dimensions: Can you describe briefly some of your work as manager of biomedical engineering at the (University of Ottawa) Heart Institute?

Zakutney: The key role of the biomedical engineering services team of the cardiovascular devices division is to be the primary resource for all medical technology issues. As a clinical engineer leading several biomedical engineering technologists, we are all key members of the patient care team. It is our mandate to ensure that no patient will ever be harmed, or treatment be delayed by medical technology. The team oversees 8000 medical devices. We maintain these devices, provide training on their h, P.Eng., John Yeow, P.Eng., Emily Seto, P.Eng., Levente Diosady, P.Eng.

"Certainly, you can draw on engineering without being a professional engineer," she said. "We work with some of the fundamental engineering principles in our research, and from the transport phenomena and design criteria, we really think about the problems in neuroscience from a design perspective. What we're trying to do is take what we know in neuroscience today and build strategies to use that knowledge to promote regeneration. At the same time, we're building tools that can be used to understand better the fundamental neuroscience." It is in precisely such an area that the boundaries between engineering and natural science become blurry, posing regulatory challenges for the profession.

Molly Shoichet, PhD

Molly Shoichet, a Canada Research Chair in tissue engineering (University of Toronto), is considered one of the country's leading biotech entrepreneurs.

proper and safe use, provide consultation on new developments and assist in the needs analysis, specification, trial and evaluation, and procurement of new technologies. Another key role we play is incident investigation when they involve medical technologies.

Engineering Dimensions: In general terms, do you find that medical professionals are turning to engineers to come up with new techniques, instruments or processes to improve patient care? If so, might this put additional pressure or responsibility on engineers of the future to look to health care as an area in which an engineering mindset can hold sway?

Zakutney: The single greatest engineering feat on the planet is the human body. As such, it is natural and necessary that biomedical engineers participate in the development of new devices, treatments and diagnosis techniques. It is the engineer who can decipher and understand these processes and subsequently help to repair, mimic and design substitutions and enhancements to them. Biomedical and clinical engineers have always believed the necessity of their role in the delivery of health care. It is only in the last 30 years that engineering has emerged as an "official" member of hospital staff. In the past, engineers would function in the background. However, now, medical professionals are realizing that the complexity of technology requires direct interaction and consultation with professional engineers to achieve their health goals.

Engineering Dimensions: Do you have any thoughts on what the emergence of biomedical engineering might mean to engineering regulators such as PEO? CMBES has established clinical engineering standards of practice, but as engineering and health care continue to overlap, might it be time for regulators to consider new designations, revisions to engineering education curriculum, etc.?

Zakutney: Currently, the International Certification Commission Board certifies clinical engineering professionals with the Certified Clinical Engineer (CCE) designation. To achieve the designation, a clinical engineer undergoes an examination process testing and requires significant active experience in the field. There is also a certification process for biomedical engineering technologists with the Certified Biomedical Engineering Technologist (CBET) designation. However, none exist for the biomedical engineering practice in research and development of medical devices. CMBES is starting to work with accreditation and standardization bodies to help formalize the requirements of clinical and biomedical engineering services in the hospital environment. As the broad spectrum of engineering specialties grows [it will] have particular impact on patient care [and therefore] specific designations for biomedical engineers are not only necessary but also needed to promote and elevate the profession. I believe that all future engineers should be exposed, in some form or fashion, to human physiology, current medical practice, and medical technology. All specialties of engineering have something real to offer patient care and not until students of engineering are exposed to the trials and dilemmas of health care providers will innovation, solutions, and inspirations be fostered.