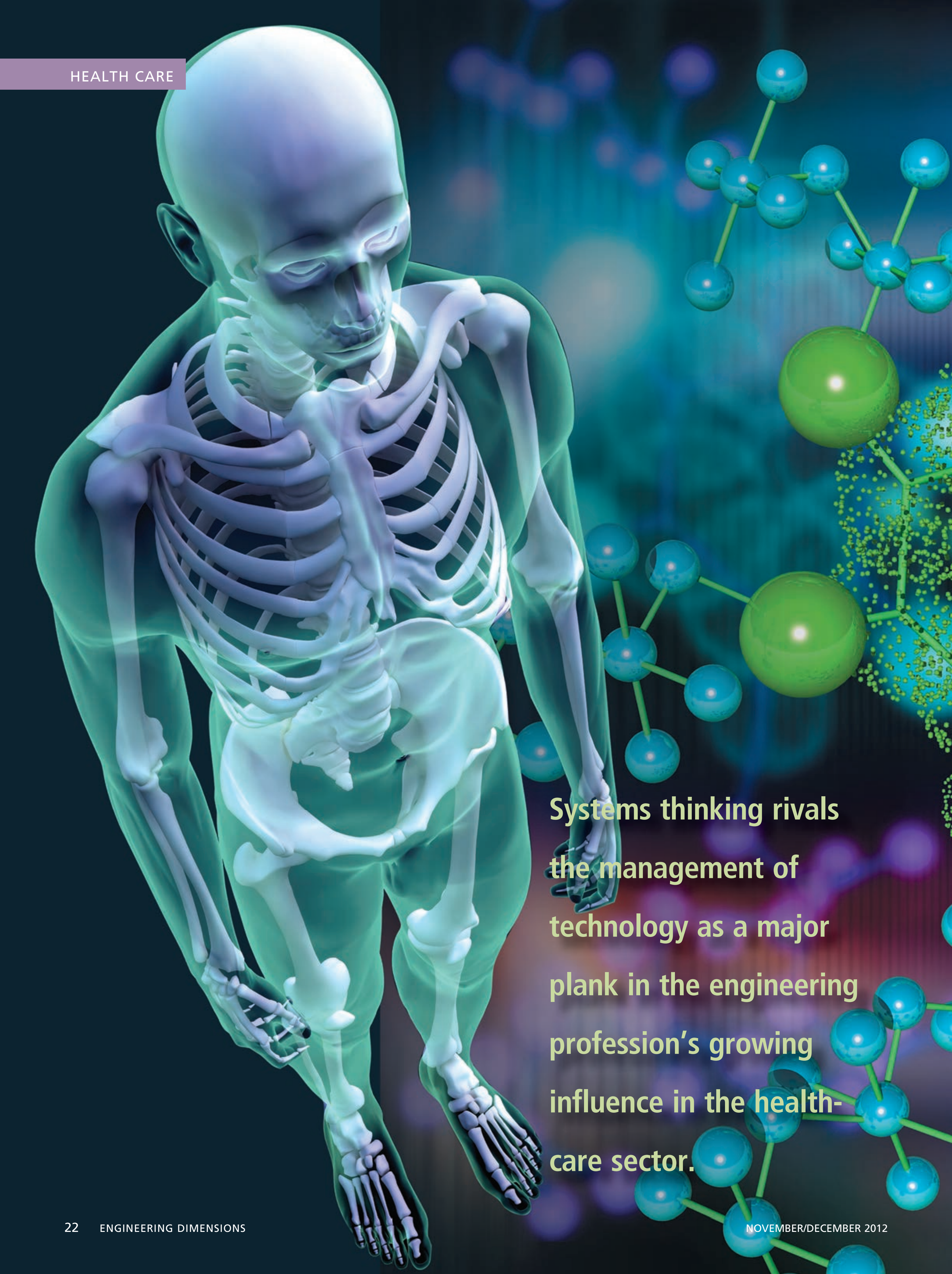


Systems thinking rivals the management of technology as a major plank in the engineering profession's growing influence in the health-care sector.

Integrating engineering & health care: It's NOT all about technology

The University of Toronto's Institute of Biomaterials and Biomedical Engineering (IBBME) is celebrating the 50th anniversary of its founding in 2012. As part of the celebrations, the institute organized a two-day conference in early October dedicated to the theme: advancing tomorrow–the integration of engineering and medicine.

The IBBME celebration featured a "tomorrow's technology showcase" primarily comprising presentations by cutting-edge companies demonstrating some of their "new and futuristic" biomedical technologies and applications.

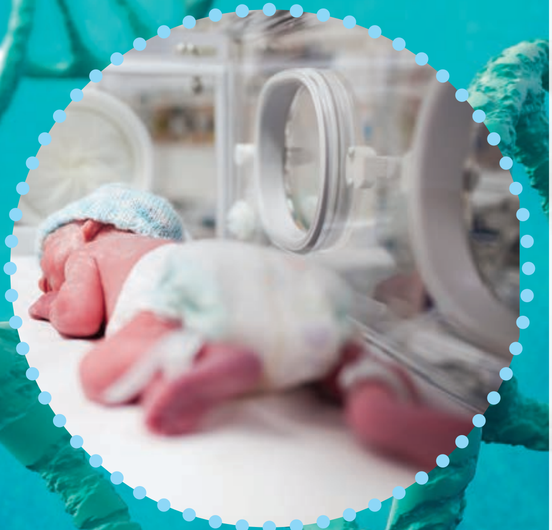
It's no longer considered novel that engineering is enhancing medical treatment and health-care delivery, but some might be surprised that the field of biomedical engineering even has 50 years of history to celebrate.

But there's little doubt the field is changing in ways that allow engineering professionals to make new and exciting contributions. Every time you turn around, it seems, an engineer in a university or research setting is touting potential breakthroughs in the treatment of cancer, in mapping out the human genome to detect and repair genetic abnormalities, in stem cell research to repair spinal cord injury or in the development of new skin for burn victims. All along life's spectrum, from the development of devices allowing children with multiple physical and cognitive challenges to communicate, to the introduction of smart sensors and computer programs permitting seniors with dementia and Alzheimer's disease to remain in their homes with greater independence and security, engineers are making new inroads in the health-care sector.

In fact, the traditional channels for engineers to improve medical practice, namely the development of new technology, almost seem old hat when considering the profession's more recent impacts on the wider health-care sector. It has certainly come a very long way since 1951 when the late electrical engineer, John Hopps, P.Eng., designed the first external pacemaker, which has prevented millions of deaths worldwide.

Moving out from the more traditional avenues of impact, the engineering profession has more recently made greater use of its systems thinking tool kit to help government officials, policy-makers and care practitioners make better use of resources to improve the administration of hospitals, operating rooms, clinics, and increasingly complex diagnostic equipment. Systems thinking is an approach to problem solving that involves considering problems as part of an overall system, rather than in isolation.

By Michael Mastromatteo



As well, some engineering professionals have turned the human factors discipline–how people interact with and respond to technology–to the service of the health-care system. And, the need to manage huge amounts of new data and information, ranging from diagnostics to drug delivery to patient records, also calls on professional engineers to apply their expertise to the service of health care and medicine. The digitalization of patient records (see feature, p. 28) is just the latest example.

SYSTEMS MINDSET

Joseph Cafazzo, PhD, P.Eng., senior director, health care human factors, University Health Network (UHN), leads research into the home use of medical technology by patients, as well as into the design and evaluation of medical technology.

"Over 50 years ago it was in the electrical and mechanical area where engineers made their greatest contribution to health care," Cafazzo says. "Today, it's the systems thinking mindset of industrial engineers that makes a big difference."

In addition to his human factors work, Cafazzo leads the UHN's Global eHealth Innovation, an organization dedicated to adapting health technologies to a more human or patient focus. A major element of Cafazzo's work is in the area of technology that facilitates patient self-care.

In many ways, Cafazzo embodies the diversified skill set of today's biomedical engineer, overseeing as he does the development of technology, and its application and use in the field.

The integration of engineering and health care traditionally concentrated on engineers' contributions to medical technology and the entire field of clinical engineering. The branch of biomedical engineering dealing with the implementation of medical equipment and technologies in hospitals or other clinical settings, clinical engineering remains a key area for P.Engs to support the health-care sector.

In general, clinical engineers are responsible for training and supervising biomedical equipment technologists, selecting technological products and managing their implementation and maintenance.

In some instances, clinical engineers work with medical device manufacturers on prospective design improvements to the operation of existing equipment in the clinical setting.

Murat Firat, P.Eng., is a certified clinical engineer and a manager of the medical engineering department at UHN.

Firat is also president of the Canadian Medical and Biological Association (CMBES), an association of 200 engineers and technologists dedicated to the safety of patients through support and management of medical devices and systems. Not surprisingly, John Hopps, inventor of the artificial pacemaker (cited above), was the founding president of CMBES.

CMBES publishes guidelines and clinical engineering standards of practice, but has no regulatory function vis-à-vis the conduct of clinical engineers.

"An engineering mindset and a focus on quality have been driving the development of clinical engineering standards of practice," Firat says. "The association also collaborates with Accreditation Canada, which provides national and international health-care organizations with an external peer review process and accredits the health-care organizations. CMBES clinical engineering standards of practice are now an integral part and reference for the accreditation of health-care organizations. CMBES believes that as the subject matter experts, this is one of their contributions to patient safety and efficient health-care delivery."

The association, which recently observed a national biomedical/clinical engineering appreciation week, has two central aims: education toward the advancement of the theory and practice of medical device technology, and professional support of members engaged in life science/medicine interdisciplinary work.

CMBES members range from professional engineers, to biomedical engineering technologists/technicians, scientists, researchers, professors and educators, who work together to serve patients and the medical community, and to oversee new technology development.

"We have many engineers working together collaboratively with front-line health-care workers," Firat told *Engineering Dimensions*. "There are not only clinical engineers, but industrial engineers, systems engineers, usability-human factors engineers, computer engineers, and more. And the appreciation grows daily, based on the priceless contributions engineers bring to health care."

Technology-focused contributions, however, have long characterized the engineering profession's contributions to the health sector. More recently, some engineers have played a key role in advances in regenerative medicine, harnessing the power of stem cells, tissue engineering and biomaterials to repair, regenerate or replace diseased cells, tissue and organs. Much of that work invites engineers not only to participate in the development of new forms of medical treatment, but also to use their entrepreneurial and business savvy to bring these processes or devices to market.

COMMERCIALIZATION GAP

Michael May is chief executive officer of the Centre for Commercialization of Regenerative Medicine (CCRM). Founded in 2011, the centre is a not-for-profit consortium supporting development of "foundational technologies" that accelerate commercialization of stem-cell and biomaterials-based products and services.

The centre is motivated in part by concerns that many potentially life-changing regenerative medical treatments never reach patients because they are not successfully moved from the laboratory to a practitioner's clinic.

May, a University of Toronto chemical engineering graduate and a protégé of pioneering biomedical engineer Michael Sefton, PhD, P.Eng., says engineers can play an important role in overcoming commercialization gaps, particularly in the health-care and regenerative medicine area.

"Engineers bring a variety of valuable skill sets to the table that serve them well in the regenerative medicine field," May says. "Fundamentally, you need to understand the science but engineers go that step further by applying their specialized training to translate that science into real-world products and devices and technologies. They have helped spawn new industries by melding multiple disciplines and regenerative medicine is an exciting example for that."

Equally significant in discussing the profession's expanding influence in health care is the rise of industrial engineering graduates in bringing new innovations to the administration of hospitals and health-care resources in Ontario.

Michael Carter, PhD, LEL, is founder of the Centre for Research in Health Care Engineering (CRHE), an independent department within the University of Toronto's department of mechanical and industrial engineering.

Created in 2008, the centre is recognized in the health-care community for its ability to bridge the academic/operational interface between teachers/learners and health-care providers.

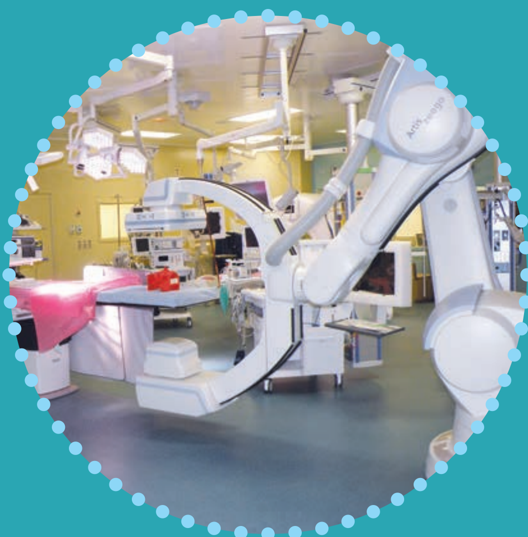
Long an exponent of industrial or systems engineering as a solution finder and model builder, Carter is proud of the inroads made by industrial engineering graduates in the health-care sector. His work was a substantial contribution to a recent policy initiative of the Ontario government to reduce patients' surgical and hospital wait times. In an era when resource allocation has come under increased scrutiny, any research bringing greater efficiency to aspects of hospital administration rises in priority.

Among the centre's recent research triumphs is a study for the Canadian Society of Cardiac Surgeons on the right number of surgeons to meet future cardiac surgery needs. Additional studies include how many beds hospitals actually need, a generic simulation model to help hospitals plan operating room schedules; an ambulatory clinic plan for Women's College Hospital in Toronto; a report for the Ontario government on key drivers for mental health; and GIS mapping of supply and demand gaps for aging-at-home services for all of Ontario's LHINs.

"Biomedical engineering has long been an established standard in health care," Carter says in discussing the new influence of engineering in health care. "Systems thinking is relatively new, but getting a lot of attention at the policy level. People are beginning to realize that we need to look at the functioning of the whole system; not just the components and influence of industrial engineering on medicine."

Carter believes that while industrial engineering is making significant inroads, the health-care sector is still lagging behind other sectors in exploiting the systems approach to bring efficiencies and enhancements.

"There are several examples that illustrate that the health-care industry is 20 years behind manufacturing and 15 years behind other service industries in embracing the full benefits of industrial engineering thinking," Carter says. "Examples include the use of information systems and the introduction of 'lean' concepts.



Health care 'discovered' lean in the past five to 10 years while manufacturing was well into it in the 1980s."

CRHE Director Neil McEvoy, P.Eng., former president of Providence Healthcare, suggests industrial engineers are well suited to digest the enormous amount of data inherent in managing elements of the health-care system.

"Few of the professions in health care are as deeply rooted in quantitative methods as engineers are," McEvoy told *Engineering Dimensions*. "Within the profession, we may make distinctions between the application areas, and some may have more visible and tangible results than others. But the analytical and design skills that engineers bring to health care are as fundamental in the areas of process improvement as they are in the electrical, HVAC and structural aspects of the buildings that house them."

McEvoy says also that only recently have advocates of "process improvement" recognized the depth that industrial engineering adds to the work of interdisciplinary teams in hospitals.

"This awareness of engineering thinking is building among a number of the professions in health care," he adds. "Nursing has welcomed the structured thinking; physicians are becoming comfortable with the attention to data, and finance specialists welcome the more advanced forecasting techniques."

In evaluating the impact of engineering on modern health-care delivery, the name Tom Closson, P.Eng., readily comes to mind. A one-time head of UHN and former president and CEO of the Ontario Hospital Association, Closson has nearly 40 years' experience in the administration of Ontario hospitals and health-care facilities.

The recipient of an Ontario Professional Engineers Engineering Medal for management (2005), Closson is well positioned to note trends in the health-care system and the contributions of engineering systems thinking to innovation and resource allocation.

"The basic reason there is such a growth of industrial engineering concepts [in the health-care sector] is you've got a large number of people and you are trying to look at how you can have better processes for them to do their work," Closson says. "It's all about lean process. Organizations are using industrial engineers to a large extent to support other staff who work in the organization, to look at how procedures work and how you can make your processes more effective to achieve certain outcomes."

NEW APPS FOR HOME HEALTH CARE

Sridhar (Sri) Krishnan, PhD, P.Eng., associate dean (research), faculty of engineering and architectural science, Ryerson University, and Canada research chair in biomedical signal analysis, is an engineering educator whose research interests include developing engineering techniques and tools for non-invasive diagnosis and monitoring of cardiovascular and neuromuscular problems.

Krishnan and program director Mahmood (Mike) Kassam, P.Eng., Dr. univ., were key coordinators in the Canadian Engineering Accreditation Board's (CEAB) recent approval of Ryerson's biomedical engineering program, the first undergraduate program of its kind in Canada.

The Ryerson program is characterized, in part, by a desire to have patients assume greater control of their own health care. Toward this end, research at Ryerson has focused in the area of applications on mobile computers and phones that can monitor the vital signs of human health on a continual or on-demand basis. Because they provide patients with more relevant and up-to-date information, they enable patients to make informed decisions about their health and lifestyle management.

Krishnan says the development of Ryerson's biomedical engineering program came partly in response to the perceived demand of students for biomedical options.

"There is greater scope and role for technology in health care, and biomedical engineering is a natural player in this," Krishnan told *Engineering Dimensions*. "The interdisciplinary nature of the program allows biomedical engineers to play a critical role in improving the human quality of life."

Krishnan is a proponent of the integration of engineering and health care to provide career flexibility within the two sectors for future practitioners. "It is possible for biomedical engineers, with some additional preparation, to write medical school entrance exams and enter the medical profession," he says. "A dual profession provides candidates with an added skill of translating some complex engineering methodologies and solutions to the medical field."

Krishnan also says there is growing interest in applying engineering methodologies to solving some complex health problems, and that such tasks involve designing instruments and devices, information and communication technologies for various health-related challenges.

Michael Noseworthy, PhD, P.Eng., associate professor, electrical and computer engineering, McMaster University, is co-director of the school's biomedical engineering program. While his research areas concentrate on innovations in medical imaging technology, the McMaster program also specializes in such areas as biomaterials and tissue engineering, medical robotics, biomedical technology and bioprocessing.

Noseworthy supports the notion of a shifting emphasis in biomedical engineering from an electrical engineering focus, to one that encompasses many more elements of health care, technology development and information management.

"A lot of the classical [biomedical engineers] in hospitals are from an electrical background," Noseworthy says. "These are the guys who fix incubators, pulsed oximeters, and other equipment. There are now lots of avenues–mechanical engineers working on bone/tendon strength and implanted hips/knees; chemical engineering people making better implanted devices, such as heart values that don't get attacked by the body's immune system, or nanotechnology for delivering insulin. There are also electrical P.Engs working on medical image system development, new devices for patient care and monitoring, and robotics for more accurate surgery."

LIFE SCIENCES AND ENGINEERING

Noseworthy suggests that an important development in engineers taking on a greater role in health care is an emphasis on life sciences in an engineering student's undergraduate education.

"Previously we never taught biology to engineers," Noseworthy says. "Now they [engineering graduates] know more biology, and they have proven themselves in health sciences. Before we had programs like this, nobody in health sciences was interested in engineers, as they figured they would only know about math, and would be afraid of a little blood. Now this is definitely not the case."

Some of the literature describing McMaster's school of biomedical engineering describes "a wide gap" between researchers trained in life sciences and those trained in engineering. It's also suggested that this gap represents an impediment to progress in a number of health-related areas. As such, schools such as McMaster are looking to the education of biomedical engineers as an enabler of ongoing innovation and development in the field.

"Health care is becoming a larger and larger challenge," Noseworthy says. "It is not sustainable, given the aging population and demand for better and better health-care. The medical doctors [alone] can't deal with this. Only engineers can build and design better stuff. But that said, it is imperative to work with the medical doctors as they define the problems. It is total team work. I think one role for PEO might be to let MD types know that biomedical engineers exist. Right now, most MDs think their solutions to their problems can all be found at conference trade shows. There is a lot of room for local research and development and perhaps PEO can help facilitate this."

With engineers working so collaboratively with doctors and other health-care professionals it raises the question of regulatory oversight of these emerging dual professionals–those with skill sets primarily in engineering, but with some near overlap with medical practice. So does the College of Physicians and Surgeons of Ontario (CPSO) have any concerns about regulatory overlap between P.Engs and MDs?

"There haven't been any regulatory issues that have come to our attention," says Louise Verity, director, policy and communications, CPSO. "Engineering science is a useful grounding for medicine and increasingly we know that medical schools are reaching out to graduates possessing a range of undergraduate degrees. As regulators, we can always learn from one another as we share common values to ensure quality practice, whether it's engineering or medicine."

In any case, the emergence of engineering in the wider health-care sector has spurred new interest in the profession among today's crop of undergraduate students. Indeed engineering educators contacted by *Engineering Dimensions* report a surge of interest on the part of undergraduate students in biomedical related programs at Ontario universities. They also cite the potential for engineers to take on dual careers, one in traditional engineering pursuits, and a second dedicated to making vital contributions in the health-care sector. Σ