Annual Report | **2018**

BIOMEDICAL ENGINEERING

Institute of Biomaterials & Biomedical Engineering
UNIVERSITY OF TORONTO

CONTRIBUTORS

Cover:
Picture of the Rosebrugh Building taken in 1964. This is where IBBME began 57 years ago. This issue illustrates how far the Institute had grown since then. (University Archives)

Content:
Warren C.W. Chan
Richard Cobbold
Tyler Irving
Jovana Drinjakovic
Qin (Bill) Dai
Julien C. Senécal

Editors:
Jenia Bloch
Warren C.W. Chan
Barbara Alexander
Yih Yang Chen

Editor-in-Chief:
Qin (Bill) Dai

Illustrations:
Qin (Bill) Dai
Denny Lie
Helado Digital

Image Sources:
Adobe Stock Images
University of Toronto Archives
Robert Lansdale Photography
IBBME Archives
Tristan McGuirk
Qin (Bill) Dai
Buddhisha Udugama
Jennifer Ma
Jovana Drinjakovic
Rodrigo-Fernandez Gonzalez
Darren Rodenhizer
Alborz Mahdavi
Brandon Burke
Neil Ta
Niloufar Khosravi

Data Sources:
FASE Annual Report
Rhonda Marley, IBBME Graduate Office
Angela Rosa, IBBME Finance Office
SciVal, Elsevier

Design:
Qin (Bill) Dai

Fact Checking:
Hans Kunov
Michael V. Sefton


IBBME
BIOMEDICAL
ENGINEERING
Institute of Biomaterials & Biomedical Engineering
UNIVERSITY OF TORONTO

Build medical devices
Grow stem cells
Develop therapies
Understand diseases

- since 1962

PhD | MEng | MHSc | MASc
ibbme.utoronto.ca

DIRECTOR | NOTE

Welcome to the first edition of the Institute of Biomaterials and Biomedical Engineering (IBBME) annual report!

It has been a pleasure to serve as the Director of IBBME. IBBME is home to researchers at the University of Toronto who are using engineering principles to solve some of the most pressing medical problems. This unique Institute is at the crossroads of research activities in the Faculty of Applied Science and Engineering, Faculty of Medicine, Faculty of Dentistry, and the Toronto Hospitals.

When you become Director of an Institute, you get a completely unique view of the whole organization. This first year has been terrific! I have discovered the wonderful and innovative research that is occurring in the Biomedical Engineering community in Toronto. I have met students that are striving to change the world of medicine by using principles that are commonly taught in engineering and the applied sciences. More importantly, I have learned a lot about the biomedical engineering community in Toronto.

The first issue highlights the history and future of IBBME, from Professor Moody's vision in the 1960s to the imprints from all of the prior Directors. It is really important to understand where we came from in order to understand where we are going! The middle part of the magazine explores and highlights some of the ground-breaking research in the Institute as well as our interactions with the community. We further profile our alumni and students. The issue finishes with a look at the future of BME in Toronto.

Enjoy!

Warren C.W. Chan
Professor and Director

PAGE CONTENT

Dr. Norman F. Moody was the first director of the Institute of Biomedical Electronics (IBE), now known as the Institute of Biomaterials and Biomedical Engineering (IBBME). This image was taken in 1964, two years after the formation of the Institute.

IBE 1962

IBME 1972

IBBME 1999

HISTORY

Biomedical engineering first emerged as an independent discipline during or shortly after the Second World War. In Canada, the beginning can be traced to the founding of the Defense Research Medical Laboratories in 1950. The primary objective of the centre was to investigate certain aspects of the interaction between humans and machines, particularly under stress. The field soon broadened from instrumentation and measurement to active support in medical research and clinical practice, and the role of the biomedical engineer changed from that of designer to collaborator.

In 1950, Dr. W.G. Bigelow and Dr. J.C. Callaghan started investigating the use of hypothermia for heart surgery at Toronto General Hospital. They invited engineer Jack A. Hopps, of the National Research Council, to join their research team, and, as a result of their collaboration, the first practical external heart pacemaker was designed and tested, much groundwork was done towards a practical implanted pacemaker, and in addition a method was devised of using radio frequency heating for bringing the subject out of hypothermia.

In the same decade, a group interested in biomedical engineering was being established at the University of Saskatchewan. In October 1958, at a cocktail party given by Dr. Wendell McLeod (Dean of Medicine), Dr. Arthur Porter (Dean of Engineering) was introduced to Dr. William Feindel (Professor of Neurosurgery), and the talk soon turned to possible cooperation between the two Faculties. To make a long story short, Professor Norman Moody was called in to work on the problem of measuring blood flow in the carotid artery. Shortly after, in July 1959, Professor Moody was appointed Chairman of Electrical Engineering at the University of Saskatchewan, and he continued his interest and activity in the field of biomedical electronics.

Dr. Porter was then invited to form the Department of Industrial Engineering at the University of Toronto. He found, when he

arrived in 1961, that here too was a strong interest in biomedical engineering; indeed, Professor Ian Dalton (Electrical Engineering) had already worked with surgeons at the Sick Children's Hospital on designing and developing a heart-lung machine. With the strong backing of the two Deans (Dean McLaughlin of Applied Science and Engineering, and Dean Hamilton of Medicine), a committee was set up to study the ways and means of establishing a formal group. One very active and enthusiastic member of this Committee was Dr. E. Llewellyn-Thomas, and strong supporters were Professor James M. Ham and Dr. John W. Scott.

The outcome of this Committee was the formation in July 1962 of the Institute of Biomedical Electronics at the University of Toronto, with Professor Norman F. Moody as Director, and, one year later, Dr. E. R. (Tommy) Llewellyn-Thomas as Associate Director.

Dr. E. Llewellyn-Thomas, an engineer and physician, joined the Institute in 1963 and later became Associate Dean of Medicine. In 1972, its tenth year as Institute of Biomedical Electronics, the Institute was again renamed the Institute of Biomedical Engineering.

Originally, the Institute had a council of 16 persons, and the Director reported to the President of the University through this council. The Director still reports to a council, which is made up of Deans of Engineering, Medicine and now Dentistry. Financial and other support comes to the Institute through these three faculties.

From the beginning, it was intended that the graduate students studying at the Institute should be drawn from a number of disciplines; i.e. engineering, the physical sciences, and the life sciences. In order not to divorce these students from their base disciplines, the Collaborative Program was conceived and developed. Students were, and still are, enrolled in their "home" departments, the Institute being a common ground where they would have their desks and laboratories to meet and exchange ideas and experiences with other researchers across the various disciplines. Close cooperation between the Institute and various departments was necessary to achieve this, thus the

1962

Institute of Biomedical Electronics (IBE) opened with Norman Moody as its first director.

1984

Launched MHSc program. IBME became a graduate unit.

1972

The Institute was renamed the Institute of Biomedical Engineering (IBME).

1999

Merged with the Centre for Biomaterials and Tissue Engineering Group. Renamed the Institute of Biomaterials & Biomedical Engineering (IBBME).

collaboration began.

Under the chairmanship of Hans Kunov and Richard Frecker, planning for a Clinical Engineering Program was completed in 1975 and approved by the Governing Council of the University but, due to fiscal constraints, the Institute was unable to launch this program until 1984. This was achieved largely through the work of the Director and his colleagues in publicizing the proposal, investigating sources of funding, offering new graduate courses and deleting old ones, all within the recommendations of the report. When the Clinical Engineering Program was finally launched, the Institute became a graduate department for the first time, enabling it to enroll students directly into the Institute. Students fulfilling the requirements of this program receive a Master of Health Sciences in Clinical Biomedical Engineering.

In April 1984, the Director organized the Institute's first Scientific Day. The keynote address was given by Professor Edward Llewellyn-Thomas, who sadly passed away shortly thereafter. Following his death, the Deans of Engineering and Medicine established the Edward Llewellyn-Thomas Memorial Lecture Series. Today, this lecture is the key event for the IBBME Annual Research Conference (IARC), in which Institute students participate in a day of oral and poster presentations of their current research.

In 1999, the Institute of Biomedical Engineering merged with the Centre for Biomaterials and the tissue engineering group in Chemical Engineering, to create today's Institute of Biomaterials and Biomedical Engineering, IBBME. In addition to Medicine and Engineering, IBBME is also a part of the Faculty of Dentistry. Many new faculty have been hired and new research directions established giving greater emphasis to the biological sciences.

In the fall of 2001, with the help of funding from the Whitaker Foundation, the Institute launched the new Graduate Program in Biomedical Engineering. This program allows students to register for graduate studies directly in IBBME, without having to register in "home" or collaborative departments. The new program has been a great success. Curriculum and research themes have been streamlined to accommodate the interests of incoming students.

BY RICHARD COBBOLD

2001

Launched MASc and PhD programs in biomedical engineering, allowing students to register for graduate studies directly.

2011

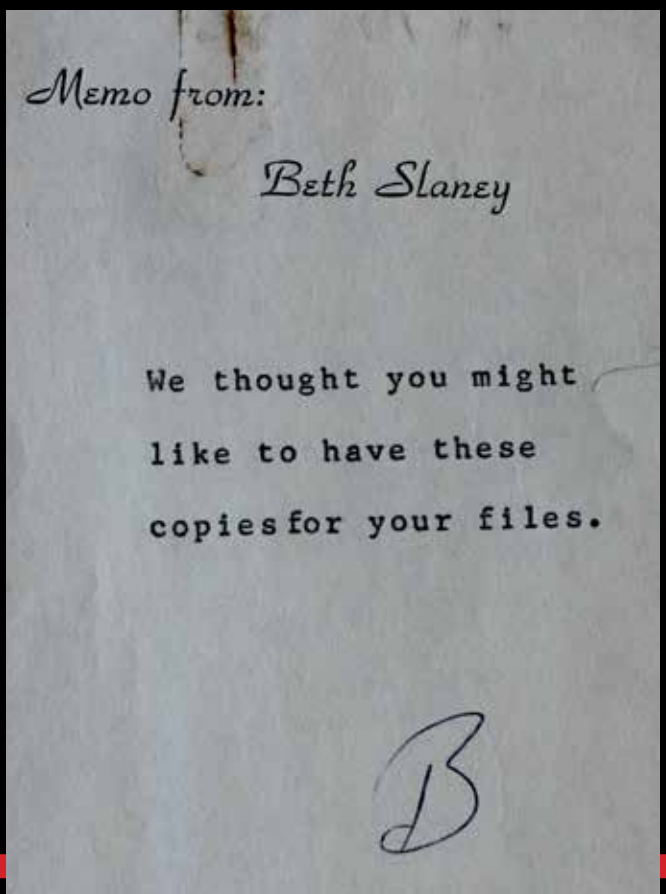
Launched its unique PhD concentration in Clinical Engineering.

2012

Celebrated 50 years of biomedical engineering innovation at the University of Toronto.

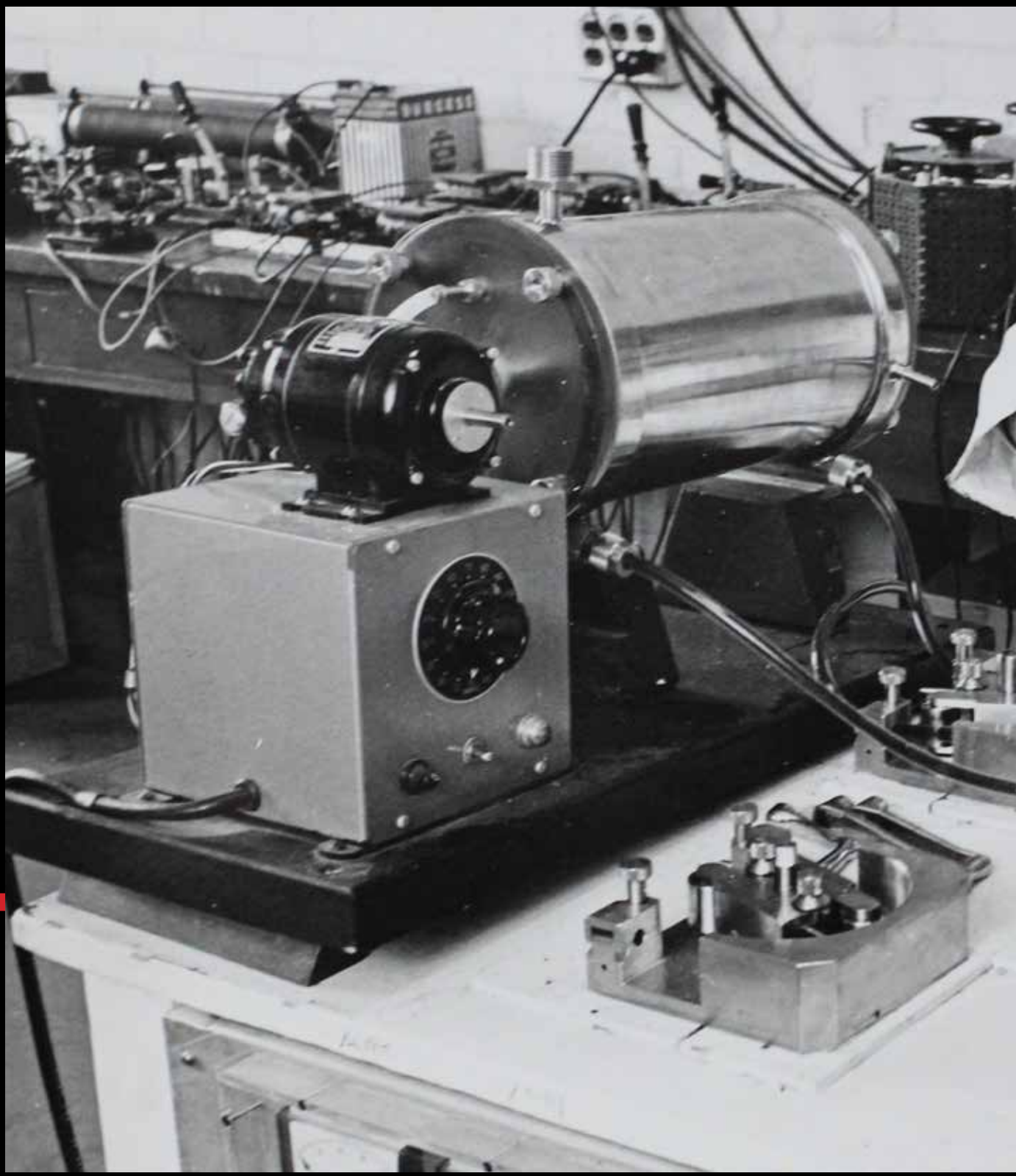
2016

Launched MEng program with focus on biomedical devices.

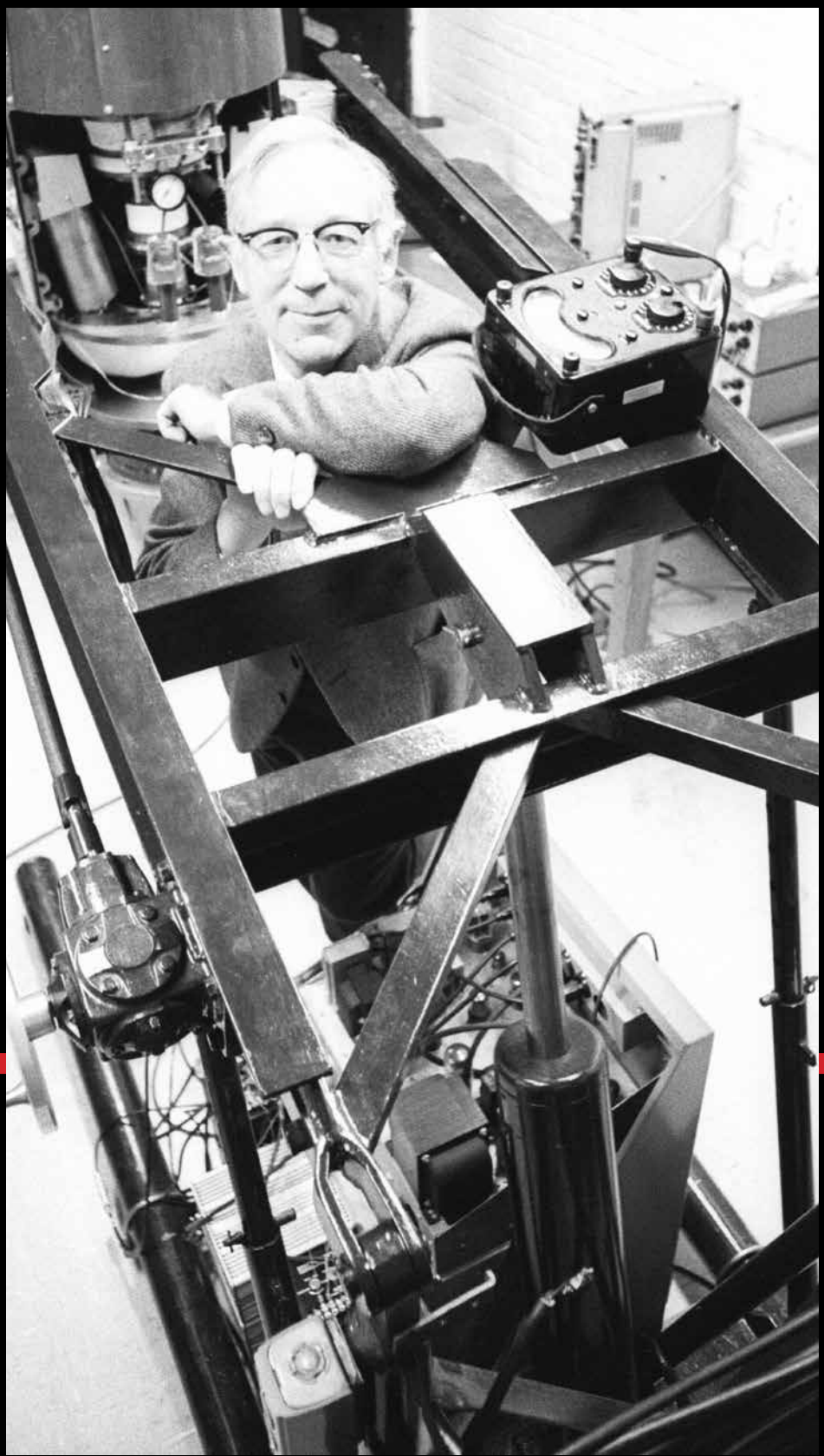


From the ARCHIVES

IBBME archived documents from the past



↑ Professor Ian Dalton (undated).



← Photographs of Dr. Norman Moody in 1974, founder and first director of the Institute of Biomedical Engineering. He is beside an image-intensifier gamma-ray camera.

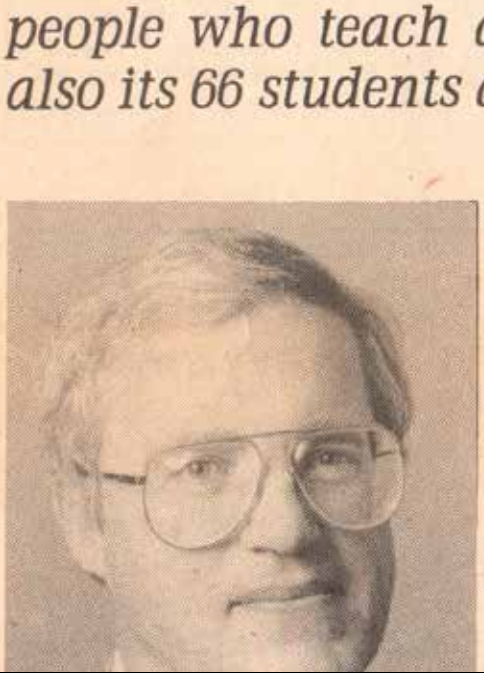

406A

← IBME student and faculty gathering in 1975. Top: Professor Kenneth C. Smith talking to students (facing right). Bottom: Ms. Anna Jamieson and Professor David James.

↑ IBME promotional magazine cover in the 1980s.

The Institute of Biomedical Engineering Celebrates 25 Years

The Institute of Biomedical Engineering (IBME) at the University of Toronto is 25 this year. Celebrations at the Institute, to be held during the week of February 22-26, 1988, will be an opportunity for IBME to bring together not only the 75 people who teach at the Institute, but also its 66 students and alumni.



tor and an associate director. One is an engineer and one is from the medical side. In the beginning, **Norman Moody** was the director and **Edward Llewellyn-Thomas** was the associate director,"

"At first, it was cal
Institute of Biomedic
tronics. It was strictl
application of electri
engineering to medi
instrumentation. At
beginning of the sixt
Faculty of Medicine
Faculty of Applied Sc
and Engineering real
that it would be usef
create an institute w
belonged to both fac
The knowledge of en
ing could be applied
tions in biology and
cine. The mandate s
to take in mechanica
ical and all other eng
specialties, and the
was changed to the
of Biomedical Engine
explains Dr. Zingg.

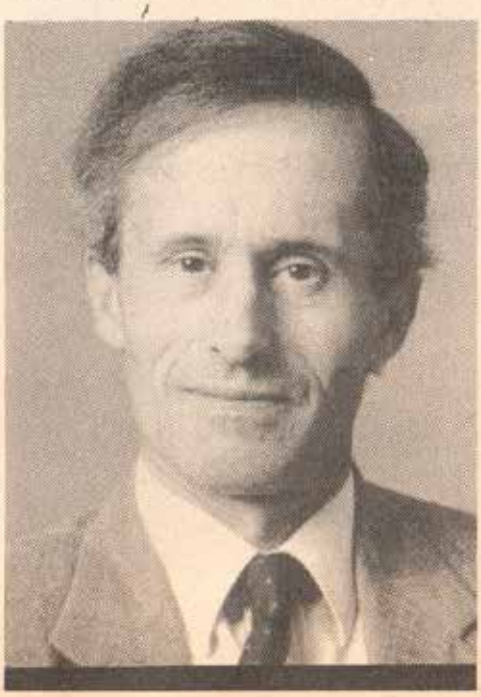
"Biomedical

led the
al Elec-
y the
ical
cal
the
ies, the
and the
cience
lized
ul to
hich
ulties.
gineer-
to ques-
medi-
oon grew
l, chem-
gineering
name
nstitute
eering,"

Responsive to the Need for Specialization

Biomedical Engineering grew out of the increasing need for specialization. Experts have had to rely on and defer to each other more and more. While this may have been difficult — a matter of pride — for some, most now find it rewarding.

"A lot has changed over the last 25 years," says **Dr.**



Richard Cobbold, who joined the Institute in 1966. "There has been a change in attitude. Specifically, twenty years ago, many physicians felt that they were at the pinnacle of human endeavor. Now, I think that most recognize limitations and that to pursue interdisciplinary

The Clinical Engineeri
program satisfies a speci
health-care need. But, th
main purpose of the Inst
remains the training of s
dents in biomedical
research.

Encouraging Industry Liaison

Research is not only time
consuming, but costly, a
scholars throughout the
versity are experiencing
ficulties with funding. Th
IBME is no exception. "N
provincial money will he
the Institute in the futur
But in the present, we're
dealing with a not insign
cant budget cut for an In
tute our size," says Dr. Jo
"Like all small institutes
IBME is at a critical stag
because money is tight."

However, Dr. Joy says
IMBE has been well treat
and protected by the Fac
ties of Applied Science a
Engineering and Medicin
But, "as equipment budg
become a thing of the pa
new equipment must co
out of research grants. W
are relying more on liais
with industry and resear
grants to keep the Institu
going."

Since Dr. Zingg becam
director, grant money ha

← Taken from the Fall 1987 issue of the "Tablet", a news tabloid produced by the Faculty of Medicine. This was a special issue that celebrates the "100 Years of Medicine at the University of Toronto". This article was the focus of the issue.


3
MINING
BUILDING

Constructed in 2000, the bridge between the 3rd floor of the Mining Building and the 4th floor of the Rosebrugh Building symbolized the collaboration and the unification of multiple disciplines under one roof.

Growing a Heart

Dr. Milica Radisic is finding ways to understand and test cardiovascular drugs using an *in vitro* testing platform - Biowire II

BY TYLER IRVING

Heart muscle cells need exercise — even when they grow outside the human body. A new device designed by U of T Engineering researchers uses a rigorous training regimen to grow small amounts of cardiac tissue and measure how strongly it beats. The platform is ideal for testing the effects of potential drug molecules, and could help bring personalized medicine closer to reality.

"Many potential new drugs fail because of toxicity issues, and cardiac toxicity is a major challenge," says Professor Milica Radisic (IBBME, ChemE), who led the research team. "You can test potential drugs on heart cells grown in a petri dish, but those cells don't look the same as the cells in a real heart, and you can't get much information about their actual cardiac function."

Radisic and her collaborators build devices that enable lab-grown cells and tissues to develop into 3D forms that more closely resemble those in the human body. Five years ago, they created the Biowire, a platform in which heart cells grow around a silk suture. By pulsing electricity through the cells, the device causes them to elongate and become more like mature human heart cells.

Their latest paper, published recently in *Cell*, describes a new platform dubbed Biowire II. It contains two wires made of elastic polymers and positioned three millimetres apart, with heart cells forming a small band of tissue between them. Each time the cells contract, they bend the wires. By measuring the amount of deflection in the wires, the researchers can determine the force of the contraction.

"The advantage of this system is that it tells us how a given drug molecule is affecting the cardiac output by examining forces of contraction and other key functional readouts," says Yimu Zhao, a PhD candidate in Radisic's lab and the lead author on the paper. "Does it weaken the heart or make it stronger? It will help find new drugs to treat heart conditions, but also eliminate drugs for other conditions that have adverse effects on the heart."

As with the original Biowire, electrical pulses are used to simulate exercise and "train" the heart cells. Zhao says the team has refined the training regimen to create tissue that is even more life-like than what was possible with the previous device, all in just six weeks.

"We have created both atrial and ventricular heart tissues, and we can even grow a heteropolar tissue, one with both atrial and ventricular ends," says Zhao. "Some drugs have a selective action on one or the other. With this system, we can detect this more efficiently."

Zhao says that one of the most impressive tests of the system came when the device was seeded with six different cell lines. Three came from patients with a condition called left ventricular hypertrophy, while the other three came from patients without the condition.

"It was a blind trial, nobody in our lab knew which cell line was which," says Zhao. "But as they grew in the device, we could clearly identify the tissues from patients with the condition by loss of contractility, which is one of the hallmarks of the disease. When we confirmed the results with our collaborators, they were so surprised — we got it exactly right."

The ability to accurately replicate the heart condition of a real patient opens the door to new applications in personalized medicine. In addition to studying the progression of disease in a particular patient, the model heart could also be used to screen several potential treatments simultaneously, narrowing in on the ones most likely to be effective for that individual.

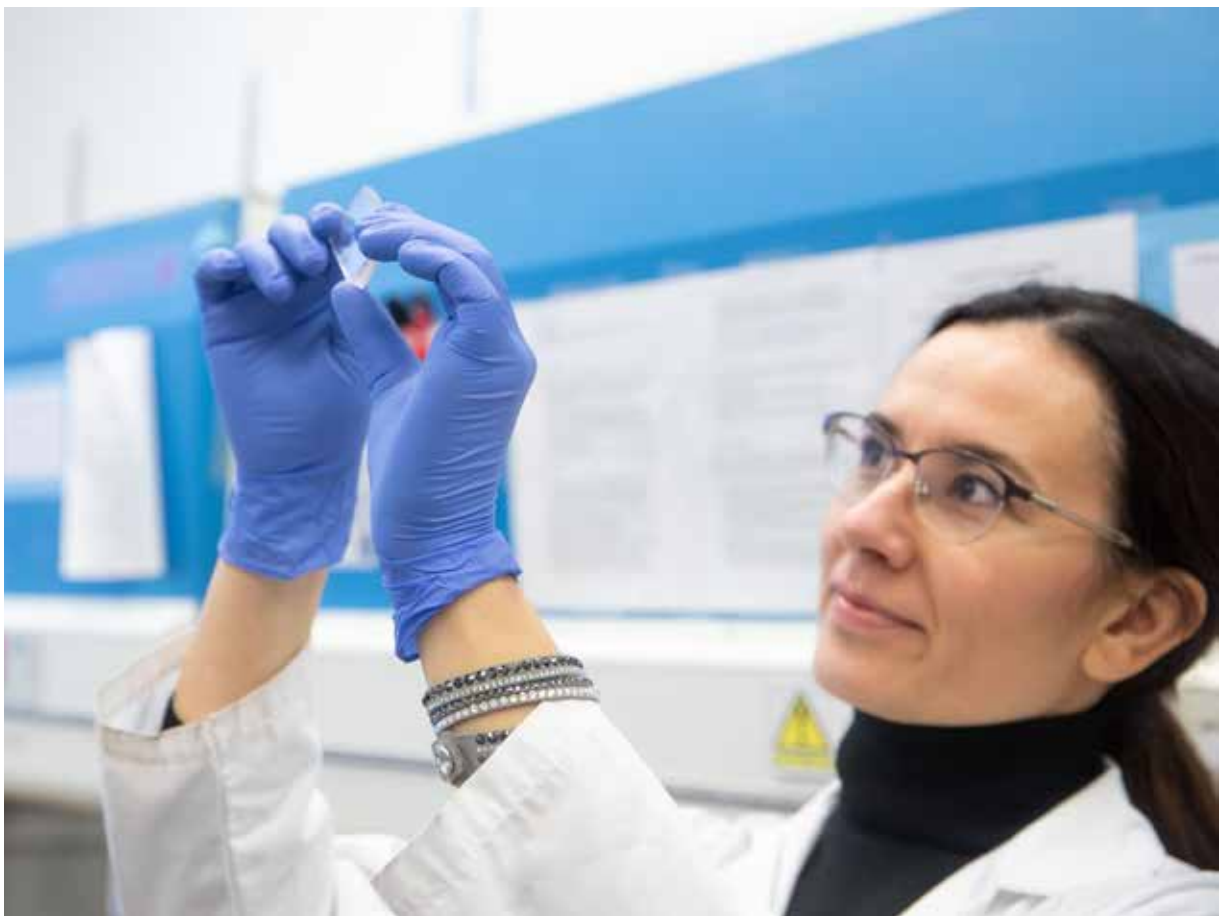
→ Dr. Milica Radisic holding one of the microfluidic devices.

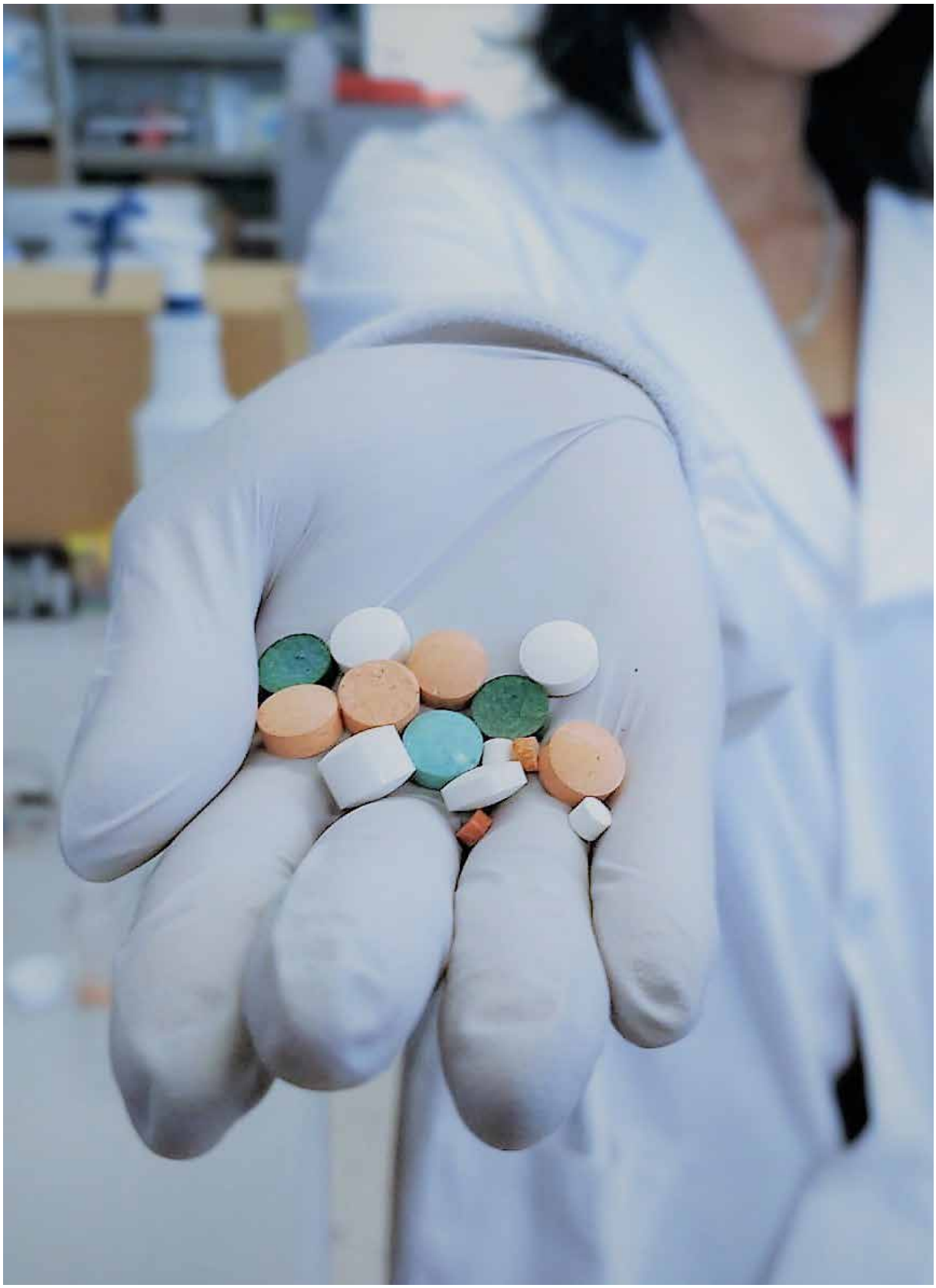
More research will be required before the platform can be used in this way, but Biowire II is already finding commercial application through TARA Biosystems, a spinoff co-founded by Radisic. The company uses lab-grown tissues to carry out testing studies for pharmaceutical companies.

"We worked closely with them on this study," says Zhao. "They are already using a modified version of our protocol." She adds that the simplicity of the system will make it easier for companies like TARA to scale up the technology and increase the number of tests they can carry out simultaneously.

Ultimately, lab-grown tissues may one day be implanted back into humans to repair damaged organs. Radisic and her team are pursuing separate technologies to address that challenge, but she says that the fact that Biowire II is already having an impact is very gratifying.

"If our lab-grown tissues can keep dangerous drugs out of the pipeline and help find new drugs to treat heart conditions, it will save thousands of lives," says Radisic. ■





← Diagnostics in a Pill

Buddhisha Udugama | Photo | *Chan Lab*

How do you bring complex multi-step assays to resource-scarce areas? These multi-coloured, water-soluble pills each represent multiple steps in an assay, allowing scientists to carry out high precision experiments in resource-scarce areas.

↑ Fight to the Death

Jennifer Ma | Watercolour | *Zandstra Lab*

This commissioned piece is created for Dr. Nika Shakiba (IBBME 1T7) to portray her work and research interest in cell competition.

“Having a Disability is Background Noise to Me”

After a climbing accident left him paralysed from the neck down, newly appointed University of Toronto Professor Michael Garton forged a new career in research

BY JOVANA DRINJAKOVIC

On a hot July day in 2006, Michael Garton was living his dream. The 24-year old British climber was scaling the tallest vertical cliff face in Europe—Norway's Troll Wall—hoping to become the first person to reach the top climbing alone.

His bid was all the more audacious in the light of the country's "no rescue" policy which would leave any climbers stranded on the notoriously inaccessible wall to fend for themselves. If he climbed for up to 18 hours each day, Garton estimated he could reach the peak—about the height of two CN towers—in seven to ten days, while hauling all his food, water and equipment, including a folding ledge to sleep on secured onto the cliff.

But then disaster struck as Garton was hit by rock fall, plunging 40 meters down the cliff before getting caught by his climbing equipment. The fall left him paralyzed and all but dead.

The same tenacity that drove Garton up the calamitous mountain 12 years ago has helped him build a successful research career culminating this month with an appointment of an Assistant Professor at the University of Toronto's Institute for Biomaterials and Biomedical Engineering. "When you are climbing and you know you are not going to be rescued if anything goes wrong, there's a feeling of being super committed and it's totally down to you," he says. "The mindset I built doing that has really helped me doing science."

He also said that climbing is easier "because it is mostly obvious where you have to go—you just have to keep pushing forward," whereas in science, "it is often difficult to know where to go. But even when you don't feel like you're making any progress, or you're failing at everything, just keep trying, keep thinking about the problem in a different way."

One of the first projects in his lab will be to engineer human cells into a kind that can mend the throbbing pain in the joints that comes with age. Say you have an arthritic knee in which the pain is caused by inflammation. Garton's plan is to take out some knee cells, insert new genetic circuitry encoding components engineered to both sense the inflammation and respond to it by releasing anti-inflammatory molecules, and then put the cells back into the knee.

"The cells will respond as and when necessary and you as a patient will never experience the disease as it is being treated by your own tissue," he says. Arthritis will be a test case. The same principles could then be applied to a variety of diseases. "I want to develop a basic chassis of the cell that can be fine-tuned to detect and respond to different diseases." Garton also said that being at U of T, with "world-renowned experts in various diseases working just across the street or in the next building" will be helpful for establishing collaborations needed to bring new therapies to patients.

A chemist by training, before the accident Garton thought little about applying his scientific knowledge to bettering society. But his views shifted during the year-long recovery in the hospital where he was

→ Mount Matterhorn was one of the first mountains successfully scaled by Michael Garton.

surrounded by the caring staff while grasping the confines of his new reality.

"I could kind of see that a lot of the staff at the hospital had the same passion for their job as I had for climbing," he says. "I realized then how selfish my whole life I've been by just focusing on how much I could enjoy myself going climbing. It really hit me—that the thing to do is to apply your passion and drive and hard work to something that is actually going to benefit society and other people and not just yourself."

That Garton is alive is only thanks to a chance encounter a few days before his accident. While preparing for the climb, he asked a passerby with a telescope if he could borrow it to make out the safest route and avoid rockfall. That summer was unusually warm and the heat had melted the ice inside the cracks of the north-facing cliff that glues together loose pieces of rock. The thawing ice released "boulders the size of trucks" that crashed on the ground every little bit making a sound like "a bomb going off".

> But even when you don't feel like you're making any progress, or you're failing at everything, just keep trying, keep thinking about the problem in a different way.

Although Garton tried to avoid the worst areas of rockfall, two days into the ascent, a lump of rock came off as he was climbing on it and knocked him off. The fall left him unconscious and when he woke up he realized he could not move. "I woke up and had a really excruciating pain in my neck," he says. "That's when I realized I had broken my neck and was paralyzed."

"It was a very odd experience, just being conscious and not being able to fight it, just having to lie there and look at the incredibly serene landscape and just think 'Ok, I only have a few more hours left and then it's death.'"

But what Garton did not know was that the man with the telescope had set up camp with friends to watch him climb. When the campers noticed Garton's body hanging off the cliff, they alerted the authorities, which despite the no rescue policy sent a Royal Norwegian air force helicopter as it was training in the area.

Ten hours passed from calling for help to when the air force winch man reached Garton. It was nighttime, and despite the midnight sun, the temperature had dropped below zero. Garton was by then in a state of severe hypothermia and had slipped into a coma. His heart stopped several times, requiring 16 defibrillations to be revived during transport to the hospital, where he stayed on life support for three weeks before coming out of the coma.

In the hospital, Garton had to learn how to do the most basic things, including how to breathe without the help of the ventilator. "When you are paralyzed, everything that you have ever learned as a tiny child, down to brushing your teeth, everything is wiped away," he says. "You go from where what you are aiming to do this year is to be the first person to climb

the highest cliff in Europe and then a few months later the main thing you are trying to achieve is breathe on your own for 10 seconds."

Garton learned how to control a computer using his voice and in September 2007, just three months after leaving the hospital, he returned to school to earn a Masters and then a PhD in computational biology at the University of Nottingham.

"I saw disabled people go both ways, a lot of people give up," he says. You have to make a choice at some point. Do I keep going or do I give up?"

In 2012, he moved to Toronto with his wife Hannah, who is Canadian. After a brief postdoctoral stint in the lab of Shoshana Wodak, then at the Hospital for Sick Children, he joined Professor Philip Kim's group at U of T's Donnelly Centre for Cellular and Biomolecular Research. He said the experience helped him become a better scientist. "At Donnelly, I wasn't treated any different to anybody else, not like I was anything special for being disabled. I was held to the same standards and that helped me to really up my game and become a much better scientist," he says.

While working with Kim, Garton invented a computational method for designing smart drug molecules that last longer in the body to reduce the frequency of taking medication. The idea came to him after a friend's toddler was diagnosed with type 1 diabetes and had to receive daily insulin injections. Garton came up with a way to convert natural protein molecules into their mirror-image forms, which retain the same therapeutic properties but are much longer-lasting.

"I like the feeling of being able to invent something to solve the problem. You are not restricted by what nature is doing. You can be somewhat more creative, you are only limited by what you can imagine you can do."

Garton's appetite for "creating new stuff" goes beyond science. Two years ago, he took up stone carving and has created life-sized sculptures of the human ear, eye and the brain. His other hobbies include sailing but he prefers activities in which he can be fully independent. Garton started sculpting by mouth after Hannah, who works as a photographer and is also his full-time carer, gave him wooden handled carving tools as a gift. At first, he'd tried velcroing regular tools to his arms but when that did not work out, he gripped the wooden handled tools with his mouth. With no instructions available on how to do it, he experimented with chipping and scraping until the stone started taking shape.

"Loads of people sculpt, but having been forced to do it by mouth means you are doing something new and I like that," he says. "For me, having a disability is background noise. In some ways it's annoying, but it also makes life interesting."

At times, Garton himself can't quite believe how things have turned out.

"I'm still pinching myself to be honest. Can't feel it but I'm trying", he says with a laugh. ■

Collective Movement

Professor Rodrigo Fernandez-Gonzalez is trying to tease out the communication barriers between cells during wound repair

BY QIN DAI

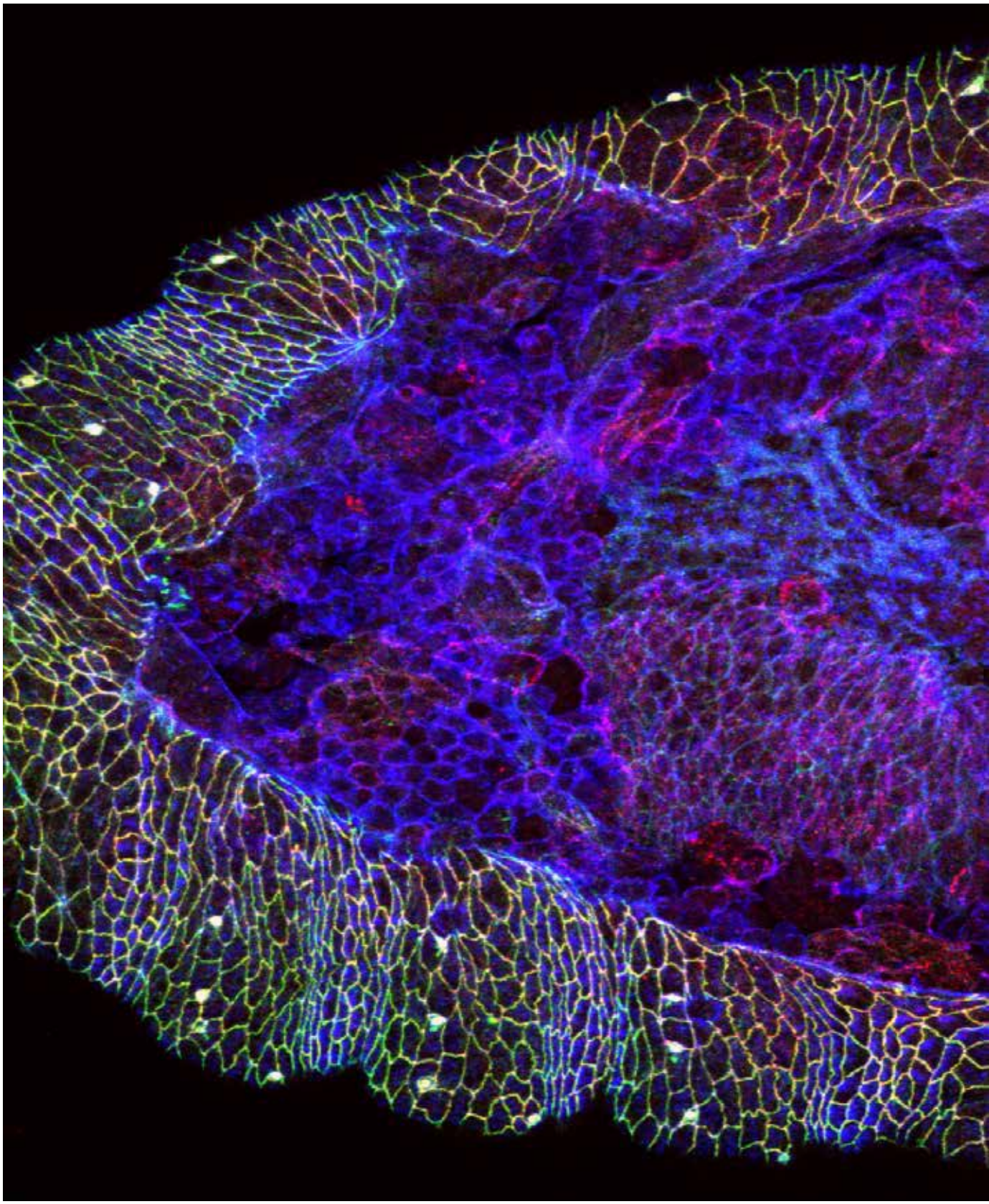
A sinkhole formed in the middle of the road following a heavy rainfall season. After the initial panic subsided, the city officials began to plan for city restoration – a pre-programmed initiative that clicks into place when natural disasters strike. The local police department is first contacted to maintain order and triage traffic, raw materials such as asphalt are shipped from overseas, underground water pipes are custom-made in local shops, and construction crews are called in to initiate the reconstruction process. The speed in which anyone can coordinate these tasks is essential in restoring functions to the city.

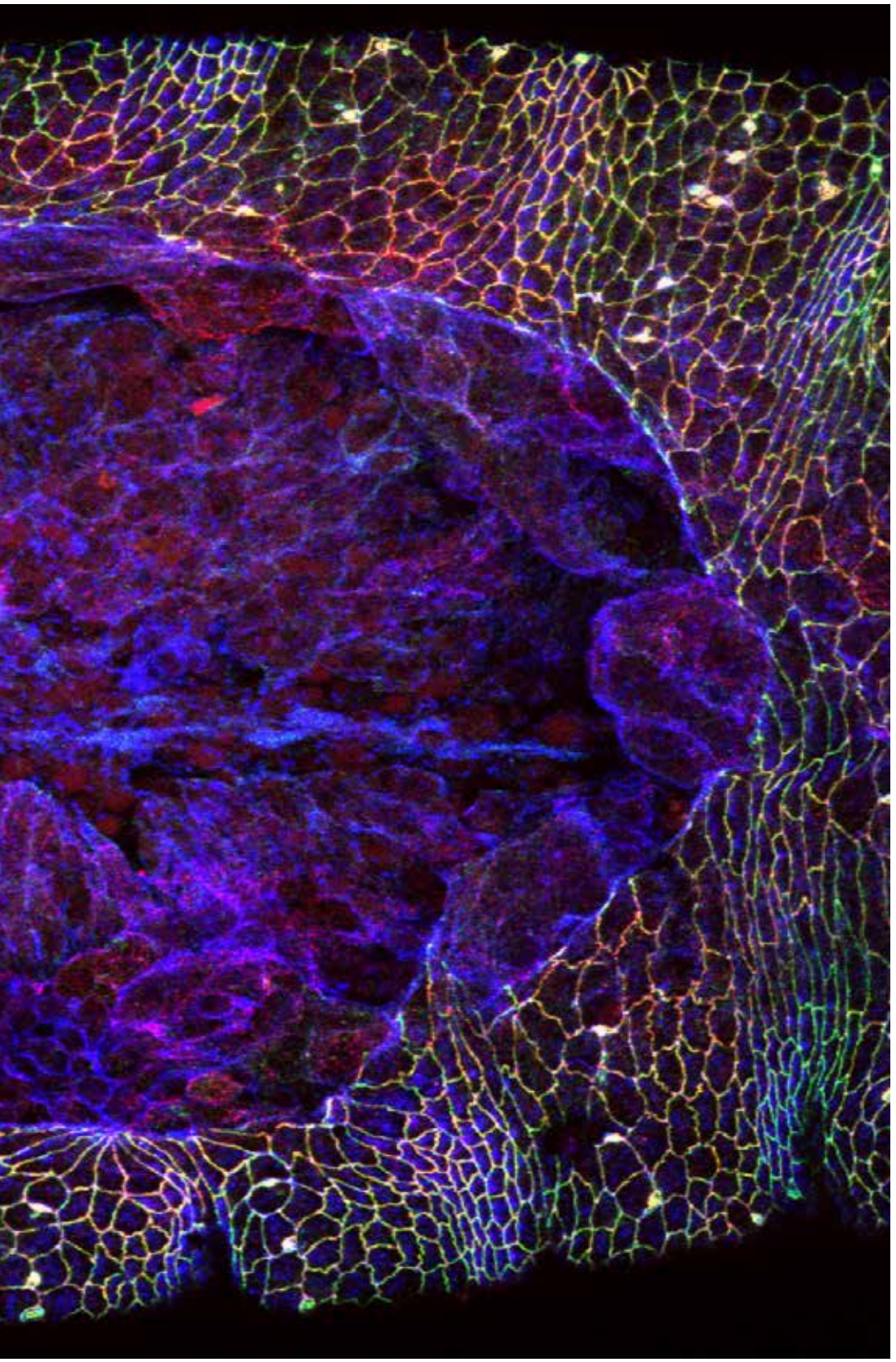
Wound healing is no different. When an injury occurs, the body coordinates cellular machineries through complex biological pathways in order to repair the damage. In embryos, which excel at tissue repair, the workhorses leading the carriage are two cytoskeletal proteins – actin and myosin. Simply put, these two subcellular components 'pull' on the cells through contractile forces and coordinate cellular movements in the body. Since force generation is so ubiquitous and fundamental in biological organisms, this dynamic duo is involved in various biological processes – from embryonic development to wound repair.

To understand how actin and myosin contribute to wound repair, Dr. Rodrigo Fernandez-Gonzalez and his team have been looking into the mechanism by which cells communicate with one another as wounds are patched and closed. In a paper published last year in the journal *Nature Physics*, Rodrigo's team discovered that wound healing progresses at variable rates across the circumference of the wound. In other words, the damaged area does not close at the same speed throughout, suggesting subtleties in the way cells communicate with one another during the wound's closure. Understanding this fundamental process is the key to developing therapies that can accelerate wound repair.

> Rodrigo and his colleagues are developing a bird's-eye view surveillance system to track how individual cells and molecules move during the process of wound healing.

When Rodrigo started his lab in 2012, he set out to answer one question – How does wound repair occur? He decided to use *Drosophila melanogaster* – also known as the fruit fly – as the model biological system. Little maggots hatch out of their eggshells following a short, 24-hour gestation period. Compared to 21 days of gestation in rodent models, scientists can observe wound-healing on fast-forward, thus allowing them to generate large amounts of data within a short span of time. Fruit flies have a monumental place in the history of biology, as various cancer-causing pathways (E.g. Wnt, Notch) were first discovered *via* this model organism. These pathways were then cross-referenced in humans, leading to the development of





← 2-dimensional fluorescent image of a wound in the epidermis of a fruit fly embryo. Various colours correspond to protein components that are involved in the wound repair process. These colours ultimately allow Dr. Fernandez-Gonzalez and his students to track how these proteins are evolving over time during the process of wound repair.

numerous therapeutic molecules for the treatment of cancer.

"We coat the surface of a petri dish with apple juice, let the flies lay their eggs, and then collect them," said Rodrigo. "A quick treatment of the eggs with bleach removes their hard shell, exposing the embryo to the external environment." Rodrigo and his team then use a laser to blast a hole, wounding the fruit fly embryo before observing the healing process under the microscope. "It's like playing a video game. You select a region on the embryo and fire! Afterwards you can observe the wound healing process in a movie." Since these fruit flies are genetically modified to have fluorescent cellular components, scientists can associate each component with a different colour under the microscope. Aside from the identification of individual cells, Rodrigo and his team can gather a plethora of 'biometric information' about each cell. These parameters include time, location, geometry, velocity of movement, distribution of proteins within the cell, and axial movement, to determine where the cell moves in the 3-dimensional space. There is an enormous amount of data that can be gathered from this process. "We had one student that gathered 100,000 images over the course of a year," said Rodrigo. In order to make sense of this massive trove of information, machine-learning algorithms were employed to ascertain trends and patterns in the role of individual cells and proteins in wound healing over time. This concept of identifying cellular components based on fluorescent 'biometric data' is analogous to tagging every person on the map with a unique GPS tracker. In other words, Rodrigo and his colleagues are developing a bird's-eye view surveillance system to track how individual cells and molecules move during the process of wound healing.

↑ Dr. Rodrigo Fernandez-Gonzalez's lab is located in the Ted Rogers Centre for Heart Research.

→ Marathon bibs hanging on the wall of Dr. Fernandez-Gonzalez's office.

Dr. Teresa Zulueta-Coarasa is the lead author on the *Nature Physics* paper and was also one of Rodrigo's first PhD students. When she joined the lab in 2012 as an industrial-mechanical engineer, she knew very little about biological systems. "I first started my career in a car company," Teresa said. "I remember that the learning curve was really steep when I joined the Fernandez-Gonzalez lab." Over the course of 6 years, she was able to pick up various skill-sets like coding, mathematical modeling, biological assays, and microscopy techniques. "When you are learning so much every day, it really motivates you to keep going," said Teresa. "I think the supervisor and the environment are the key, and it is extremely important to develop relationships with good people. Rodrigo is a nice person, he has a lot of great ideas and he also gives you the freedom to pursue your own ideas while offering guidance."

When you walk into Rodrigo's office, you are greeted with a collection of marathon bibs arranged in 5 rows and 4 columns. An odd one sticks out - the 21st bib in a new row. A unicorn that is symbolic of the Boston Athletic Association decorates the left corner along with a caption reading '2018 Boston Marathon'. Qualifying for this particular run is no easy feat, as only 10% of runners qualify to participate in the race. "Training for a marathon would mean I would be dedicating 7-8 hours a week preparing," When asked whether he saw any correlation between the collective movement of the runners and the research he does, Rodrigo demurred. "Honestly, no," said Rodrigo with a chuckle. "During the run, there are going to be times when you feel great, but there are long spreads of time when it's miserable. Much like science. So I guess one prepares you for the other. I was a scientist before I was a runner, so being a scientist prepared me for the run".

BRAIN CONTROL

Dr. Tom Chau's lab is bringing mobility to those who opt to use their mind to control movements

BY QIN DAI

The concept of telekinesis has dominated popular culture in the last couple of decades. Notable comic book heroes and villains are often imbued with supernatural powers to move physical objects with their minds. Although their powers are entertaining to watch on the big screen, how they achieve such feats are often riddled with contrived explanations with little scientific backing. For example, is it even possible for someone to use their brain power to move a wheelchair across the room with ease? In Dr. Tom Chau's lab, the question isn't *whether* this is achievable, but rather *how* it can be achieved.

← This BB-8 unit was engineered to respond to the brain signals collected by the electrodes on the wearable helmet.

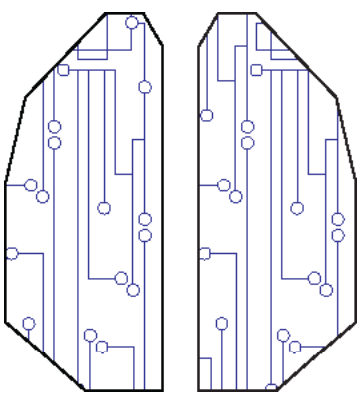
Located at the Holland Bloorview Kids Rehabilitation Hospital, the Chau Lab's main goal is to design, understand, and engineer rehabilitation tools that facilitate movement in patients. Some of the patients who come through the lab are unable to facilitate their movements independently. To address these patient-specific problems, a big part of Dr. Chau's lab is to build Brain-Computer Interface (BCI) devices that respond to patient's brain signals. In a way, Dr. Chau is building a set of devices that allows his patients to access the power of telekinesis.

George Hanna is a Biomedical and Electrical Engineering student who joined Dr. Chau's lab a year and half ago. "My project focuses on translating subtle eye movement and attention into joystick control." George said, "Imagine you're in a wheelchair and you want to move forward, back, left, or right. You just have to pay attention to a 2-by-2 grid on your screen for two or three seconds and you will be able to 'will' the wheelchair in that direction."

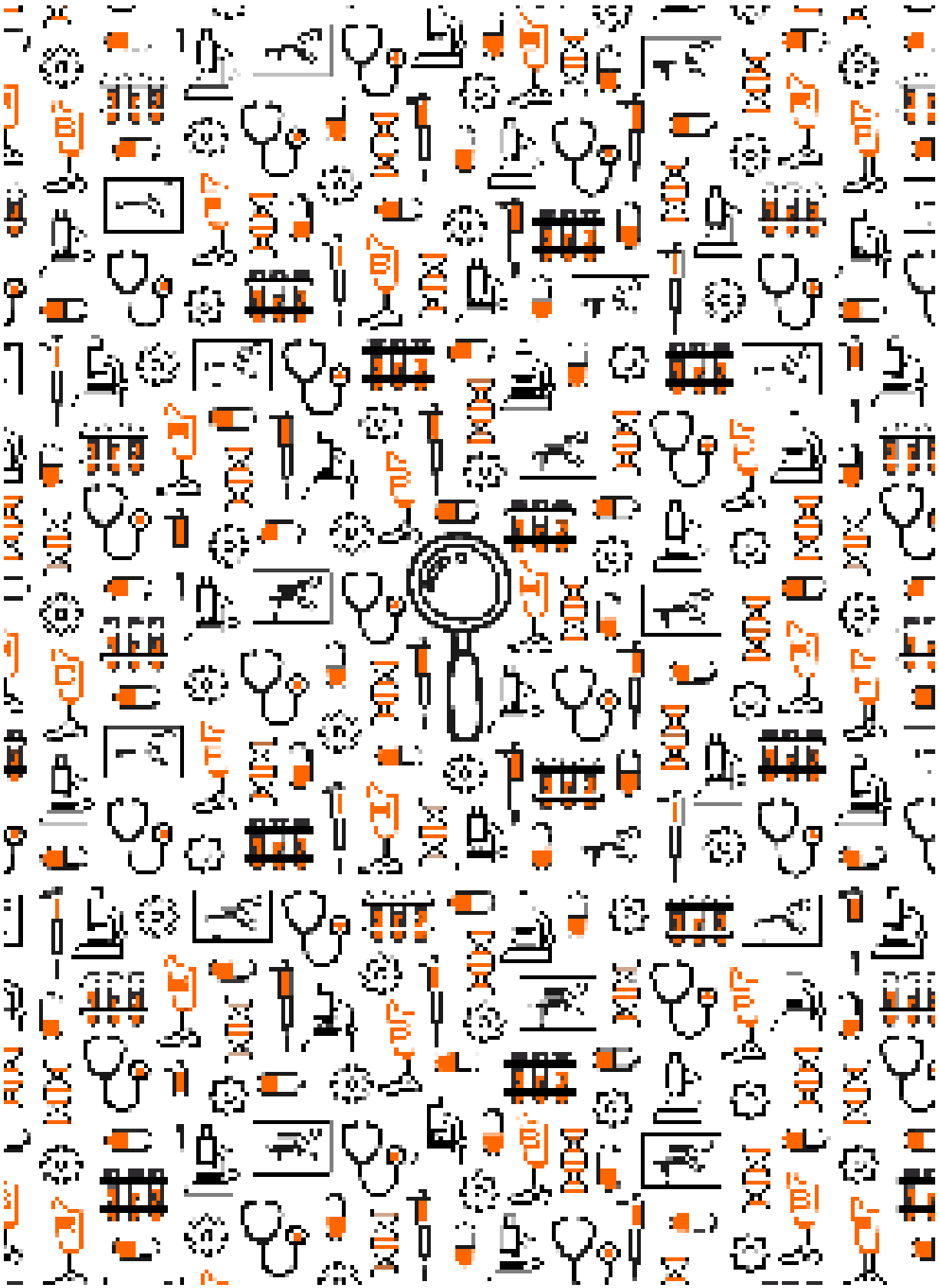
To demonstrate this concept, George showed me a video where he controlled the movement of a modified BB-8 unit (StarWars Universe) by using an electrode-fitted helmet on his head. As he focused his attention on one quadrant of a grid of blinking LEDs, he was able to change the

trajectory of the BB-8. George's helmet measures signals from the occipital region of the brain on the back of the head. This region is responsible for translating visual inputs and recognizing outlines of objects. The essence of a BCI device is to translate various types of brain activity into an external control signal, which then engages the circuits on the hardware, resulting in movement. In this case, the helmet fitted with electrodes on George's head acts as a "sender" component. It measures what George was visualizing on the occipital part of the brain (attention and eye position on the grid) and sends it to the receiving component on the BB-8 in order to make it move. Although this is a prototypical idea, George's ultimate plan is to use the helmet to control the movement of a wheelchair.

A unique part of his project is the opportunity to consult with patient's family while building the device. "You work directly with the patients who have various types of conditions, and we essentially have this model of involving the family in the research, so they have a say as to whether your thesis is useful to them or not." said George, "It is kind of like a start-up product cycle, where you do something, you iterate on it, you get their [client] feedback, so you end up with a practical product as opposed to an abstraction." ■



← George Hanna is a IBBME MASc student in Dr. Tom Chau's lab at the Holland Bloorview Kids Rehabilitation Hospital.



DISCOVERY IN THE COMMUNITY

A student-led STEM initiative has gained traction in a Toronto high school

BY QIN DAI

High school students from George Harvey Collegiate Institute (GHCI) were busy performing experiments in the IBBME design studio located in the Mining Building. Today they are learning about how the application of force affects the design of canes used by rehabilitation patients. Quevawne, a grade 11 student from GHCI, was eager to share his experience. "When I talk to my friends who are going to different schools, they were like 'where are you going on Friday?' and I say, 'I get to go to the University of Toronto." Quevawne said with a proud smirk on his face. "I brag a little, but not too much."

The IBBME Discovery Program started in 2016 as an outreach project to bridge the transition between secondary and post-secondary education, by bringing Science, Technology, Engineering, and Math (STEM) to socio-economically challenged communities. The vision of the project is to give high school students the opportunity to conduct hands-on experiments using research-grade equipment and facilities located at the University of Toronto. Founded by Locke Davenport-Huyer, Genevieve Conant (IBBME 1T7) and Dr. Andrey Shukalyuk, the Discovery program had rapidly grown over the past 2 years to include 4 educators, 15 graduate student instructors, and a University of Toronto faculty member. "The program formed from an idea of connecting high school learning to university in a meaningful way," Mr. Davenport-Huyer said, "As with any change in thinking, getting this off the ground involved the formation of strong collaboration between our partners with the Toronto District School Board, who provide essential insight into effective educational strategies." Since 2016, the Discovery program has welcomed more than 200 high school students through the doors of the University of Toronto.

What motivated Locke to start this program was the desire to bring STEM across the socio-economic barriers, while focusing on exposing students to the hands-on inquiry of scientific discovery. "I think it's important to give everyone a chance to thrive," said Mr. Davenport Huyer, "expensive research equipment is not often accessible to high school students. This learning experience gives them a chance to try new things." The program also emphasizes equity of student participation, ensuring that entire class cohorts participate in the program with the hope that a differing learning environment will inspire student interest in STEM as an extension to the knowledge-focused delivery of the high school classroom.

Currently, the structure of the program is as follows: as an element of their curriculum, senior high school students (grade 11 and 12) participate in 4 separate, full day sessions at 3 different laboratory locations, hosted by IBBME. During these sessions, students are split into groups of 4, while under the mentorship of a graduate student instructor, they execute a subject specific (Biology, Chemistry, or Physics) term project over a 2-month span. To date, these projects have ranged from designing an antibacterial gel to optimizing walking canes, linking relevant curriculum knowledge to cutting edge biomedical engineering topics. Projects culminate in a final poster session where the students present their work to the public, an opportunity that is atypical for many high school students.

Many of the students involved have never stepped inside a university before. “It’s amazing that we are the only school in the Toronto District School Board that has this program. It just makes the experience that much more special.” Quevawne said. For other students, performing hands-on scientific experiments dispels some of the intimidating auras surrounding a university institution. Obria, a grade 11 student, described her initial experience as a Discovery program attendee. “The first time I came [to Discovery], I was intimidated by the labs. I didn’t know what to do. But now we are here again, we really get to do things on our own and actually think. I enjoy that because we have more control over what we are doing.” Obria said. The students' fondness is reflected in their diligent attendance to the program, thus far the attendance rate is close to 100%.

The continued success with GHCI has motivated program expansion to nearby high schools in the Toronto District School Board in Winter 2019. In preparation for implementation, Western Technical High School has dispatched teachers – including Vice-Principal Kim Woods and science lead Teresa Frost – to shadow how laboratories are run in one of the sessions. “[GHCI] have been through this for a couple of years, and we want to see how it works,” said Vice-Principal Woods, “This program will inspire kids and give them the confidence that STEM will be an actual possibility for them.” Expanding this program to other schools broadens its impact, and will create a sense of community.

We really get to do things on our own and actually think. I enjoy that because we have more control over what we are doing.

- Obria

It’s an experience to see how big [the University] is instead of being secluded in your own little area. I like that.

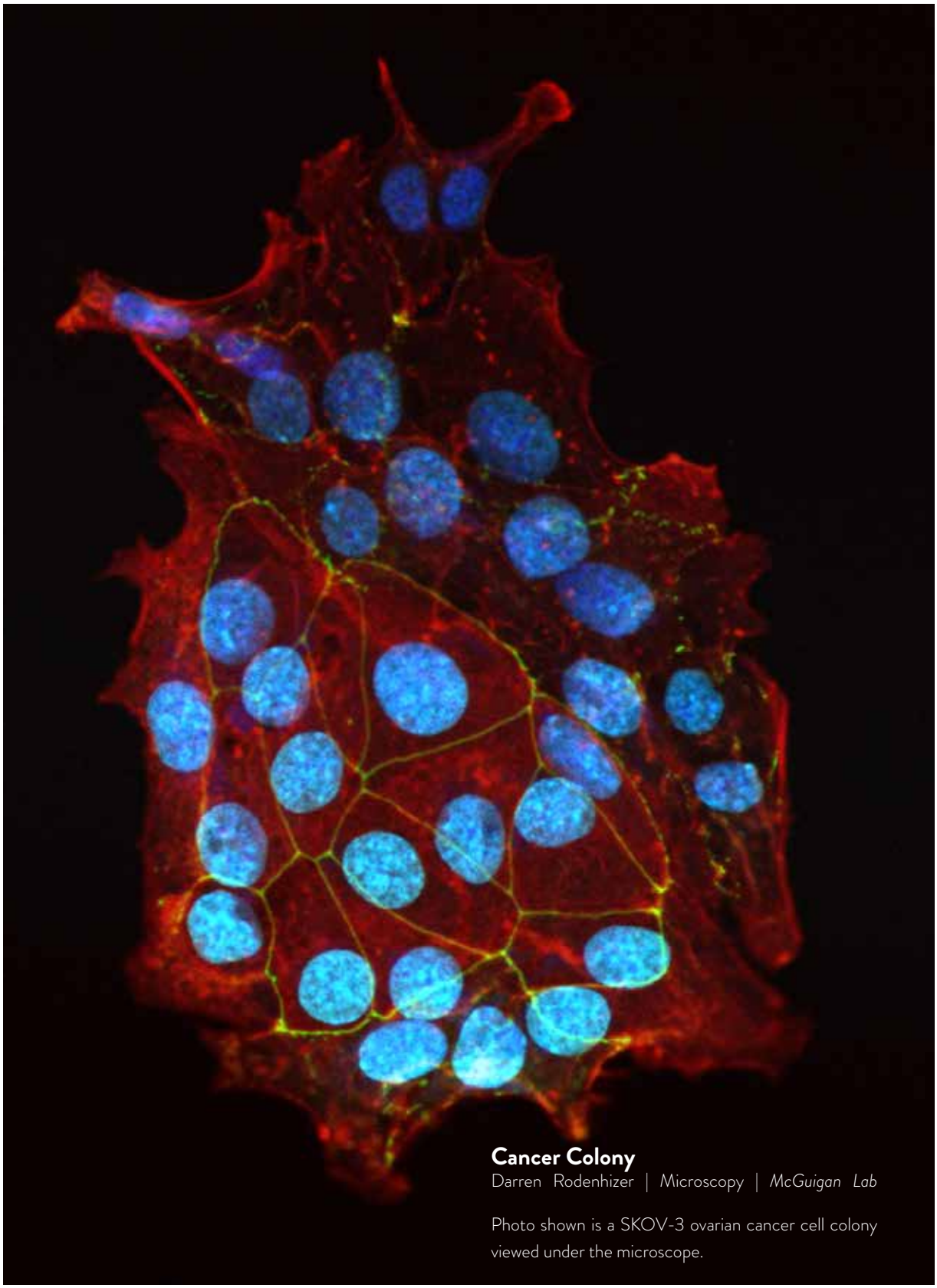
- Quevawne

The IBBME Teaching Lab has 3,000 square feet of laboratory space that is located on the third floor of the Mining Building.

Despite the growth in participating student numbers, this initiative has remained free of cost to the high schools. Equipment and material cost has been compensated by IBBME or donated by faculty members. In September, the Discovery program has received more than $22,000 in NSERC PromoScience funding, a government initiative aimed at providing financial support in promoting the understanding of science and engineering to young Canadians.

The success of the Discovery program has been disseminated at international conferences and is also expected to be quantified and published in scientific journals. Dr. Dawn Kilkenny is the faculty liaison who had supported the ongoing efforts of Discovery. Attendance rates, grades, and continuance into STEM fields, are some of the collected metrics. "We have disseminated our findings to communities of practice. the Canadian Engineering Education Association, the Biomedical Engineering Society, and the American Society for Engineering Education and have received a lot of positive feedback." said Dr. Kilkenny, "The next step is expanding this into a multi-school initiative and have several University of Toronto departments involved." ■

↑ Discovery volunteer team. From left to right: Dawn Bannerman, Serena Mandla, Huntley Chang, Julien C. Senécal, Romario Regeenes, Jonathan Rubianto (back), Neal Callaghan, Dr. Andrey Shukalyuk (back), Carina Kamango Esmael (front), Locke Davenport Huyer (back), Allie Clement (front), Daniel Smieja (back), Alexandria Michelini (front), Claudia Lutfallah (back), Dallis Ferguson (front), Angus Lam (back), Shouka Parvin Nejad (front).



Cancer Colony
Darren Rodenhizer | Microscopy | *McGuigan Lab*

Photo shown is a SKOV-3 ovarian cancer cell colony viewed under the microscope.

Catching up with an Alumnus

In early 2015, Dr. Alborz Mahdavi started his company, Protomer Technologies after completing his studies at the University of Toronto and California Institute of Technology.

BY QIN DAI

Briefly describe your research at the University of Toronto.

I started my research career working for Professor Parham Aarabi in Electrical Engineering as a summer undergraduate student. Dr. Aarabi was an amazing mentor and he encouraged me to follow my passion and chart my own path. At the time I wanted to focus more on biotechnology. So I started working in Professor Peter Zandstra's lab at the Institute of Biomaterials and Biomedical Engineering (IBBME) and eventually did my Masters of Applied Science (MASc) there. My project was focused on automated image processing of embryonic stem cells, quantifying various protein levels in cells, and then validating them using computational models.

Tell me about your company Protomer Technologies.

We specialize in engineering proteins and peptides using artificial amino acids chemistries amongst other things. We are developing an artificial insulin that can sense blood sugar levels and automatically activate when needed. Our system is like a "smart insulin" that diabetic patients can inject and forget.

Our work space in Pasadena, California is just shy of 3,000 square feet and we have 4 pre-clinical drugs in the pipeline. We actively collaborate with the California Institute of Technology (CalTech) and currently have contracts from several multinational pharmaceutical companies.

What's your day-to-day like as the Chief Executive Officer (CEO)?

As the CEO I must know every part of the business. In the early days of the company I had to do pretty much everything, and along the way you pick up a wide array of skillsets. Just to give a quick run-down, I had to plan the company's research direction, meet with pharma partners, sign deals, raise grants, write patents, work with corporate and intellectual property lawyers, hire people, run payroll, coordinate with licensing offices of various universities, etc. We hired some amazingly talented people in the early days of the business, and they had really shaped the company.

On a day to day basis I usually start early, plan the day, meet with our scientists to discuss progress and plan projects. By lunch time there is usually lot of emails to answer. In the afternoon I am either working on the business side

of things or I have additional in-depth discussion with our scientists. I still spend a considerable amount of time at the bench troubleshooting things with our team. We do the 90/10 rule like Google, so everyone has a 10% activity devoted to something outside their specific projects. I usually try to be at the gym between 6-8 pm at least three days a week, and then back in the office around 9 pm until at least 11pm. Some days can run as late as 1:30 am.

You did stem cell research here at the University of Toronto, dabbled in polymer science at Massachusetts Institute of Technology (MIT), and then created artificial amino acids at CalTech; what drove you to pursue this diverse set of topics?

I think the common thread is that I want to make a big impact in the world. After I finished my MASc at the University of Toronto I got connected with Dr. Ali Khademhosseini and Dr. Jeff Karp (IBBME 0T2, 0T3), who were working at MIT at the time with Dr. Robert Langer. At the Langer Lab I was designing medical adhesives inspired by nature, by mimicking the mechanism Geckos use to attach to surfaces. This concept was eventually licensed into an MIT spinoff company called Gecko Biomedical. At MIT I learned two things: research has to be driven by an unmet medical need, and there is a tremendous amount of effort required behind the scenes to translate a product.

When I moved to Caltech, the focus was on transformative science that will change the world. The lesson I learned here is that big rewards comes with big risks. Dr. Frances Arnold who just won the Nobel prize in chemistry in 2018 was on my PhD committee. She really encouraged me to take big risks by trying new ideas and not be afraid to fail. This entire experience drove me to start my own company. Having the opportunity to develop a technology that could potentially benefit millions of people really resonated with me.

How did your time here at engineering science and IBBME influence your future career decisions?

When I was going through my undergraduate education I didn't think differential equations and complex analysis was that useful for a career in biotech, but it really made my life easier when I was pursuing my PhD at CalTech. The pace of courses at Caltech was astonishingly fast, but I think some of those courses I took in undergraduate studies really helped me. I also ran into a lot of good people in IBBME. Professor Peter Zandstra was an amazing mentor. Not only did he provide me with the opportunity to learn how to do science and publish well, he gave me plenty of useful career advices as well. Professor Michael Sefton connected me with the MIT professors, and then there were numerous other mentors: Professors Warren Chan and Chris Yip were influential people in my life and I learned a lot from them.

Do you have any advice for aspiring engineers?

Ultimately, we want to learn about ourselves, especially early on in our careers. I would suggest students try different things and have many different experiences and push their boundaries and limits. Finding your passion and being the best at something can bring enormous joy and satisfaction. I hope that I will be fortunate to always work on something that is fulfilling and have amazing mentors and great friends, and I would wish the same for any aspiring scientist or engineer, because life is extremely short. ■

Undergraduate Field Report

Julien C. Senécal is a third year Biomedical Systems Engineering student. He spent 4 months at Massachusetts Institute of Technology.

BY JULIEN C. SENÉCAL

During the summer of 2018, I worked at the Massachusetts Institute of Technology (MIT) in Dr. Kwanghun Chung's laboratory. I joined the lab because of its expertise in the field of tissue clearing and brain imaging. As a student in biomedical engineering, I'm interested in learning more about the novel techniques used to screen and treat brain disorders.

I conducted research under the supervision of Dr. Alexandre Albanese (IBBME PhD 1T4), a postdoctoral fellow interested in characterizing the phenotype of cell populations in cerebral organoids (mini brains) using three-dimensional (3D) whole-tissue imaging. In short, if there is something wrong with your brain, we can grow organoids with your DNA to study your neurons' behavior.

Human brains are highly vascularized, with more than 100,000 kilometers of blood delivering oxygen and nutrients to keep the cells alive. Mini-brains, however, lack a vasculature. To address this fundamental limitation of the in vitro brain model, the Chung Lab is printing synthetic microvasculature to perfuse organoids.

My summer project consisted of culturing endothelial cells on the luminal (inside) surface of the microvasculature. The objective was to improve the biological accuracy of the in vitro model by introducing a platform to facilitate cell co-culture. Some of my achievements include the development of a cell culture protocol on the vasculature, and design improvements to enhance its biological applications. In the future, this biomaterial could be used for other organoid models and implants. My independent summer project was a great opportunity to apply the skills learned in Biomedical Engineering Systems Option in Engineering Science such as fluid mechanics (AER210), cell culture (BME205) and rapid prototyping (AER201). This summer was also an occasion to learn new skills; I learned sterilization techniques used to clean an incubator infested with fungi, I designed and fabricated scaffolds using 3D printed molds, and I became interested in computational image analysis using machine learning.

It was a great privilege to be part of MIT, a community which was both scientifically and artistically stimulating. Though my stem cells required daily love and attention, I managed to escape to the beach on weekends, run along the Charles River at night, and attend a concert on a boat. I want to extend my thanks to the Division of Engineering Science for helping me fund this opportunity, as well as all the members of the Chung Lab for a memorable summer. ▮

All-Terrain Knee

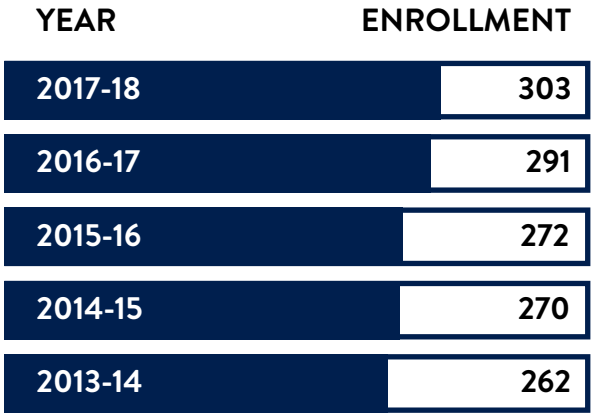
Brandon Burke | Photo | *Andrysek Lab Collaborator*

Brian, the boy in the photo has a bilateral above-knee amputation. He has been wearing the All-Terrain knee for the past 3 years, a product that was developed as part of research conducted at IBBME and Holland Bloorview Kids Rehabilitation Hospital.

GRADUATE STUDENTS

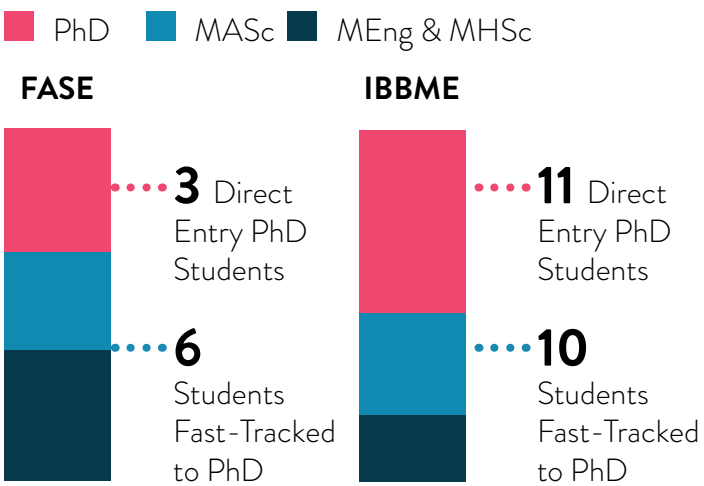
Enrollment Trend

IBBME graduate student body has been experiencing steady growth in the past 5 years. The net positive influx of students (admitted: 96) versus efflux (graduated: 84) in the 2017-18 academic year means IBBME had garnered additional interests from applicants.



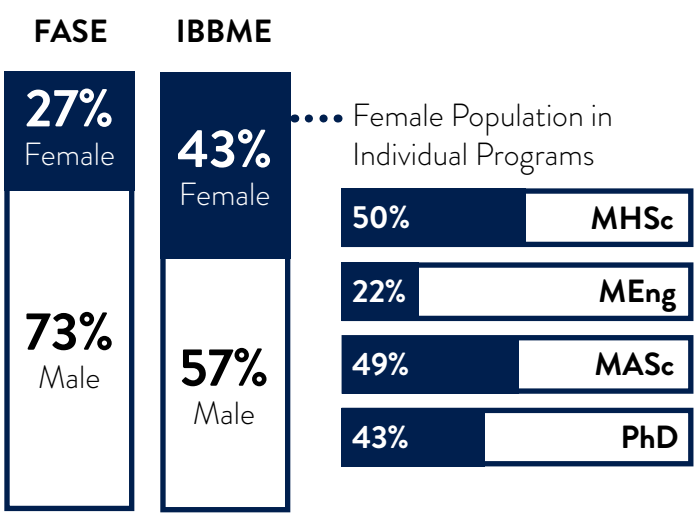
Enrollment Breakdown

IBBME is one of the leading research intensive units within Engineering. More than 52% of its graduate population consists of PhD students in 2017-2018. Comparatively, FASE averages 35%. We have a significantly higher number of students directly pursuing PhD from undergrad (11 in IBBME) and number of students fast-tracking from MASc to PhD (10 in IBBME).



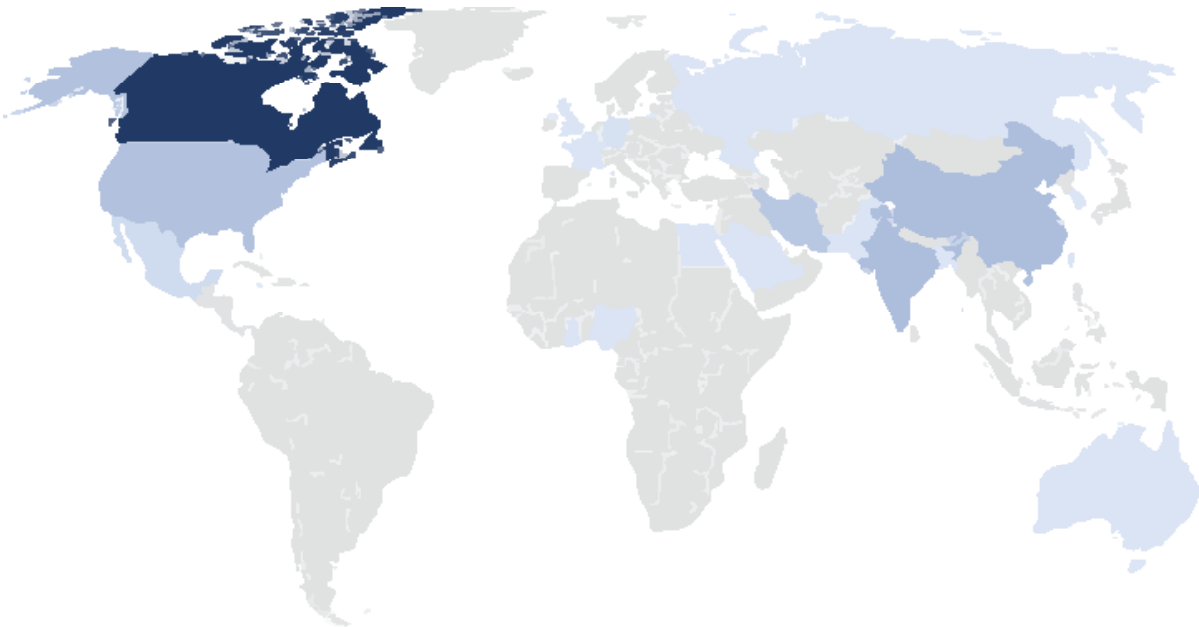
Gender Distribution

IBBME has a balanced female to male graduate student body ratio. Out of 303 total graduate students in IBBME, 130 are female (43%) and 173 are male (57%). Compared to the Faculty of Applied Science and Engineering (FASE) graduate student population, 663 are female (27%) and 1,751 are male (73%).



Enrollment Geography

IBBME student body consists mostly of domestic students. More than 50% of the enrollment come directly from the domestic pool, while China, India, United States, and Iran each consist up to 8% of the total enrollment.

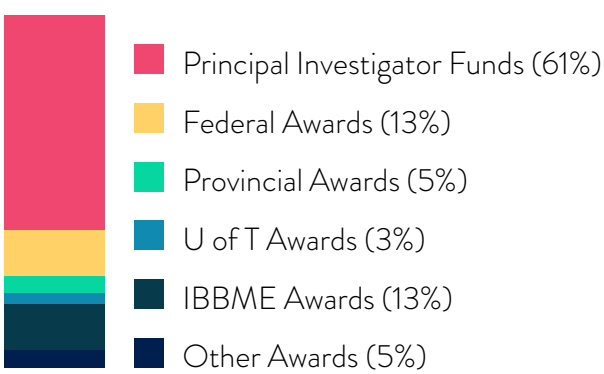


High **Low**

Student Funding

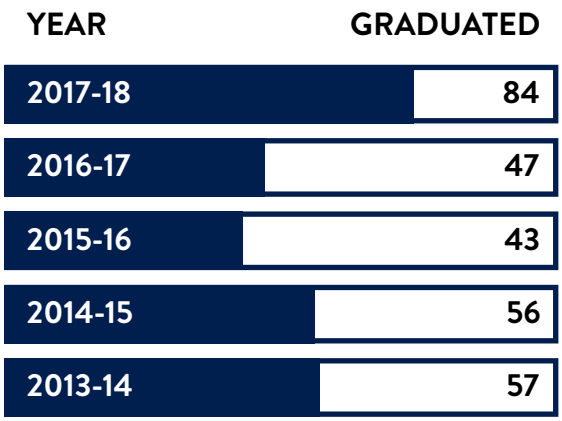
Student funding had grown at a steady pace over the past 5 years. Funding broke the $7 million mark in the 2017-2018 academic year. The majority (61%) of the student funding came from principal investigators, followed by federal awards and IBBME awards.

YEAR	FUNDING
2017-18	$7.31M
2016-17	$6.67M
2015-16	$6.02M
2014-15	$6.05M
2013-14	$5.09M



Graduate Summary

There is a drastic increase in IBBME graduates in the 2017-2018 academic year. The numbers on the right of the bar graph indicate the number of graduates who have successfully defended their thesis in the academic year.

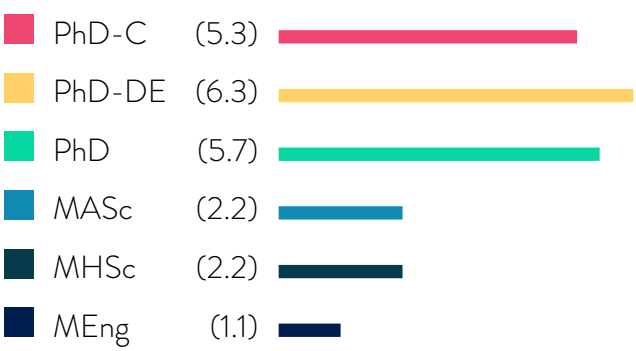


Graduate Breakdown

Graduate proportion is similar to the current student body breakdown, indicating a balanced exit rate amongst students within each of the programs. Bracketed percentages indicate the proportion of students out of 84 total graduates in 2017-18. PhD-C: Clinical Specialization. PhD-DE: Direct-entry.

Graduation Time

Graduation time is dictated by degree type. PhD-C: Clinical Specialization. PhD-DE: Direct-entry. PhD: students who had previously obtained a masters. The number of years was calculated as an average.



RESEARCH CAPACITY

Funding Trend

IBBME hit a record high in 2017-2018 in total research funding. The number represented on the right hand side of the bar graph is the total funding package that is active during the respective academic year.

YEAR	FUNDING
2017-18	$12.02M
2016-17	$7.82M
2015-16	$8.04M
2014-15	$5.30M
2013-14	$7.04M

Grant Distribution

IBBME continues to thrive with research funding from all sectors. Amongst all funding packages, approximately 30% are new funding initiatives. Majority of the funding are operating grants.

25
New Grants

58
Ongoing Grants

Selected Grants

Warren Chan
Nanoparticle Delivery
CIHR Foundation Grant

Milica Radisic
Organ-on-a-Chip Engineering
Canada Foundation for Innovation

Craig Simmons
The Global Fibrosis Network
Connaught Fund

Funding Breakdown

Majority of the research, equipment, and personnel funding originate from the federal government of Canada. 'Other Sponsors' are categorized as fundings from education bodies, foundations, hospitals, international organizations, and societies.

Federal Grants **$9,254,405**

Other Sponsors **$1,405,778**

Provincial Grants **$1,356,505**

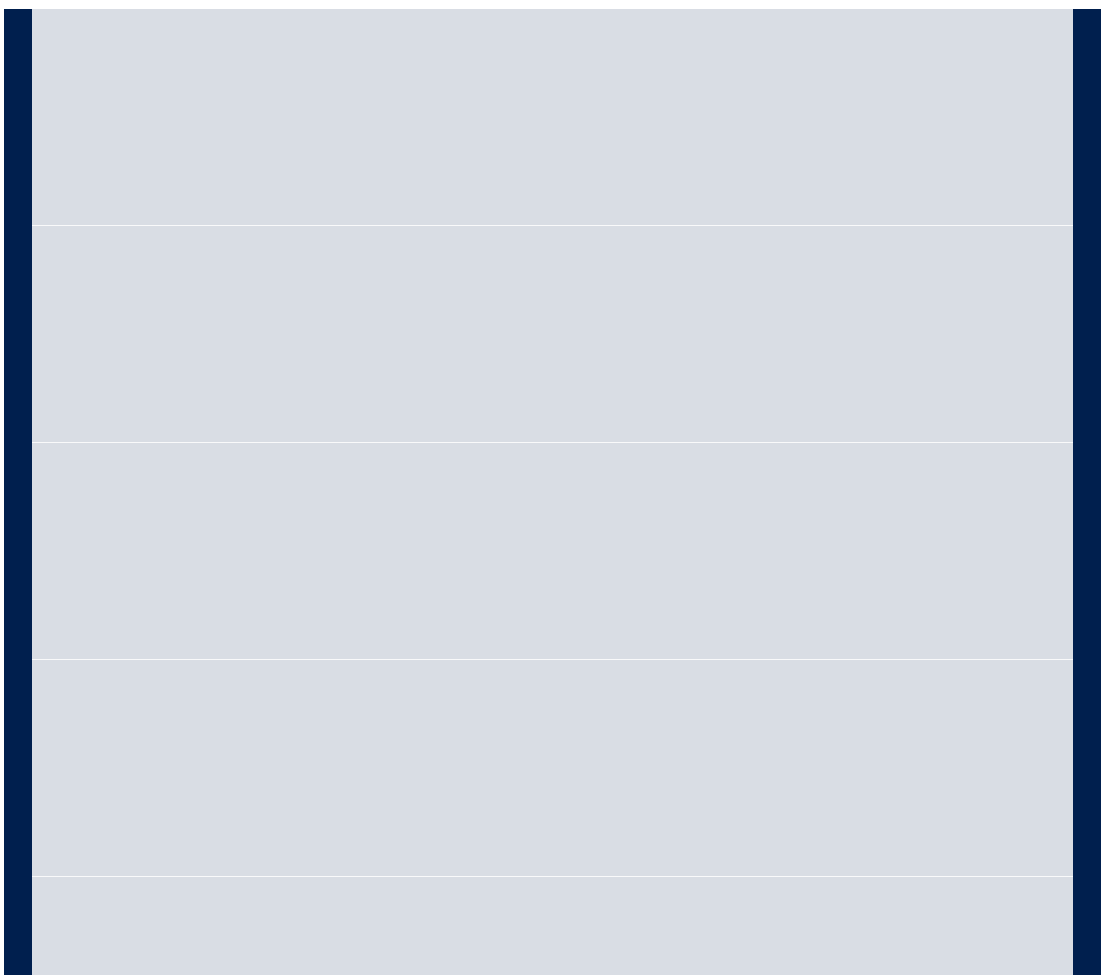
Publication Record

IBBME has published 189 peer-reviewed papers in 2018. The data on the right was aggregated via SciVal, an Elsevier subsidiary.

YEAR	PUBLISHED
2018	189
2017	216
2016	222
2015	210
2014	211

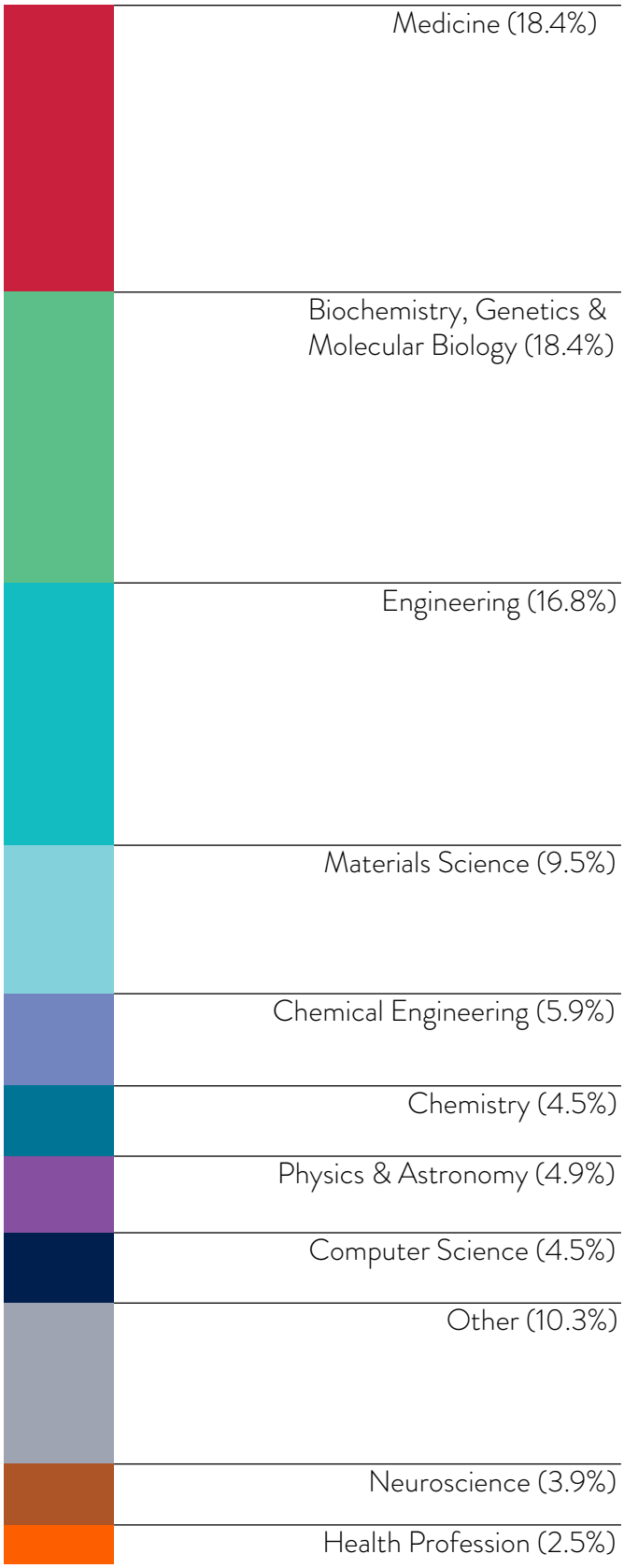
Keyword Identifiers

IBBME has a diverse set of research topics. Here, a total of 1,517 publications produced by IBBME faculty members from 2013-2018 were aggregated and the frequency of recurring keyphrases was captured. The size of the font refers to the relative frequency in which the phrase occurs in publications. The following keyphrases were generated by SciVal.



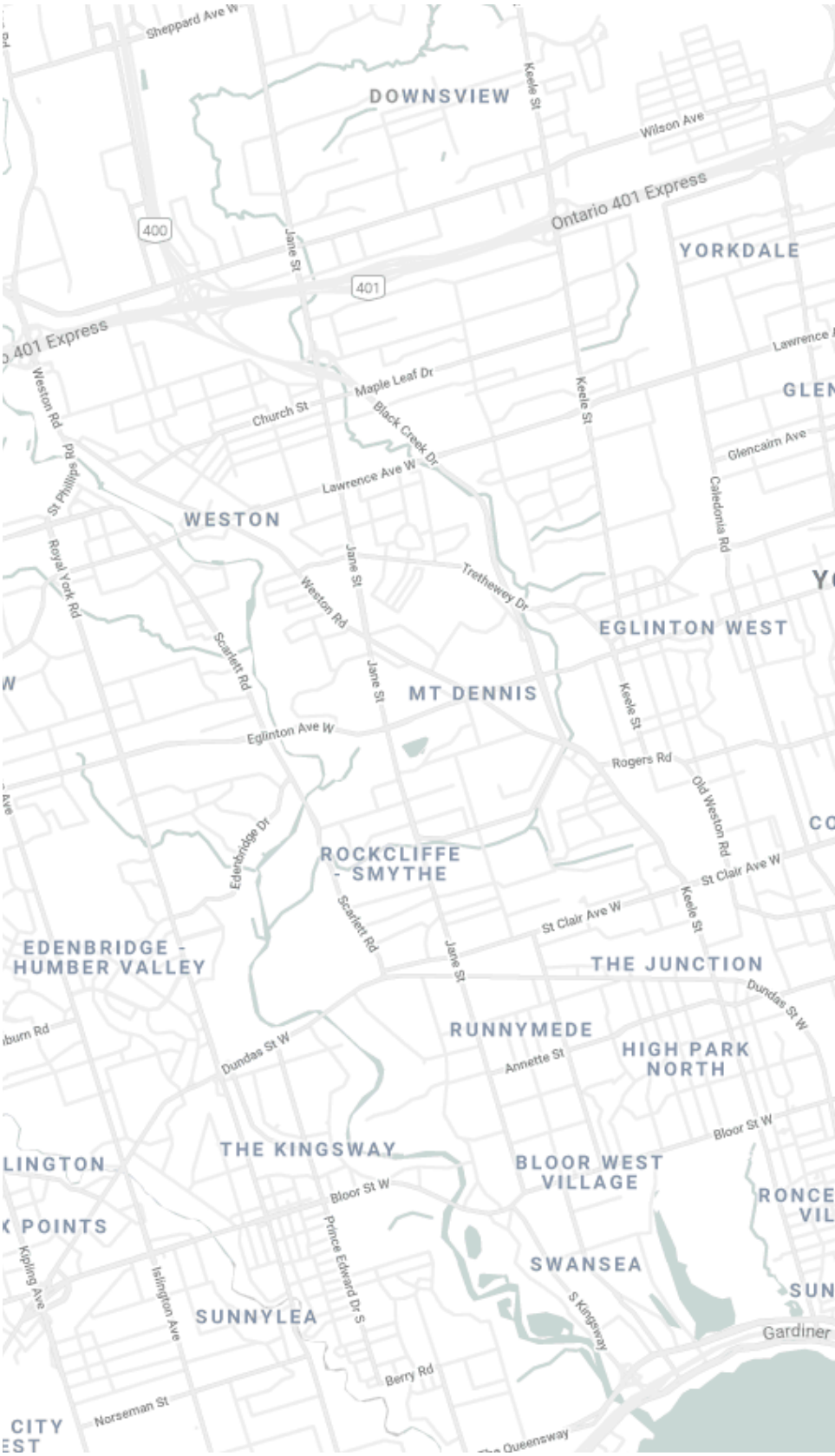
Research Disciplines

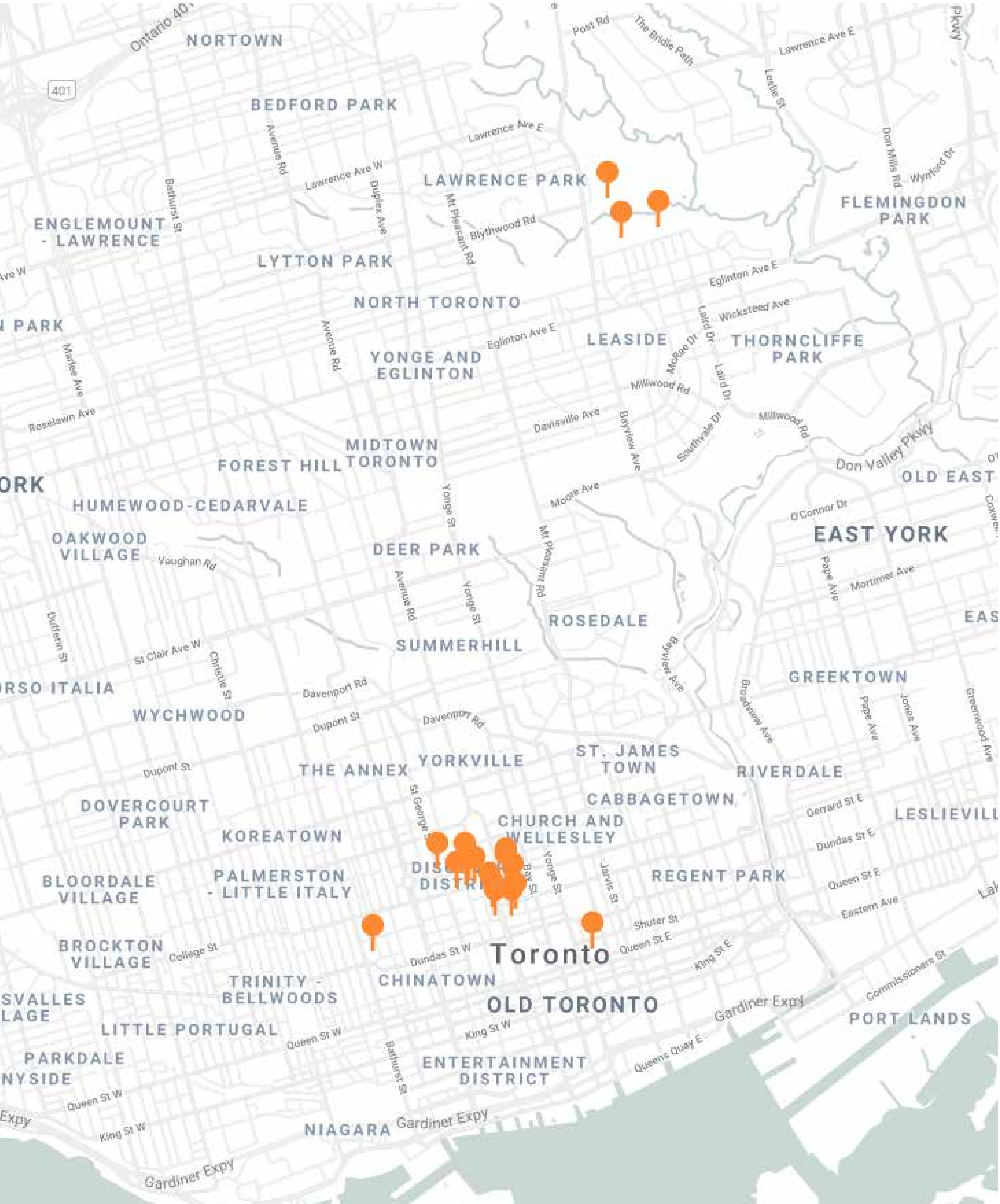
IBBME research publications are categorized into 11 different areas as indicated on the right. The percentages were calculated by breaking down the proportion of publications of each topic within the total number of publications generated by IBBME faculty members between 2013-2018. The data on the right was aggregated via SciVal.



Research Locations

IBBME research facilities are mainly located in two clusters. The first cluster is within the downtown core of the city of Toronto, in close proximity to the University Campus, MaRS Discovery District, Ted Rogers Centre for Heart Research, and various hospitals. The second cluster is located in North Toronto, where a series of rehabilitation and clinical hospitals reside. Each orange pin indicate the location of a research facility. Map Data ©2019 Google




NORTOWN
BEDFORD PARK
LAWRENCE PARK
ENGLEMOUNT - LAWRENCE
LYTTON PARK
FLEMINGDON PARK
NORTH TORONTO
LEASIDE
THORNCLIFFE PARK
YONGE AND EGLINTON
MIDTOWN TORONTO
FOREST HILL
HUMEWOOD-CEDARVALE
OLD EAST
OAKWOOD VILLAGE
DEER PARK
EAST YORK
ROSEDALE
SUMMERHILL
GREEKTOWN
WYCHWOOD
YORKVILLE
THE ANNEX
ST. JAMES TOWN
RIVERDALE
CABBAGETOWN
DOVERCOURT PARK
KOREATOWN
CHURCH AND WELLESLEY
BLOORDALE VILLAGE
PALMERSTON - LITTLE ITALY
REGENT PARK
BROCKTON VILLAGE
Toronto
TRINITY - BELLWOODS
CHINATOWN
OLD TORONTO
LITTLE PORTUGAL
PORT LANDS
PARKDALE
ENTERTAINMENT DISTRICT
NIAGARA
Gardiner Expy
Don Valley Pkwy

← Rendition of the Donnelly Centre (right). The Rosebrugh Building, the original location where IBE started in 1962, can be seen on the left hand side of this rendition.

FUTURE OF BIOMEDICAL ENGINEERING

The current director of IBBME shares his thoughts on the evolving role of the biomedical engineering field and how it will shape healthcare

BY WARREN C.W. CHAN

Imagine a set of meandering roads sprawled across the great plane of academia, each representing a distinctive discipline in the realm of research and innovation. Some of these roads may rarely come into contact with one another, while some roads repeatedly converge with each other. Biomedical engineering isn't as much of a road as it is an intersection, where multiple disciplines can leverage their individual strengths on this fertile ground.

Biomedical engineers are defined by a specific set of principles. A biomedical engineer believes in the idea of convergence, where concepts from different fields are merged and complemented to solve an important scientific problem. A biomedical engineer believes in the idea of changing the world by solving time-relevant problems

on the global scale. A biomedical engineer believes in the ability of multidisciplinary teams. Ultimately, biomedical engineers want to shape the planet by benefiting the lives of millions of people.

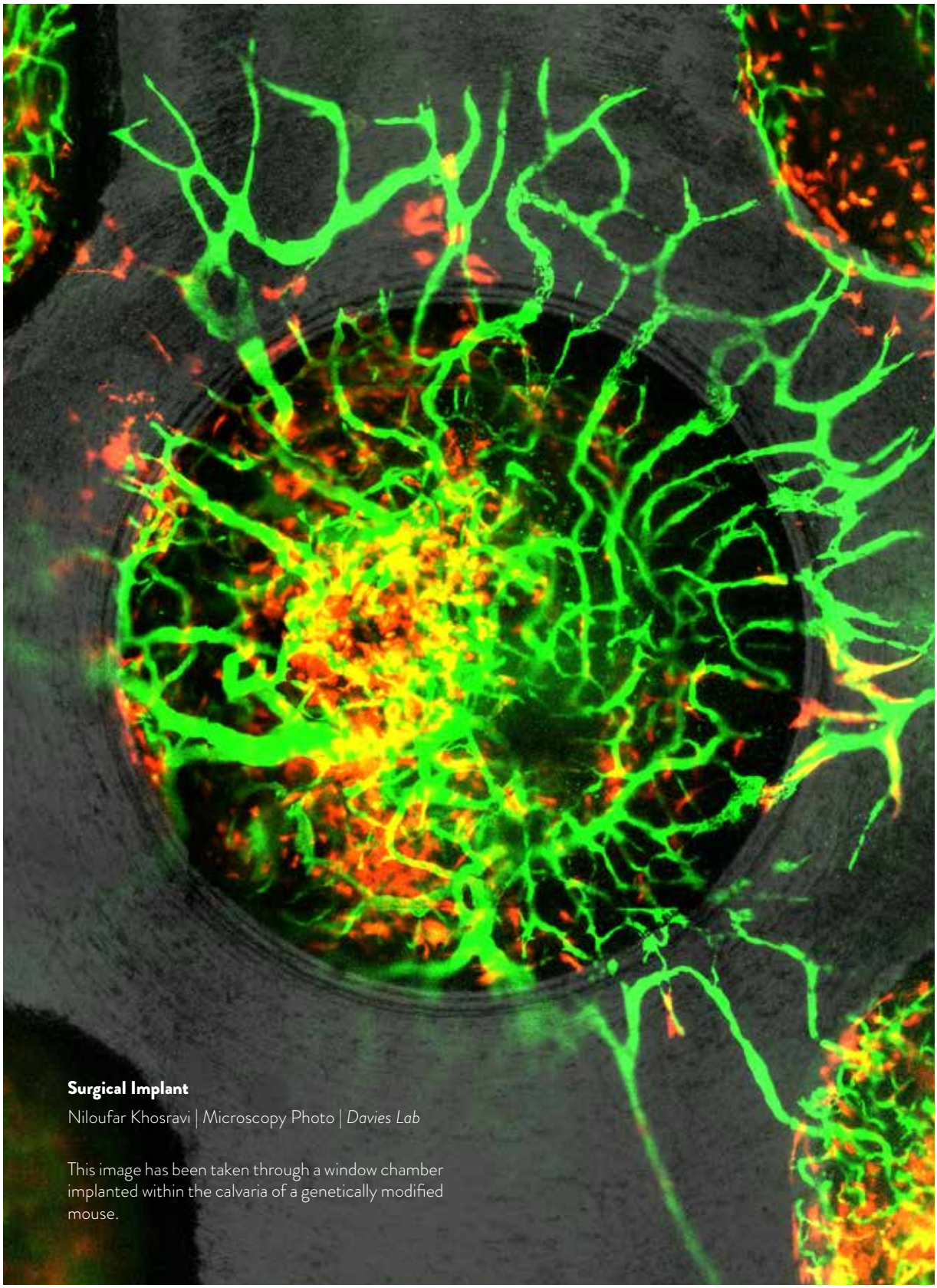
The biomedical engineering spirit is infectious and has started a movement in universities and companies that has lasted over two decades. Conventionally, university entities are organized into silos, where researchers are defined by the field they are trained in. For example, most faculty in a chemistry department obtained a degree in Chemistry during their undergraduate and graduate education. The same can be said about other disciplines. A biomedical engineering department or institute is different. A typical biomedical engineering department or institute can include faculty trained in chemistry, biology, engineering, physics, mathematics, medicine, and even the humanities. The co-localization of varied expertise provides the faculty an opportunity to learn from one another and to look at the problem through different lenses. The students, post-doctoral researchers, technicians, and engineers mingle in this microcosm of academic diversity that leads to creative technological innovations that may solve problems that, in some cases, the end-user did not know existed. Biomedical engineers act as the connectors of different fields, but they can zoom in on the problem.

A biomedical engineer believes in the idea of convergence, where concepts from different fields are merged to solve an important scientific problem.

The culture of biomedical engineering department bodes well for the training of students. The dawn of robotics, artificial intelligence, and automation will eliminate many technical jobs. The future engineer must be nimble and possess an entrepreneurial spirit to build a career where he or she can chart their own path. The biomedical engineering programs at top universities are dynamic – constantly changing to meet the demands of medicine, industry, and education. While this perpetual change may be initially disorienting, it teaches students to adapt to and thrive in rapidly changing environments. It teaches students to be comfortable with the unknown by giving them the tools to identify a problem and to develop a systematic interdisciplinary approach to solving it. Biomedical engineering programs train students to lead and to reach for positive global impact on humanity. This is why over 200 universities have started biomedical engineering departments or institutes in the last 20 years.

The University of Toronto started its biomedical engineering initiative in the 1960s. Since the onset, this initiative has led to a zestful biomedical engineering program. Through the evolution of the program in the last five decades, the Institute of Biomaterials and Biomedical Engineering (IBBME) has acquired many faces and is at the nexus of the entire University's research enterprise. Originating from the Rosebrugh and Mining building, the IBBME faculty and its trainees quickly expanded their research operations to the Donnelly Centre, MaRS Discovery District, and numerous hospitals across Toronto. Now there are over 300 graduate students in the Institute with undergraduate degrees in engineering, biology, chemistry, physics, psychology, and medicine. This melting pot of researchers make the Institute a special place that leads in developing new engineering principles and scientific discoveries.

The future of biomedical engineering is bright and incredible! The future will be laced with innovation that may be difficult to envision at this point in history. The Institute will participate in this rapidly growing field and is poised to become a global leader in biomedical engineering. This will be accomplished by training our students to be problem driven and self-starters, to think on their feet, to be organized, to be comfortable in an uncomfortable research environment, and to use the tools of the technological revolution to shape the future of medicine. This will have an indelible impact on human health and well-being. ■



Surgical Implant

Niloufar Khosravi | Microscopy Photo | *Davies Lab*

This image has been taken through a window chamber implanted within the calvaria of a genetically modified mouse.

FACULTY & STAFF

CORE FACULTY

Jan Andrysek | PhD, PEng
(1) Scientist, Holland Bloorview Kids Rehabilitation Hospital, (2) Assistant Professor (IBBME) (3) Associate Director, Professional Programs (IBBME)

Julie Audet | PhD, PEng
(1) Associate Professor (IBBME, ChemE, DC), (2) Vice-Dean, Graduate Studies

Berj L. Bardakjian | PhD, PEng
Professor (ECE, IBBME)

Elaine A. Biddiss | PhD
(1) Scientist, Holland Bloorview Kids Rehabilitation Hospital, (2) Assistant Professor (IBBME)

J. Christopher Bouwmeester | PhD, PEng
Assistant Professor, Teaching Stream (IBBME)

Warren C. W. Chan | PhD, FAIMBE
(1) Professor & Canada Research Chair in Nanobioengineering (IBBME, ChemE, CHM, DC, MSE) & (2) Director (IBBME)

Tom Chau | PhD, FAIMBE, FCAE, PEng
(1) Senior Scientist, Raymond Chang Foundation Chair in Access Innovations (2) Vice President, Research, Holland Bloorview Kids Rehabilitation Hospital, (3) Professor (IBBME, ECE, RSI), (4) Adjunct Scientist, Toronto Rehabilitation Institute, UHN

Hai-Ling Margaret Cheng | PhD, PEng
(1) Assistant Professor (IBBME, ECE, PHM), (2) Adjunct Scientist, Hospital for Sick Children

Leo Chou | PhD
Assistant Professor (IBBME), (2) Investigator, Medicine by Design

John E. Davies | PhD, DSc, FSBE
(1) Professor (DEN, IBBME) (2) Associate Director, Graduate Programs

Rodrigo Fernandez-Gonzalez | PhD
(1) Associate Professor (IBBME, CSB), (2) Adjunct Scientist, Hospital for Sick Children

Geoffrey Fernie | PhD, FCAHS, CEng, PEng
(1) Senior Scientist & Director, Research Institute, Toronto Rehabilitation Institute, UHN, (2) Professor (SRG, IBBME)

Michael Garton | PhD
Assistant Professor (IBBME)

Penney M. Gilbert | PhD
Associate Professor & Canada Research Chair, Endogenous Repair (IBBME, BCH, DC)

Marc D. Grynpas | PhD
(1) Senior Scientist, Samuel Lunenfeld Research Institute, Mount Sinai Hospital, (2) Professor (LMP, IBBME, MSE, SRG)

Rita Kandel | MD, FRCPC
(1) Clinician-Scientist & Chief, Pathology & Laboratory Medicine, Mount Sinai Hospital, (2) Professor (LMP, IBBME)

Dawn M. Kilkenny | PhD
(1) Associate Professor, Teaching Stream (IBBME), (2) Associate Director, Undergraduate Programs (IBBME), (3) Associate Chair of EngSci

Azadeh Kushki | PhD
(1) Scientist, Holland Bloorview Kids Rehabilitation Hospital, (2) Assistant Professor (IBBME)

Ofer Levi | PhD
Associate Professor (IBBME, ECE)

Kei Masani | PhD
(1) Scientist, Toronto Rehabilitation Institute, (2) Assistant Professor (IBBME)

Naomi Matsuura | PhD, PEng
Associate Professor (MSE, IBBME, MRAD)

Alison McGuigan | PhD
Associate Professor (ChemE, IBBME)

Alex Mihailidis | PhD, PEng
(1) Senior Scientist & Barbara G. Stymiest Research Chair in Rehabilitation Technology, Toronto Rehabilitation Institute, UHN (2) Professor (OCT, IBBME, CSC, RSI), (3) Scientific Director, AGE-WELL

Milos R. Popovic | PhD, FAIMBE, PEng
(1) Senior Scientist, Toronto Rehabilitation Chair in Spinal Cord Injury Research & Associate Scientific Director, Research, Toronto Rehabilitation Institute, UHN, (2) Professor (IBBME, ECE, MIE, IMS, RSI)

Milica Radisic | PhD, FAIMBE, FCAE, FCAE, PEng
(1) Professor, Canada Research Chair, Functional Cardiovascular Tissue Engineering (IBBME, ChemE) & Associate Chair, Research (ChemE) (2) Affiliate Scientist, Toronto General Research Institute, UHN

Jonathan V. Rocheleau | PhD
(1) Percy Edward Hart Professor & Associate Director, Research (IBBME), (2) Scientist, Toronto General Research Institute, UHN

Paul Santerre | PhD, FAAAS, FAIMBE, FBSE, PEng
Professor & Baxter Chair in Health Technology & Commercialization (DEN, IBBME, ChemE)

Michael V. Sefton | ScD, FAAAS, FAIMBE, FCIC, FBSE, FRSC, PEng
University Professor, Michael E. Charles Professor (ChemE, IBBME, DC) & Executive Director, Medicine by Design

Molly S. Shoichet | OC, OOnt, PhD, FAAAS, FAIMBE, FBSE, FCAHS, FCAE, FRSC, FTERM
University Professor & Canada Research Chair, Tissue Engineering (ChemE, IBBME, CHM, DC, IMS)

Craig A. Simmons | PhD, FCSME, PEng
(1) Distinguished Professor of Mechanobiology (MIE, IBBME, DEN), (2) Scientific Director, U of T Translational Biology & Engineering Program (TBEP), Ted Rogers Centre for Heart Research

Eli D. Sone | PhD
Associate Professor (IBBME, MSE)

David A. Steinman | PhD, FASME, PEng
Professor (MIE, IBBME)

Kien (Kevin) Truong | PhD, PEng
Associate Professor (ECE, IBBME)

Aaron R. Wheeler | PhD
Professor & Canada Research Chair, Bioanalytical Chemistry (CHM, IBBME)

Christopher M. Yip | PhD, FAAAS, FEIC, PEng
(1) Professor (ChemE, IBBME, BCH, DC), (2) Director (IBBME—until June 30, 2017), (3) Associate Vice-President, International Partnerships

Paul B. Yoo | PhD, PEng
Associate Professor (IBBME, ECE)

Lidan You | PhD, FCSME, PEng
Associate Professor (MIE, IBBME)

Peter Zandstra | PhD, FAAAS, FAIMBE, FRSC, PEng
(1) University Professor & Canada Research Chair, Stem Cell Bioengineering (IBBME), (2) Professor & Director, School of Biomedical Engineering, and Director, Michael Smith Laboratories, University of British Columbia

José Zariffa | PhD, PEng
(1) Scientist, Toronto Rehabilitation Institute, (2) Assistant Professor (IBBME)

CROSS-APPOINTED FACULTY

Christine Allen | PhD
Professor & GlaxoSmithKline Chair in Pharmaceutics and Drug Delivery (Leslie Dan Faculty of Pharmacy)

Cristina Amon | ScD, FAAAS, FASEE, FASME, FCAE, FCSME, FEIC, FIEEE, FRSC, NAE, PEng
(1) Dean (Faculty of Applied Science and Engineering), (2) Professor (MIE)

Richard Aviv | MBChB, MRCP, FRCR, FRCP, DABR
(1) Professor & Associate Vice Chair, Research—Brain, Spine & Nerve (Department of Medical Imaging), (2) Neuroradiologist, Sunnybrook Health Sciences Centre, (3) Associate Member (IMS), (4) Affiliate Scientist, Sunnybrook Research Institute.

Deryk Beal | PhD, Reg. CASLPO, CCC-SLP
(1) Clinician-Scientist, Bloorview Research Institute, Holland Bloorview Kids Rehabilitation Hospital, (2) Assistant Professor (Department of Speech-Language Pathology) (3) Collaborative Program in Neuroscience,

Sandra Black | OOnt, MD, FRSC
(1) Professor & Deborah Ivy Christian Brill Chair in Neurology, Department of Medicine, (2) Senior Scientist, Evaluative Clinical Sciences, Director, Hurvitz Brain Sciences Research Program, and Director, LC Campbell Cognitive Neurology Research Unit, Sunnybrook Research Institute, (3) Associate Professor (RSI), (4) Graduate Department of Psychological Clinical Science, U of T Scarborough, (5) Adjunct scientist, Rotman Research Institute, Baycrest Health Sciences, (6) Consultant neurologist, Sunnybrook, U of T, (7) Adjunct scientist, Toronto Rehabilitation Institute, UHN, (8) Site leader, Heart and Stroke Foundation Canadian Partnership for Stroke Recovery, (9) Executive director, Toronto Dementia Research Alliance

Earl R. Bogoch | MD, FRCSC
(1) Professor (Department of Surgery), (2) Associate Scientist, Li Ka Shing Knowledge Institute, and Medical Director, Mobility Program, St. Michael's Hospital

Gregory Borschel | MD, FAAP, FACS
(1) Research Director, Division of Plastic & Reconstructive Surgery, Department of Surgery, (2) Surgeon, Plastic & Reconstructive Surgery, and Associate Scientist, Neurosciences & Mental Health, Sick Kids Hospital

Joseph A. Cafazzo | PhD, PEng
(1) Institute of Health Policy, Management & Evaluation, (2) Lead, Centre for Global eHealth Innovation, and Senior Director, Medical Engineering & Healthcare Human Factors, UHN

Peter L. Carlen | MD, FRCPC
(1) Professor, Division of Neurology, Department of Medicine, (2) Senior Scientist, Krembil Research Institute, Toronto Western Hospital, UHN, (3) Associate Professor (Department of Physiology, Faculty of Medicine)

Karina Carneiro | PhD
Assistant Professor (Department of Dentistry)

Angela M. Cheung | MD, PhD
(1) Professor & Canada Research Chair, Musculoskeletal & Postmenopausal Health (Division of General Internal Medicine, Department of Medicine), (2) Senior Scientist, Toronto General Research Institute, UHN

Douglas Cheyne | PhD
(1) Professor (Department of Medical Imaging, Department of Speech Language Pathology), (2) Senior Scientist, Neurosciences & Mental Health, Sick Kids Research Institute

Catherine Coolens | PhD
(1) Professor (Department of Radiation Oncology), (2) Radiation Physicist, Princess Margaret Hospital, UHN, (3) Adjunct Professor (Institute for the Advancement of Technology for Health (TECHNA), UHN)

Dennis Cvitkovitch | PhD
Professor (Faculty of Dentistry)

James M. Drake | FRCSC
(1) Professor (Department of Surgery), (2) Senior Associate Scientist, SickKids Research Institute, Head, Division of Neurosurgery & Harold J. Hoffman / Shoppers Drug Mart Chair, Sick Kids Hospital, (3) Director, Centre for Image-Guided Innovation & Therapeutic Intervention, and Co-Lead, Centre for Image-Guided Care, Hospital for Sick Children, (4) Consultant Neurosurgeon, Bloorview MacMillan Children's Centre

Tilak Dutta | PhD
(1) Scientist & Team Lead, Home & Community Team, Toronto Rehabilitation Institute, UHN, (2) Associate Professor (RSI)

Anthony Easty | PhD, FAIMBE, FCMBES, FEIC, CCE, PEng
Adjunct Professor (IBBME)

Atena Roshan Fekr | PhD
(1) Affiliate Scientist, Toronto Rehabilitation Institute, UHN, (2) Assistant Professor (MIE)

Walid Farhat | MD, FRCSC, FAAP
(1) Professor (Department of Surgery), (2) Pediatric Urologist, Fellowship Program Director &, (3) Associate Surgeon-in-Chief of Education, The Hospital for Sick Children

Jeffrey Fialkov | MD, FRCSC
(1) Craniofacial Surgeon, Division of Plastic and Reconstructive Surgery, Sunnybrook Health Sciences Centre, (2) Associate Professor (Department of Surgery), (3) Associate Scientist, Holland Musculoskeletal Research Program, Sunnybrook Research Institute

Yoav Finer | DMD, PhD
Associate Professor & George Zarb/Nobel Bio Care Chair in Prosthodontics (Faculty of Dentistry)

Bernhard Ganss | PhD
Professor (Faculty of Dentistry)

Howard J. Ginsberg | MD, PhD, FRSCS
(1) Assistant Professor (Division of Neurosurgery, Department of Surgery), (2) Neurosurgeon, St. Michael's Hospital

Sidhartha Goyal | PhD
Assistant Professor (Department of Physics, Department of Ecology & Evolutionary Biology)

Teodor Grantcharov | MD, PhD, FACS
(1) Staff Surgeon, Keenan Chair in Surgery & Scientist, Li Ka Shing Knowledge Institute, St. Michael's Hospital, (2) Professor (Department of Surgery)

Axel Guenther | PhD
Professor & Wallace G. Chalmers Chair of Engineering Design (MIE)

Anne-Marie Guerguerian | MD, PhD, FAAP, FRCPC
(1) Staff Physician, Critical Care Medicine, and Senior Scientist, Neurosciences & Mental Health, Hospital for Sick Children, (2) Assistant Professor (Department of Paediatrics, Interdepartmental Division of Critical Care, Collaborative Program in Neuroscience)

Robert V. Harrison | PhD, DSc
(1) Professor & Vice-Chair of Research (Department of Otolaryngology—Head & Neck Surgery), (2) Professor (Department of Physiology, IMS) (3) Senior Scientist & Director, Auditory Science Laboratory, Sick Kids Hospital

Benjamin D. Hatton | PhD
Assistant Professor (MSE)

Boris Hinz | PhD
(1) Distinguished Professor of Tissue Repair & Regeneration (Faculty of Dentistry), (2) Associate Professor (Department of Surgery)

Kullervo Hynynen | PhD
(1) Professor & Canada Research Chair, Imaging Systems & Image-Guided Therapy (Department of Medical Biophysics), (2) Senior Scientist & Director, Physical Sciences, Odette Cancer Research Program, Sunnybrook Research Institute

George Ibrahim | MD, PhD, FRSCS
Assistant Professor (Department of Surgery)

Mohammad Islam | PhD
(1) Assistant Professor (Department of Radiation Oncology), (2) Senior Physicist, Princess Margaret Cancer Centre, UHN

David A. Jaffray | PhD
(1) Professor (Department of Radiation Oncology, Department of Medical Biophysics), (2) Senior Scientist, Head, Radiation Physics Department, Fidani Chair in Radiation Therapy Physics, Princess Margaret Hospital, (3) Director, Institute for the Advancement of Technology for Health (TECHNA), UHN, and Executive Vice President, Technology & Innovation, UHN, (4) Principal, Image-Guided Therapy (IGTx) Group & Site Leader, Medical Technology Innovation Priority Platform, Ontario Cancer Institute

Sasha M. John | PhD
Research Associate, Rotman Research Institute, Baycrest Hospital

Golnaz Karoubi | PhD
Scientific Associate & Research Program Manager, Latner Thoracic Surgery Research Laboratories (Waddell Research Group), UHN

Armand Keating | MD, FRCSC, FRCPC
(1) Professor (Division of Hematology, Department of Medicine), (2) Scientist, Krembil Research Institute, Toronto Western Hospital, (3) Director, Cell Therapy Program, Orsino Cell Therapy Translational Research Laboratory, Princess Margaret Cancer Centre, (4) Affiliate Scientist, Experimental Therapeutics, Toronto General Research Institute

Shana O. Kelley | PhD
Professor (Department of Chemistry, Pharmaceutical Sciences, Biochemistry)

Shafique Keshavjee | MD, LMCC
(1) Professor (Division of Thoracic Surgery, Department of Surgery), (2) Surgeon-in-Chief, James Wallace McCutcheon Chair in Surgery, Program Medical Director, Surgical Service and Critical Care, UHN, (3) Director, Toronto Lung Transplant Program, Toronto General Hospital and SickKids Hospital, (4) Senior Scientist, Division of Experimental Therapeutics, and McEwen Centre for Regenerative Medicine, UHN

Eugenia Kumacheva | PhD
Professor & Canada Research Chair, Advanced Polymer Materials (Department of Chemistry)

Dinesh Kumbhare | MD, PhD, FRCPC, FAAPMR
(1) Associate Professor (Division of Physical Medicine & Rehabilitation, Department of Medicine, Institute of Health Policy, Management & Evaluation, Faculty of Kinesiology & Physical Education), (2) Affiliate Scientist, Toronto Rehabilitation Institute, UHN

Michael Laflamme | MD, PhD
(1) Senior Scientist, Toronto General Hospital Research Institute & Staff Pathologist, UHN, (2) Associate Professor (Department of Laboratory Medicine & Pathobiology)

Stephen Lapinsky | MBBCh, FRCP
Professor (Department of Medicine) Site and Education Director, Intensive Care Unit, Mount Sinai Hospital

Jérémie Lefebvre | PhD
(1) Scientist, Krembil Research Institute, UHN, (2) Assistant Professor (Department of Mathematics)

Ren-Ke Li | MD, PhD
(1) Professor & Canada Research Chair, Cardiac Regeneration (Division of Cardiovascular Surgery, Department of Surgery), (2) Professor (Department of Laboratory Medicine & Pathobiology), (3) Senior Scientist, Division of Experimental Therapeutics, Toronto General Research Institute, UHN, (4) Adjunct Scientist, St. Michael's Hospital

Xinyu Liu | PhD, PEng
Associate Professor (MIE)

Radhakrishnan (Krishna) Mahadevan | PhD
Professor (Department of Chemical Engineering & Applied Chemistry)

Thierry Mallevaey | PhD
Associate Professor (Department of Immunology)

Andreas Mandelis | MSE,PhD, FRSC, FAPS, FSPIE
(1) Professor and Canada Research Chair, Diffusion-Wave and Photoacoustic Sciences & Technologies (MIE, ECE)

Michael Thompson | PhD
Professor (Department of Chemistry)

Patricia L. Trbovich | PhD
(1) Badeau Family Research Chair in Patient Safety & Quality Improvement, North York General Hospital, (2) Associate Professor (Institute of Health Policy, Management & Evaluation), (3) Affiliated Faculty (Institute for the Advancement of Technology for Health (TECHNA), UHN)

Piero Triverio | PhD, FAAAS, SMIEEE, PEng
Associate Professor (ECE)

Taufik A. Valiante | MD, PhD, FRCSC
(1) Staff Neurosurgeon, Scientist, Krembil Research Institute & Co-Director, Epilepsy Program, Toronto Western Hospital, UHN, (2) Associate Professor (Division of Neurosurgery, Department of Surgery), (3) Affiliate Scientist, Institute for the Advancement of Technology for Health (TECHNA), UHN

Sara Nunes de Vasconcelos | PhD
(1) Assistant Scientist, Division of Experimental Therapeutics, Toronto General Research Institute, UHN, (2) Assistant Scientist, Heart & Stroke/Richard Lewar Centre of Excellence (HSRLCE), Faculty of Medicine, (3) Assistant Scientist, Ontario Stem Cell Initiative

Sowmya Viswanathan | PhD
Affiliate Scientist, Krembil Research Institute, UHN

Thomas K. Waddell | MD, PhD, FRCSC, FACS
(1) Professor & Pearson-Ginsberg Chair (Division of Thoracic Surgery, Department of Surgery), (2) Thomson Family Chair in Translational Research & Head, Division of Thoracic Surgery, UHN, (3) Senior Scientist & McEwen Chair for Regenerative Medicine, Toronto General Research Institute

Robert A. Weersink | PhD, MCCPM
(1) Assistant Professor (Department of Radiation Oncology), (2) Affiliated faculty (Institute for the Advancement of Technology for Health (TECHNA), UHN)

Cari M. Whyne | PhD
(1) Professor (Department of Surgery), (2) Senior Scientist, Physical Sciences & Director, Holland Musculoskeletal Research Program, Sunnybrook Research Institute, (3) Director, Orthopaedic Biomechanics Lab, Sunnybrook Health Sciences Centre

Harold Wodlinger | PhD
Adjunct Professor (IBBME)

Willy Wong | PhD
Associate Professor (ECE)

Azadeh Yadollahi | PhD
Scientist, Toronto Rehabilitation Institute, UHN

Kazuhiro Yasufuku | MD, PhD
(1) Associate Professor (Division of Thoracic Surgery, Department of Surgery), (2) Staff Thoracic Surgeon, Division of Thoracic Surgery, Toronto General Hospital, and Scientist, Latner Thoracic Surgery Research Laboratory, Toronto General Research Institute, UHN

Albert J. M. Yee | MD, FRCSC, DABOS
(1) Professor (Division of Orthopaedic Surgery, Department of Surgery), (2) Associate Scientist, Physical Sciences, Holland Musculoskeletal Research Program, Sunnybrook Research Institute

Edmond W. K. Young | PhD
Assistant Professor (MIE)

Gang Zheng | PhD, FAIMBE
(1) Professor (Department of Medical Biophysics), (2) Senior Scientist and Joey & Toby Tanenbaum/Brazilian Ball Chair in Prostate Cancer Research, Princess Margaret Cancer Centre, and Core Lead, Institute for the Advancement of Technology for Health (TECHNA), UHN, (3) Associate Professor (Leslie Dan Faculty of Pharmacy)

Anton Zilman | PhD
Assistant Professor (Department of Physics, Department of Cell & Systems Biology)

EMERITUS

Richard Cobbold | PhD
Professor Emeritus (IBBME, ECE)

Alf Dolan | PhD
Professor Emeritus (IBBME)

Richard Frecker | MD, PhD
Professor Emeritus (IBBME)

Michael Joy | PhD, PEng
Professor Emeritus (IBBME, ECE, Department of Physics)

Hans Kunov | PhD, PEng
Professor Emeritus (IBBME, ECE)

Morris (Mickey) Milner | PhD, PEng
Professor Emeritus (IBBME)

Kenneth H. Norwich | MD, PhD
Professor Emeritus (IBBME, Department of Physics)

Robert Pilliar | PhD, PEng
Professor Emeritus (IBBME, Faculty of Dentistry, Department of Material Science & Engineering)

STAFF MEMBER

Barbara Alexander
Manager of Operations

Jenia Bloch | PhD
Industrial Liaison Officer

Qin (Bill) Dai | PhD
Scientific Manager

Ivy Hon
Acting Undergraduate Programs Coordinator

Judy Gilligan
Operations Assistant

Rhonda Marley
Graduate Programs Coordinator

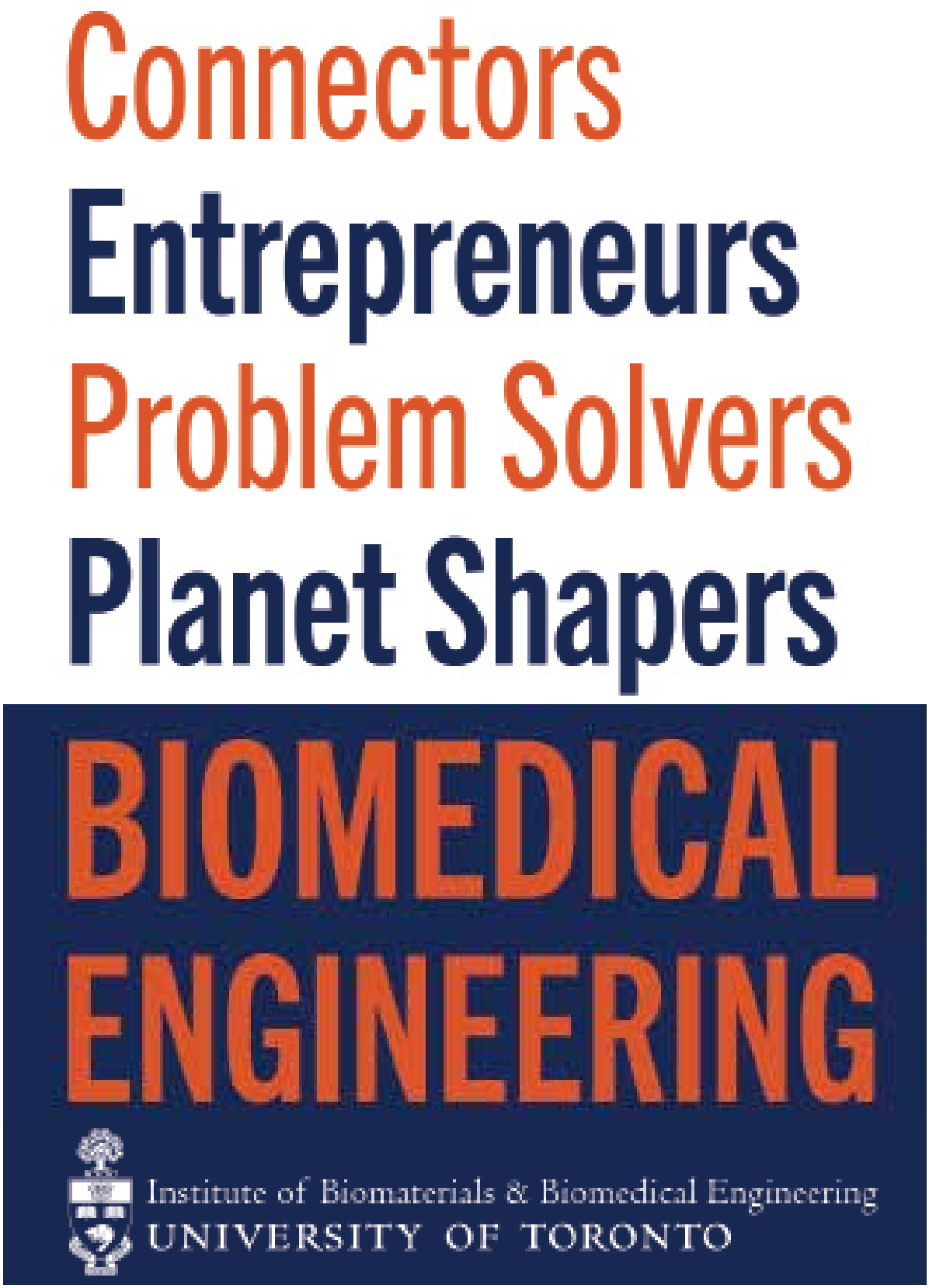
Angela Rosa
Acting Human Resources Administrator & Finance Officer

David Seto
Information Technology Support Specialist, Web & Audio-Visual

Andrey Shukalyuk | PhD
Teaching Laboratory & Safety Coordinator

Jason Wen | PhD
Project Coordinator

Wah-Ming Wong
Acting Finance Officer, Research


Connectors
Entrepreneurs
Problem Solvers
Planet Shapers
BIOMEDICAL
ENGINEERING
Institute of Biomaterials & Biomedical Engineering
UNIVERSITY OF TORONTO

Cover:
Picture of Rosebrugh Building taken in 1964. This is where IBBME began 55 years ago. This issue illustrates how far the Institute had grown since then. (University Archives)

Editor:
Qin (Bill) Dai
Jenia Bloch
Warren C.W. Chan
Barbara Alexander

Illustration:
Qin (Bill) Dai
Denny Lie
Helado Digital

Content:
Warren C.W. Chan
Richard Cobbold
Tyler Irving
Jovana Drinjakovic
Qin (Bill) Dai
Julien C. Senécal

Fact Checking:
Hans Kunov
Michael V. Sefton

Image Source:
Adobe Stock Images
University of Toronto Archives
Robert Lansdale Photography
IBBME Archives
Tristan McGuirk
Qin (Bill) Dai
Buddhisha Udugama
Jennifer Ma
Jovana Drinjakovic
Rodrigo-Fernandez Gonzalez
Darren Rodenhizer
Alborz Mahdavi
Brandon Burke
Neil Ta
Niloufar Khosravi

Institute of Biomaterials & Biomedical Engineering
University of Toronto
Rosebrugh Building, 164 College Street, Room 407
Toronto, Ontario M5S 3G9 Canada
416-978-7459