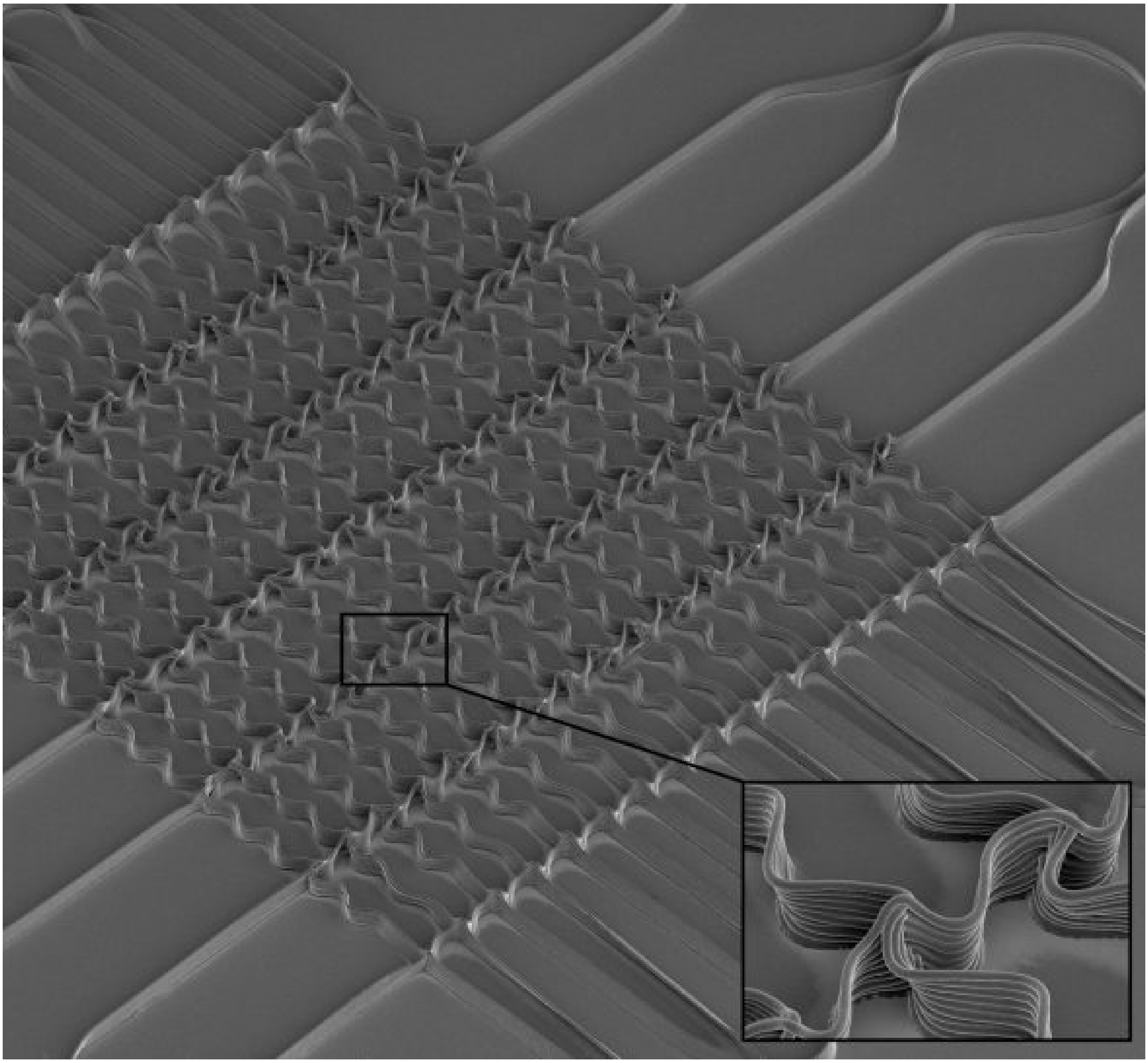
BIOMEDICAL ENGINEERING

Annual Magazine | Volume 3 | **2020**



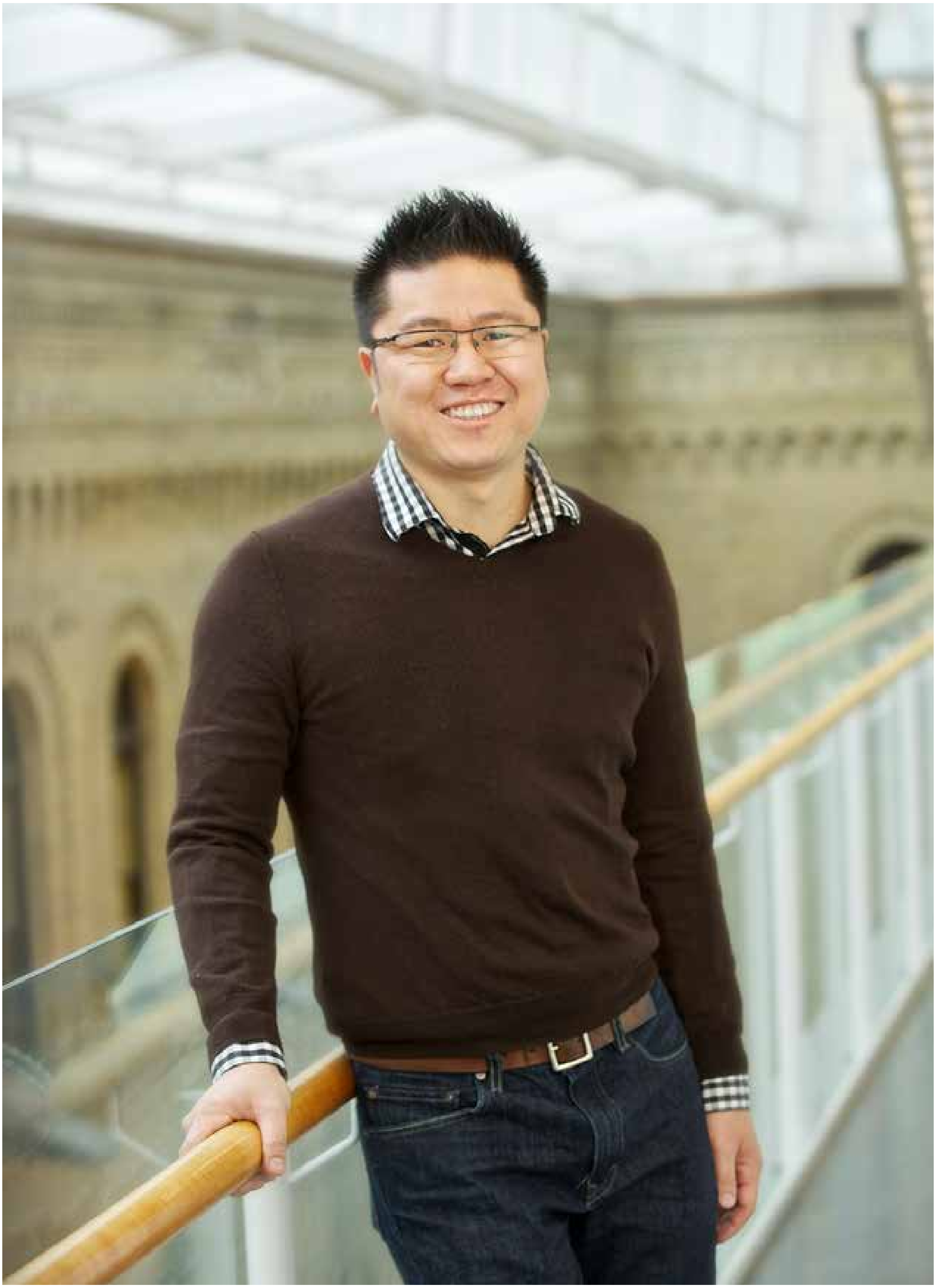
Institute of Biomedical Engineering
UNIVERSITY OF TORONTO

Cover by:
Professor Craig Simmons & Bahram Mirani

Description: Scaffolds composed of stacked layers of orthogonally-oriented sinusoidal fibres can exhibit non-linear anisotropic mechanical properties, similar to those of native heart valve tissue. These scaffolds are fabricated via melt electrospinning writing of polycaprolactone for heart valve tissue engineering applications.

Cover decided by popular vote by the BME community.

Data Sources:
FASE Annual Report
SGS Office
Graduate Office, BME
Finance Office, BME
SciVal, Elsevier



NOTE FROM THE DIRECTOR

Welcome to the 2020 edition of the Institute of Biomedical Engineering (BME) annual magazine. On behalf of the Biomedical Engineering community at the University of Toronto, I hope that you and your loved ones are safe and well during these trying times. As we endure the challenges brought on by the recent health crisis together, I want to assure you that we are doing everything possible to secure a prosperous future for the next generation of Biomedical Engineers.

Our faculty members and student researchers are still engaged in cutting edge research despite the pandemic. Ranging from developing artificial islets for insulin production, to building technologies that improves hand hygiene, our researchers are addressing some of the most pressing topics in the field of biomedical engineering.

We are proud of our alumni's immense achievements after completing our graduate programs. In this issue, we featured three of our alumni: Peter Aldrige, Amanda Fleury, and Rahul Sarugaser. Each of them embarked on a distinctive industry career path, and they were able to leverage the skillsets acquired during graduate school to propel their career forward.

The "Faces of Biomedical Engineering" are back, featuring 7 of our graduate students from PhD, MASc, and MEng programs. Our learners are talented and have varied interests in and out of academia.

I hope you enjoy this volume, and we look forward to another exciting year ahead!

Warren Chan

Warren C.W. Chan
Professor and Director

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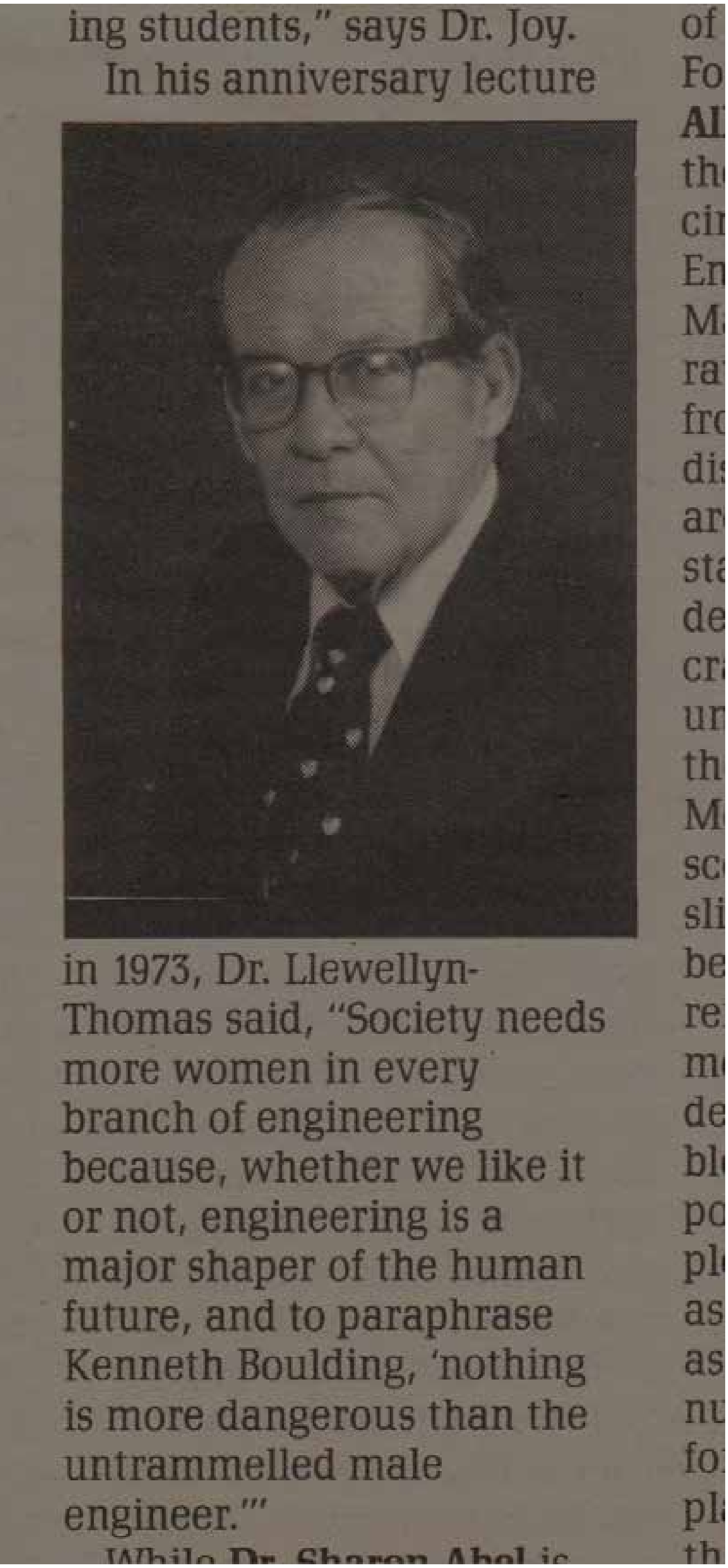
"In the last five or six years, we have been able to develop very small transducers very cheaply using the same technology used for integrated circuits. The impact of integrated circuits on sensor technology has been rapid. Sensors provide the 'eyes' which enable us to see how things are operating — 'eyes' in a electrical sense because they convert physical data into an electrical signal which can then be processed in a computer or microprocessor."

There are many medical and non-medical applications of this technology in industry. But incomplete understanding of the fundamental operating mechanisms has created difficulty in developing the technology for commercial use. That fundamental understanding, says Dr. Cobbold, is where universities come in. But to a large extent, industry has not taken advantage of

techniques for diagnosis. Dr. Zingg's is one such project. He is using fibre optics to develop an endoscope which will enable doctors to see around curves and into currently inaccessible areas.

One research project which has brought international attention to the IBME is that of Dr. Richard Cobbold and **Dr. Wayne Johnston**. For 12 years, they have been working together on Doppler Ultrasound. Like others at the IBME, their partnership began informally when a student casually mentioned Dr. Cobbold's research to Dr. Johnston over lunch.

Doppler Ultrasound is effective in assessing arterial disease using the Doppler effect, or, the change in frequency which results when an ultrasound wave returns after being sent into a blood vessel. "When you send an ultrasound wave into a vessel, you might find it has



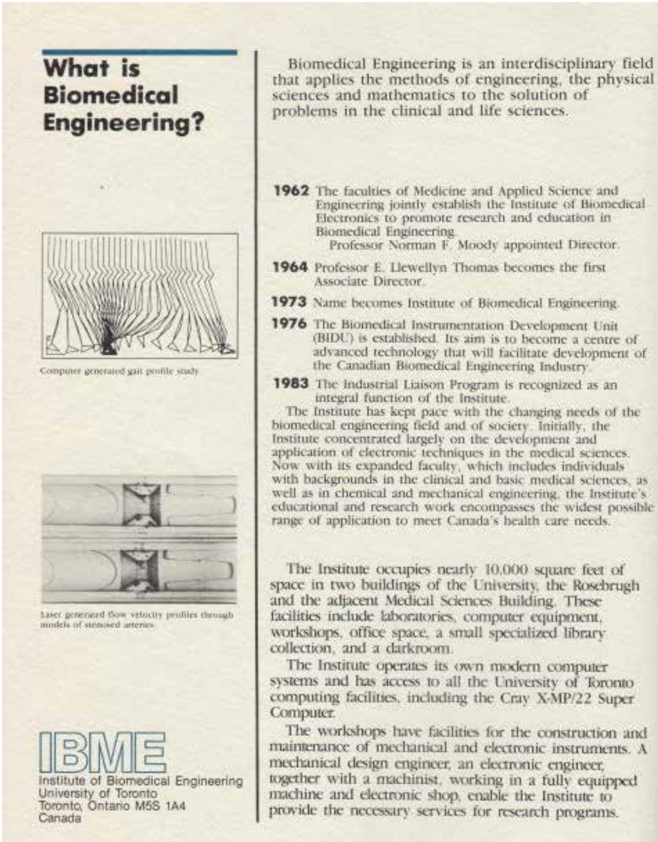
ing students," says Dr. Joy.

In his anniversary lecture in 1973, Dr. Llewellyn-Thomas said, "Society needs more women in every branch of engineering because, whether we like it or not, engineering is a major shaper of the human future, and to paraphrase Kenneth Boulding, 'nothing is more dangerous than the untrammelled male engineer.'"

While **Dr. Sharon Abel** is

Evolution of BME in Toronto

As the Institute of Biomaterial and Biomedical Engineering (IBBME) changed its name to the Institute of Biomedical Engineering (BME), it is time to revisit some of the previous identities the Institute has taken on. For the past 58 years, biomedical engineering at the University of Toronto had experienced three name changes. Along with it, the meaning of biomedical engineering has also evolved over the years. We spoke to some of the previous directors of the Institute and asked them to share some thoughts on the field of biomedical engineering.



What is Biomedical Engineering?

Biomedical Engineering is an interdisciplinary field that applies the methods of engineering, the physical sciences and mathematics to the solution of problems in the clinical and life sciences.

Computer generated gait profile study

1962 The faculties of Medicine and Applied Science and Engineering jointly establish the Institute of Biomedical Electronics to promote research and education in Biomedical Engineering.
Professor Norman F. Moody appointed Director.

1964 Professor E. Llewellyn Thomas becomes the first Associate Director.

1973 Name becomes Institute of Biomedical Engineering.

1976 The Biomedical Instrumentation Development Unit (BIDU) is established. Its aim is to become a centre of advanced technology that will facilitate development of the Canadian Biomedical Engineering Industry.

1983 The Industrial Liaison Program is recognized as an integral function of the Institute.

The Institute has kept pace with the changing needs of the biomedical engineering field and of society. Initially, the Institute concentrated largely on the development and application of electronic techniques in the medical sciences. Now with its expanded faculty, which includes individuals with backgrounds in the clinical and basic medical sciences, as well as in chemical and mechanical engineering, the Institute's educational and research work encompasses the widest possible range of application to meet Canada's health care needs.

Laser generated flow velocity profiles through models of stenosed arteries

The Institute occupies nearly 10,000 square feet of space in two buildings of the University, the Rosebrugh and the adjacent Medical Sciences Building. These facilities include laboratories, computer equipment, workshops, office space, a small specialized library collection, and a darkroom.

The Institute operates its own modern computer systems and has access to all the University of Toronto computing facilities, including the Cray X-MP/22 Super Computer.

The workshops have facilities for the construction and maintenance of mechanical and electronic instruments. A mechanical design engineer, an electronic engineer, together with a machinist, working in a fully equipped machine and electronic shop, enable the Institute to provide the necessary services for research programs.

IBME
Institute of Biomedical Engineering
University of Toronto
Toronto, Ontario M5S 1A4
Canada

← BME graduate programs pamphlet (1992).

→ Previous and current directors of biomedical engineering at the University of Toronto.

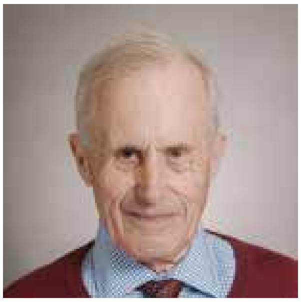
Brief History by Robert Pilliar (Director: 1992-1999):

The original Institute of Biomedical Engineering was based mainly on merging research activities from the Department of Electrical Engineering and the Faculty of Medicine (primarily Department of Physiology). The Centre for Biomaterials' activities were founded more on materials-related research aimed at clinical applications of materials and structures in Medicine and Dentistry.

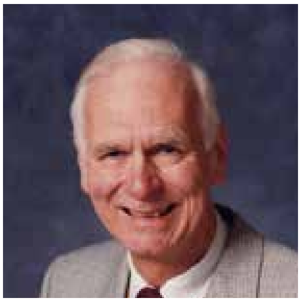
A need for an understanding of biocompatibility became a dominant theme of many collaborative studies in this area starting around the mid-1970s with increasing involvement of medical and clinical researchers with others in Applied Science & Engineering (mainly departments of Chemical Engineering, Materials Science & Engineering and to a lesser degree Mechanical Engineering) as well as individuals from the Arts & Science Faculty (mainly Chemistry). By the time the Centre for Biomaterials (C4B) and Institute of Biomedical Engineering (IBME, 1974-1999) merger occurred and for a few years prior to that, the biological sciences input to the biomaterials field, as evidenced by presentations at major scientific conferences such as the World Biomaterials Congresses, had become very significant and in many cases, more prominent than the traditional engineering topics and methodologies that had dominated earlier studies.

The engineering-based researchers that continued to contribute significantly to progress in the biomaterials field were those that, either by osmosis through dedicated collaborations with biologists/clinician researchers or through further biology-based self-education, had become experts in the emerging Biomaterials field. This then formed the basis for IBBME research activities at the time of the C4B/IBME merger and the key to its success, as in pre-merger times. This success was dependent on the close association, communication and collaboration between the non-biology- and biology-based disciplines, a factor that was greatly enhanced through the merger and establishment of laboratory and office space for collaborators within IBBME. This continues to be the key to success and innovation of IBBME research.

Norman Moody
Institute of Biomedical Electronics (IBE)
Director: 1962 - 1974



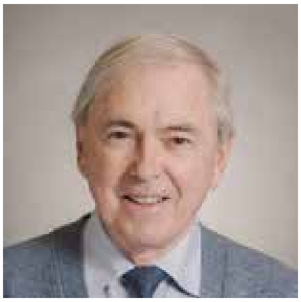
Richard Cobbold
Institute of Biomedical Engineering (IBME)
Director: 1974 - 1983



Walter Zingg
Institute of Biomedical Engineering (IBME)
Director: 1983 - 1989

Hans Kunov
Institute of Biomedical Engineering (IBME)
Director: 1989 - 1999

Dennis Smith
Centre for Biomaterials (C4B)
Director: 1986 - 1992



Robert Pilliar
Centre for Biomaterials (C4B)
Director: 1992 - 1999

Michael Sefton
Institute of Biomaterials and Biomedical Engineering (IBBME)
Director: 1999 - 2005

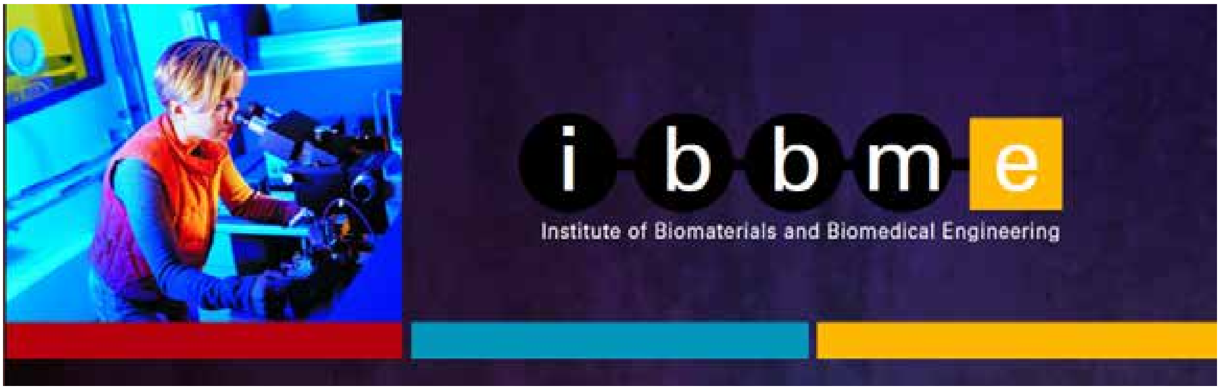
Ross Ethier
Institute of Biomaterials and Biomedical Engineering (IBBME)
Director: 2005 - 2007

Paul Santerre
Institute of Biomaterials and Biomedical Engineering (IBBME)
Director:2008 - 2013

Christopher Yip
Institute of Biomaterials and Biomedical Engineering (IBBME)
Director: 2013 - 2017

Craig Simmons
Institute of Biomaterials and Biomedical Engineering (IBBME)
Interim Director: 2017 - 2018

Warren Chan
Institute of Biomedical Engineering (BME)
Director: 2018 - Present



What is the identity of biomedical engineering?

Richard Cobbold (from archives): Biomedical engineering first emerged as a separate 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 the 1950's, one of the purposes of which 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 a designer to a collaborator.

Hans Kunov: We used to build medical equipment; now we build biological systems. Biomedical engineering is a vast and expanding field. It is necessary to focus teaching and research to well defined areas of expertise, without losing sight of the big picture.

Robert Pilliar: Biomedical Engineering is a catch-all moniker that represents an evolving field of study, open to contributors from all basic and applied science disciplines willing to apply the acquired knowledge, skills and expertise from their home discipline to this multidisciplinary research field.

Michael Sefton: The focus used to be on application of engineering in medicine and now and throughout the history of IBBME, it is more about integration of engineering and medicine. Somewhat akin to the origins of chemical engineering as the combination of engineering and chemistry, as distinct from an offshoot of mechanical engineering.

Ross Ethier: Biomedical engineering is the profession that uses technology and our engineering knowledge to improve human health. It is incredibly broad, covering topics as diverse as medical device design, development of regenerative medicine-based therapies, invention of new imaging technologies, and using big data to understand disease processes. Biomedical engineering is the field that naturally attracts talented people with analytical, quantitative backgrounds who are not afraid to grapple with the messy reality of clinical medicine and biology.

Paul Santerre: Biomedical engineering represents a field that enables one to be as multidisciplinary as they wish, from molecules to cells, to engineering design, to the commercialization of devices, to patients. Hence, it gives us a chance to attract many more excellent students than we would normally, because we capture the career academic as well as the translational scientist.

Chris Yip: A truly challenging question to answer and one that is constantly evolving – Biomedical engineering is perhaps among the first truly integrative fields of study that has focused on translating between the engineering and biomedical sciences. Applying quantitative engineering approaches to the challenging and uniquely complex questions and insights from biology and medicine has long been the hallmark of biomedical engineering.

Warren Chan: Biomedical engineering uses principles from engineering and the physical sciences to solve the most challenging medical problems. This transdisciplinary field addresses the problems from the molecular, cell, tissue, and patient level. Students trained in Biomedical Engineering knows how to look at problems from every angle and find the fastest strategy to solving the most pressing problems.

← Advertisement banner featuring the logo for Institute of Biomaterials and Biomedical Engineering (2008).

→ Depiction of biomedical engineering on graduate school advertisement pamphlet (1992).

What is the future of biomedical engineering?

Robert Pilliar: Future evolution of the Institute's operations hopefully will retain the strong multidisciplinary tradition that has developed over the years. This has been our strength in the past and will continue to be so as new undergraduate and graduate students are drawn into the Institute of Biomedical Engineering program.

Michael Sefton: Convergence of life sciences and engineering will be complemented with convergence of engineering disciplines, in new technologies such as wearables and digital health being integrated with biological components.

Ross Ethier: Biomedical engineering is the field that has most transformed the delivery of clinical medicine: think how barren the operating room would be without all the imaging equipment, the heart-lung bypass machine, the real-time monitors, and the surgical tools. Biomedical engineering is the branch of engineering that most directly focuses on human well-being and health; for me, this makes it the most exciting and rewarding place to work.

Paul Santerre: I think that the future belongs to advances in the rational design of health care solutions that are practical. Health care systems are bankrupt, so innovations need to use the forefront of nanomaterials, AI, and molecular/cellular biology to create efficiently engineered solutions that are scalable to the health market place. It is such thinking that will rationalize governments to continue to invest in BME research. I think that BME at UofT needs to promote more translational thinking integrated into the curriculum so that we better prepare our students for where the job opportunities lie.

Chris Yip: As the saying goes, the future looks bright. The boundaries and definitions of the engineering and biomedical fields are constantly in flux – with trainees and researchers from both domains eager to learn more from each other, gaining a better appreciation of the opportunities, challenges, and complexities inherent to their fields. Building these trans- and cross-disciplinary partnerships, something that is inherent to BME, will undoubtedly let us revisit old paradigms, perspectives, and models in different ways that will directly and positively impact human health.

Warren Chan: Biomedical engineering became a major research theme in the late 1990s and early 2000s. It went through its bumps and bruises as we learned what it means to be a researcher and be educated in Biomedical Engineering in the last 20 years. The field has built a solid foundation and is soaring. In the next 50 years, it will soar to new heights in the design of new technologies to help patients, or new personalized drugs to treat diseases. Trainees in this field will translate these technologies, build new economies, and solve some of the most critical problems facing society. ■

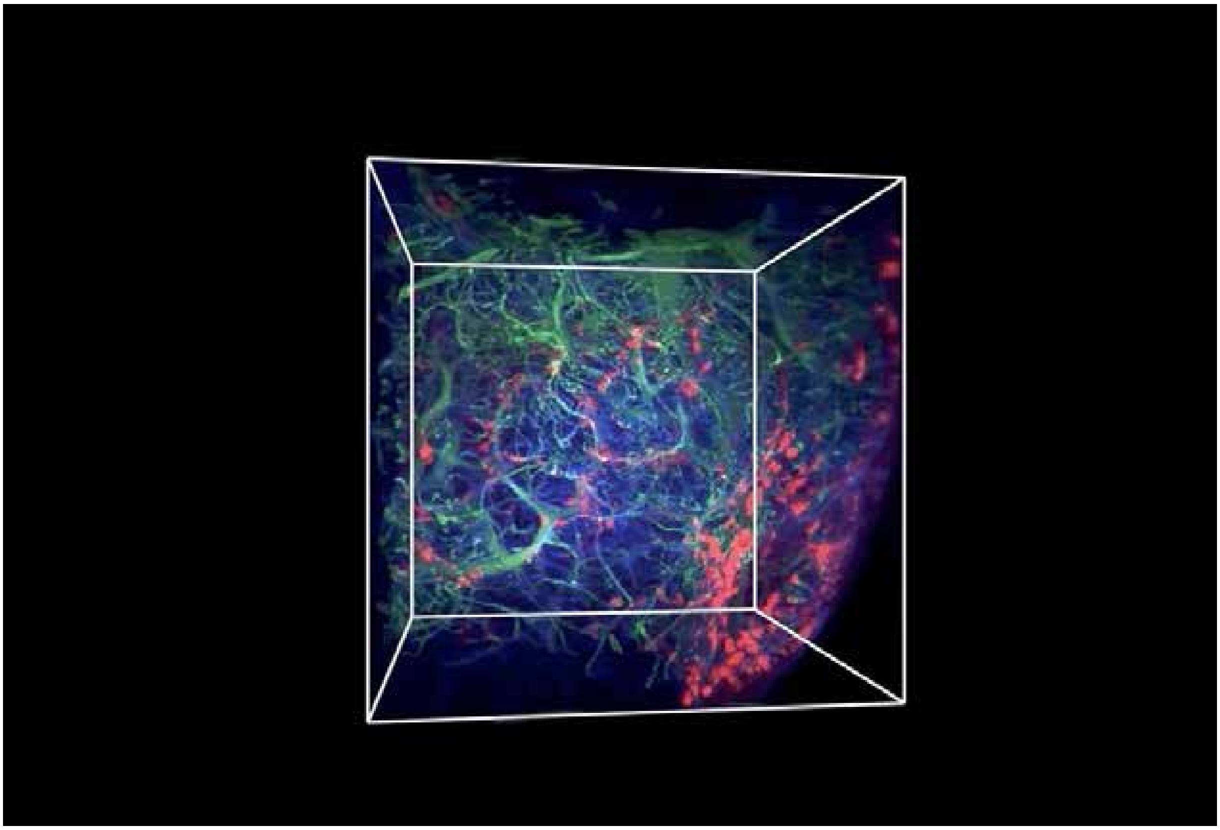
Researchers develop a method to improve artificial islet transplantation success rate

PHOTO: QIN (BILL) DAI

Researchers from the Institute of Biomedical Engineering, Chemical Engineering, and the Donnelly Centre have developed a method to fine-tune the cellular composition of artificial islets – the organ responsible for regulating blood glucose in the body. This advance could improve the success rate of implantable islets to treat people living with diabetes. The study was led by senior graduate student Dr. Alexander Vlahos in Dr. Michael Sefton's lab, and the findings were published in the journal Biomaterials (DOI: 10.1016/j.biomaterials.2019.119710).

In a healthy individual, pancreatic islets are responsible for secreting insulin – a vital molecule that regulates glucose level in the human body. This function is severely dampened in those living with diabetes, where significantly lower insulin production can lead to blindness or kidney failure.

Recent advances have enabled researchers to implant artificial islets (called pseudo-islets) directly under the skin to regenerate normal glucose modulation in animals. This provides a longer lasting and hands-off method for diabetes management as opposed to repeated insulin injection.



← Researchers spearheading this study. From left to right: Sean Kinney, Dr. Alexander Vlahos, and So-Yoon Won.

↑ 3-dimensional rendering of a pancreatic islet. Green represents the blood vessels. Courtesy of Sefton lab.

"The success rate of transplantation is dependent on the health of the pseudo-islet," says Dr. Alex Vlahos, the lead author of the publication, "Most of the islet cells die soon after transplantation. In our study, we developed a method to fine-tune the size and composition of the pseudo-islet to improve the success of implantation."

The researchers first harvested donor islets and isolated the cells responsible for insulin production. The key was to recombine them in a 3D environment to resemble an islet. These artificial islets were then reintroduced into a diabetic animal to restore glucose level. The authors also observed proper blood vessel formation, a hallmark of healthy regeneration of an organ.

"The next step is to evaluate the therapeutic impact of human artificial islets," says Sean Kinney, a co-author on the study, "The ultimate goal is to implant these islets into humans and have them last a decade. But there's still quite a few barriers we have yet to overcome."

Improvement to transplantation success is crucial for its translation into the clinic. Due to the scarcity of islet donors, this is not yet a widely adaptable method. Normally one islet transplantation would require three donors, but if the engraftment rate is better, three donors could be reduced to one. This can effectively increase the number of patients this method can serve.

"Creating artificial islets gives us the opportunity to create an organ that is better than what nature has provided." says Dr. Michael Sefton, the corresponding author on this research, "Islets have evolved to control our blood sugar and we have learned to transplant them. We can now engineer them to be better than nature when transplanted – to reduce their oxygen consumption per unit of insulin produced or to better withstand the host response." ■

U of T startup develops technology that encourages hand hygiene to prevent the spread of COVID-19

Improving hand hygiene (HH) is one of the most effective solution to reduce COVID-19 from spreading in hospitals and nursing homes. To this end, Dr. Geoff Fernie is developing a wearable technology that reminds first-line responders to wash their hands despite their busy schedules. This technology could significantly reduce the spread of Hospital-Acquired Infections (HAIs) including COVID-19.

"Studies in some hospitals showed that our device has doubled the hand hygiene rate, which should reduce the infection rates. We hope this system helps change the habits of healthcare workers, making it safer for everyone." says Professor Geoff Fernie at the Institute of Biomedical Engineering at the University of Toronto, and the former director of the KITE Research Institute.

With the recent development of COVID-19 cases, Fernie says "the need for this system is more crucial than ever". The additional COVID-19 cases have significantly increased the workload for healthcare professionals, making it easier to miss opportunities when washing hands as recommended.

In a large Intensive Care Unit (ICU) such as the one at University Health Network (UHN), a nurse may have over 350 hand hygiene opportunities during a 12-hour shift, or up to 30 opportunities each patient care hour where hand hygiene is recommended.

Better adherence to HH could reduce this infection rate and reduce this unnecessary death rate. However, realistic estimates of hand washing before and after interacting with a patient range from 30% to 60%.

"The idea we are proposing is a nurse or physician arrives at work, retrieves a personalized device, and carries on with their day as normal." says Fernie. "The device will remind them about hand-washing throughout the day."

Dubbed as the 'Buddy Badge', the wearable device acts as a transponder. Along with the badge, the technology also consists of a system of sensors connected to hand washing stations, doorways, and critical routes to the patient's room. For instance, if the badge wearer has not washed their hands before entering a patient's room, it will discreetly vibrate to remind them to do so.

Fernie and his team have been working on wearable technology for 17 years. In 2018, this technology took form of a startup company Hygienic Echo, with the primary goal of reducing infections in communal settings. This idea was published in 20 peer reviewed scientific articles, and since filed 9 patents.

This technology had deployed in the first hospital in Summer of 2020 and in the first nursing home this Fall. ■

New evidence on factors that promote bone mineralization

← A research team led by Dr. Eli Sone have discovered a new role in mineralization played by a class of molecules. (Top left: Dr. Magdalena Wojtas, bottom left: Dr. Alexander Lausch, right: Dr. Eli Sone)

A research team led by Dr. Eli Sone (BME, MSE, Dentistry) have discovered a new role in mineralization played by a class of molecules, glycosaminoglycans (GAGs). GAGs had the opposite effect than previously thought in the process of bone mineralization. Instead of 'switching' off mineral formation, the GAGs promote the mineralization process. This knowledge will enable engineers to design better tissue regeneration strategies for treating bone and tooth-related diseases. The finding was recently published in the Proceedings of the National Academy of Sciences of the USA (PNAS).

"In an infectious gum disease like periodontitis, bacteria invade into the root of the tooth and destroy the ligament that connects the mineralized tooth to the jaw bone. There are currently no reliable method for regenerating tooth attachment." says Sone, the corresponding author of this finding. "Part of the reason is that we don't fully understand the mineralization processes that govern tooth attachment."

Teeth are connected to the jawbone through a small, un-mineralized ligament. A high degree of spatial control over mineralization – the deposition of calcium phosphate into collagen fibrils – is required to maintain the ligament, which anchors into mineralized tissues on both ends. Many researchers in the field believed the process of mineralization is inhibited by glycosaminoglycan (GAGs), long chains of sugar typically attached to proteins. However, Sone and colleagues decided to investigate further.

In order to study the effect of GAGs on the mineralization process, Magdalena Wojtas (postdoctoral fellow and lead author) together with Alexander Lausch (former PhD student) developed a 3-dimensional tissue model to study this phenomenon under a controlled environment. By producing thin slices of tooth and jaw bone interfaces from mice, removing the mineral, and subjecting them to enzymatic treatments that removes GAGs, the researchers can ascertain the effect of GAG removal.

"The advantage of this top-down approach is that it's a closer representation of what happens in the body," says Sone, "If you take a molecule out of context, you often get contradictory results. But in this case, we retained as much of the original environment as we could."

The researchers then treated these tissues with a mineralization solution. Based on the hypothesis that GAGs inhibit mineralization, the researchers expected that the removal of GAGs from the tissues would result in increase the rate in which the minerals are deposited into the ligament.

"We saw the opposite." says Wojtas, "We saw that dentin – a mineralized tissue of the of the tooth – mineralizes at a much slower rate than in controls. That tells us that GAGs are actually playing a role of promoting mineralization in that system."

"We're excited to apply what we've learned about how mineralization is so finely controlled in this biological system to create tissue engineering scaffolds for regeneration of hard-soft tissue interfaces" says Sone. ■

From biomedical engineering to wall street

PHOTOS: QIN (BILL) DAI

A graduate from the Institute of Biomedical Engineering at the University of Toronto (2008), **Dr. Rahul Sarugaser** took an unconventional step away from benchtop science and ventured into the world of investment. Now, he is evaluating investment prospects in healthcare, biotech, and cannabis at a tier-1 investment bank in Toronto. We sat down with Rahul at his office at Raymond James Ltd. to reflect on how he began his journey in Biomedical Engineering, and his transition into a seemingly adjacent field.

What do you do at Raymond James?

I'm a Managing Director for equity research, and I cover healthcare, biotechnology and cannabis.

People don't usually associate biomedical engineering with venture capital. Does your biomedical engineering background apply here?

A lot of questions we ask here are related to biomedical engineering. For example, how do you make a more commercially viable plant? That's genetic engineering. How do you manufacture a chocolate line out of cannabis? That's all chemical engineering. Can you take the plant out of that manufacturing system? Through biosynthesis and bacteria, and that's biotechnology.

My strength lies in my ability to harness my background in engineering, medicine, formulation, and chemical engineering, all the stuff that I learned in Biomedical Engineering at University of Toronto. These are the skill sets that I'm now embracing, to set myself apart as a unique equities analyst on Bay or Wall street, compared to most of my counterparts who mostly come from a financial background such as CA's and CFA's.

Why is having a different perspective/background important in your role?

When I was in venture capital, understanding technology was extremely important. It makes the difference between a company that's going to succeed or fail. When you look into more mature companies, that are now on the capital markets, they are already in phase two clinical trials and beyond, meaning commercial or close to commercial. The technology is always evolving, and needs to be continuously vetted; that's where my science and engineering background comes in.

An example is the cannabis sector, which has been a real boon for the Canadian economy. It is going to become a commodity like gas or lumber. We know that cannabis plant is composed of chemicals like THC, CBD, and terpenes. If we can manufacture these chemicals in E. Coli or yeast in fermenters or extract terpenes from fruit production, one can make the end product for 10 cents on the dollar in comparison to what it would cost to make it from a cannabis plant. Being one of the few analysts on Bay or Wall street to understand this process is highly valuable.

The ability to think critically, creatively, and the ability to think about harnessing technology in different spaces is really important here. I was fortunate to hone these skills at BME.

How did you make the transition from sciences to capital markets?

I graduated from my PhD in the summer before the financial crisis, in early 2008. After completing business school at Oxford, it was because of the connections I made in BME at UofT that landed me a fantastic spot working at MaRS. I started at MaRS with a venture capital fund, and within five months, was recruited to the Centre for Commercialization in Regenerative Medicine (CCRM) that was founded by Drs. Peter Zandstra and Michael May. I was employee number three, and spent almost five years with Zandstra and May building CCRM from a start-up; by the time I left, CCRM was on its way to about 100 people.

At CCRM I had the opportunity to engage with the Canadian venture capital community, and was fortunate enough to build a great network on the industry side too. We worked with companies like Pfizer, GSK and several big pharmaceutical companies, right through to small biotech firms. It really was a unique opportunity to watch the landscape of commercial development right from startups to mature pharma companies, and get to engage with people all along that spectrum. That was almost the perfect training ground to graduate into capital markets.

What do you think is the identity of a biomedical engineer?

One of my favorite things about biomedical engineering is that its phenotypes are so diverse. BME is composed of electrical engineers who are involved in developing prosthetics and AI, all the way to my background, which is molecular biology and drug development. What was beautiful about BME was that I interacted with peers and other students from various backgrounds. That was one of the biggest strengths of biomedical engineering. The lessons one learns and the fundamental training you get is so broadly applicable and that is what really makes it special.

I am a huge fan of UofT, the Institute, the people and the environment. But I would say that checking these boxes is not an automatic ticket to success. These components give one the foundation, but it's up to the individual to take that and use it as a springboard to seek out other opportunities.

Knowing what you know now, do you have any advice to future students?

My PhD supervisor (John E. Davies) always uses this expression. "One volunteer is worth 10 indentured persons." It's been a philosophy that I've embraced as I've grown in my career, and as people have come to me for advice or mentorship. That's something that I've always learned to appreciate. Someone who is enthusiastic and is willing to fight uphill to get something, has a much higher likelihood of success than someone who had it handed to them.

So, the one lesson that I share with most people is that, while intellectual horsepower is extremely important, gumption is equally important. ■

From researcher to product engineer

PHOTO: SURATH GOMIS

Graduated in 2019 with a PhD in biomedical engineering, **Dr. Peter Aldridge** continued his passion in developing and engineering novel therapeutics for stem cell therapies at BlueRock Therapeutics in Toronto. Here he shares some of his insights on applying biomedical engineering concepts in an industry position.

What do you do at BlueRock Therapeutics?

I'm a product engineer at BlueRock. Our mission is to create a new class of cellular medicines derived from stem cells. We're taking cells that have been differentiated to match a native cell type, and then injecting those cells in order to restore function lost due to a degenerative disease. Our lead program is Parkinson's disease, where we are trying to deliver dopaminergic neurons to the brain. We also have active cardiology and immunology programs.

The job of the product engineering team is to develop medical devices to prepare and deliver those cells. Unlike traditional therapeutics, where the drug is a chemical compound, we're injecting live cells, which means there are some additional considerations to take into account. For example, these cells will be frozen before they're shipped to hospitals, but will need to be thawed and loaded into a delivery device prior to injection, and we have to do this while maintaining aseptic conditions and without stressing out the cells too much. There are also a lot of variables that can change depending on the organ we're delivering to; the brain and the heart each present totally different environments to the cells. So we're constantly working on new prototypes to make the delivery process as simple and effective as possible.

What did you do for your PhD?

I did my PhD work in Prof. Shana Kelley's lab, designing microfluidic devices to sort cells. My first project was a device to isolate and sort circulating tumour cells (CTCs), which are shed from solid tumours into the bloodstream. Being able to isolate and analyze CTCs in a blood sample provides a way to monitor disease progression in a less invasive way than a traditional biopsy. The challenge is that a blood sample might only have a handful of CTCs amongst a few billion healthy blood cells, so isolating the CTCs becomes like trying to find a needle in a haystack.

In our case, what we did was use antibody-labelled magnetic nanoparticles to target surface proteins that were likely to be found on cancer cells, but not on blood cells. Then, you can basically use a magnet to pull the magnetically labelled cells out of the blood sample. We took that principle and used a microfluidic chip to sort CTCs based on how magnetic they became after labelling. The idea being that if you could identify surface proteins that were indicative of a particularly metastatic phenotype, then you could analyze patient blood samples as a prognostic indicator or to drive treatment decisions.

After studying mechanical engineering as an undergrad and a master's student, I always saw myself as an engineer first and scientist second, which made BME a really great place to work. While my main focus was to design and fabricate microfluidic prototypes, I got lots of exposure to cell biology and working in a wet lab alongside some really talented people.

What skillsets did you find to be useful and transferrable from your graduate studies?

I like to break this down into two categories: communication/writing and technical skills.

Planning experiments, writing reports, presenting data, making figures, analyzing results, etc., all that stuff I find to be just as useful in an industry setting. Just like if I was writing for an academic journal, I need to be able to communicate to the rest of the company what experiments I've been working on and what the results were, so that we can decide what's working, what isn't, and what to do next. My PhD helped me develop a lot of those skills.

On the technical side, I draw on the lab work I did at U of T all the time. For example, I doubt I would have been hired at BlueRock if I didn't have some background in cell culture, microscopy, or some basic knowledge of gene editing techniques, all of which I was exposed to for the first time when I was a PhD student. I'm still designing and testing devices that act on cells in some way, so in that respect there's a lot of similarities between what I did for my PhD and what I do now.

What advice would give to prospective and current students in biomedical engineering?

PhD is a lengthy process, so you have time for diversions, side projects and outside interests. Even projects that didn't culminate in a publication ended up being beneficial to me in the long run. Don't be afraid of investing a few months here and there to learn a new skill, work on a side project, or pursue something different. ■

Common thread – from sewing to developing wearable technologies

PHOTOS: QIN (BILL) DAI

Dr. Amanda Fleury took up sewing as a hobby during her undergraduate years, not knowing it would become the common thread that would connect her PhD research to her job prospects. Graduated in 2018 from Dr. Tom Chau's lab at BME, Amanda spent majority of her PhD researching brain-computer interfaces and various cloth materials that could be applied to commercial products. Now, Amanda is leveraging her biomedical engineering skills to develop wearable technologies for meditation.

↓ Muse S headband (Photo: InteraXon)

What is your role at InteraXon?

I'm the product engineer here at Interaxon. I am responsible for designing a headband for the third generation MUSE product line, which features a wearable soft fabric.

What is the MUSE headband? Which part did you work on?

It records your brain activity and gives you biofeedback during meditation. It provides information on the state of calm or focus in your mind via sensors located on the forehead area. When worn, the electronic components measure brain signals and connects to your phone via a meditation app. With your earbuds you hear the sounds of a soundscape as you're meditating. The soundscape gets stormy as your mind wanders away, and then gets calmer as your mind comes back to your point of focus. It's about giving you feedback so you can self-correct.

Main benefit of Muse S over Muse 2 is the soft material form factor, which makes it much more appropriate for sleep and pre-sleep meditations. When I first joined the company, we just started the ideation on this product, and I was responsible for making the textile headband. I believe I made 20 different prototypes to encapsulate different user experiences.

How did you end up at InteraXon?

I did my PhD in Tom Chau's lab and worked on fabric-based sensors. The research was primarily focused on Brain Computer interfaces and enhancing communication opportunities for kids with disabilities. So it was a natural transition from my PhD to industry.

At Tom's lab I designed and built wearable solutions to fit a variety of communication needs. I also have an interest in fashion and sewing, so that skill set definitely came to be of help during my PhD. We were asking questions like what would the technology look like? How could we incorporate sensors? What kind of material should we use?

It started out with a year of talking to kids with communication challenges and their parents to gauge the need, and coming up with tailored solutions for individual cases. We got a whole bunch of ideas and I ended up with six years of work that ended up becoming a PhD.

What is the identity of a biomedical engineer?

There's a huge amount of diversity in the skill set of a biomedical engineer, especially coming out of a program like BME where the research is so broad. With that said it's really difficult to summarize us with a broad stroke. I originally thought biomedical engineering was mostly prosthetics research, because that was my vision for helping people with disabilities. But at U of T I find that biomedical engineering is only part of the equation. I think it's super useful to get that broad perspective and to see what other people in the field are doing.

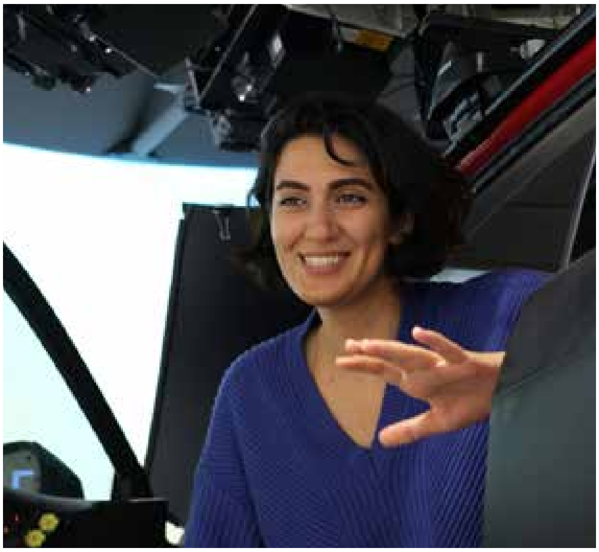
What advice would you offer students who are transitioning into industry?

A big part is recognizing the value of the skills that you do have and not undervaluing or underselling your graduate degree.

There are two sets of skillsets that I find valuable during transition. There are industry agnostic skills that anyone going for graduate school will get, things that if you hire anyone with a PhD you know that you're getting, skills like communication more specifically scientific communication. Being able to write papers to communicate experiments and the science that you've done. As a PhD student it's easy to get narrowly focused on your own area of research and not take the blinders off. But working at a company, there's a lot more sort of cross pollination of ideas. This is where communication becomes extremely important.

Then there are specific scientific and technical skills. For my PhD, I sewed majority of my own sensors and incorporated them into working prototypes. After coming to InteraXon, I hand built 90% of the prototypes for Muse S. That skill set was super important, and having an understanding electronics, such as how to set up a circuit and knowing how to troubleshoot when things went wrong, was also crucial. ■

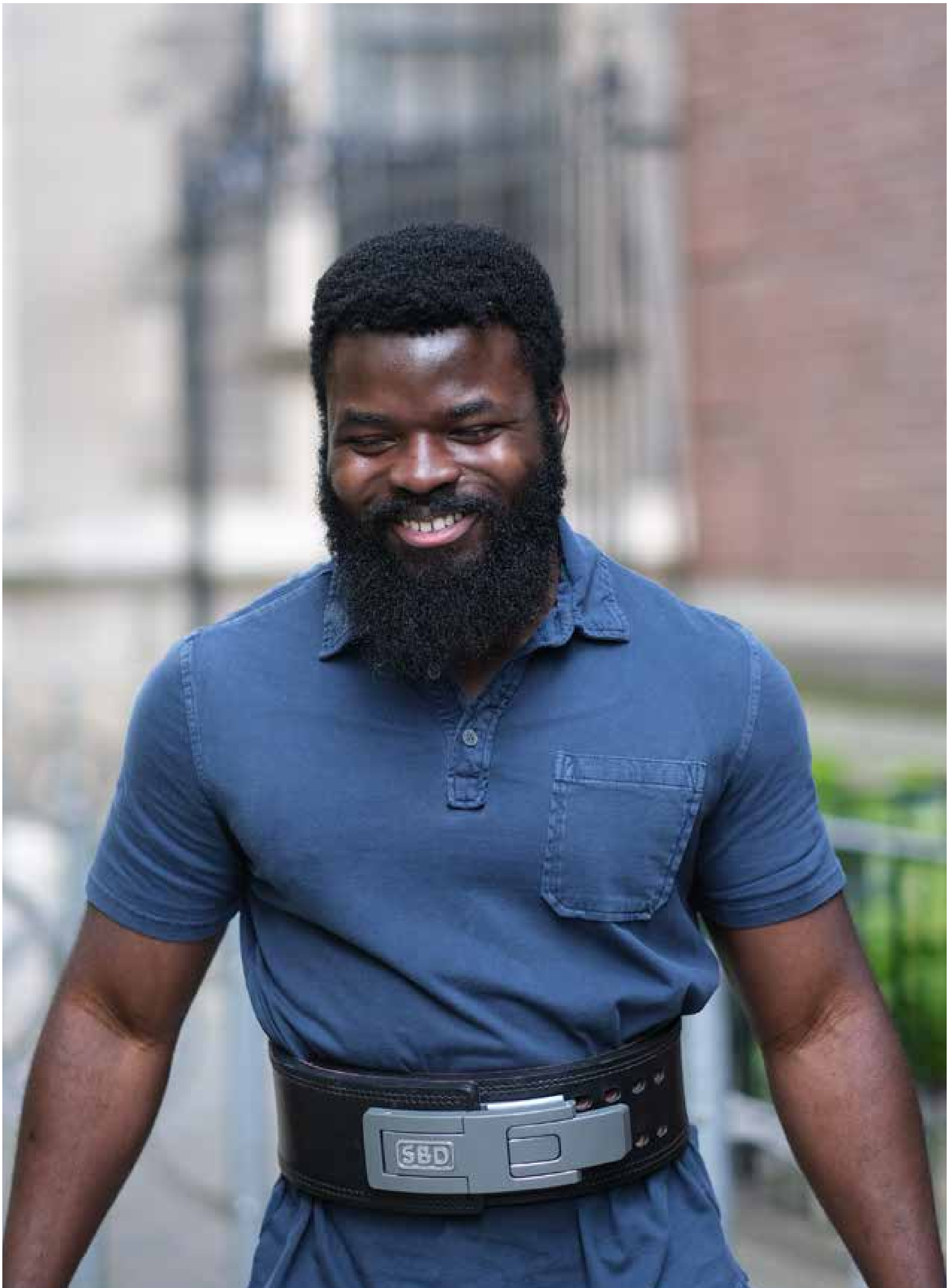
This interview was conducted in March of 2020, prior to the COVID-19 quarantine. Amanda has since moved on from InteraXon and is currently completing a data science fellowship with Insight Data Science. She is looking for opportunities at the intersection of data science and wearable technology.



FACES OF BME

PHOTOS: QIN (BILL) DAI

We sat down with several Biomedical Engineering graduate students and talked about what motivates them outside of their labs.


SBD

Abdulmateen A. | MASc Candidate | Leo Chou Lab

Powerlifting gave me a venue aside from research to pursue objective measures of progress and success.

Numbers do all the talking. If you are squatting 200 pounds one day, and then a couple of weeks later you're squatting 300 pounds, you know you've improved.

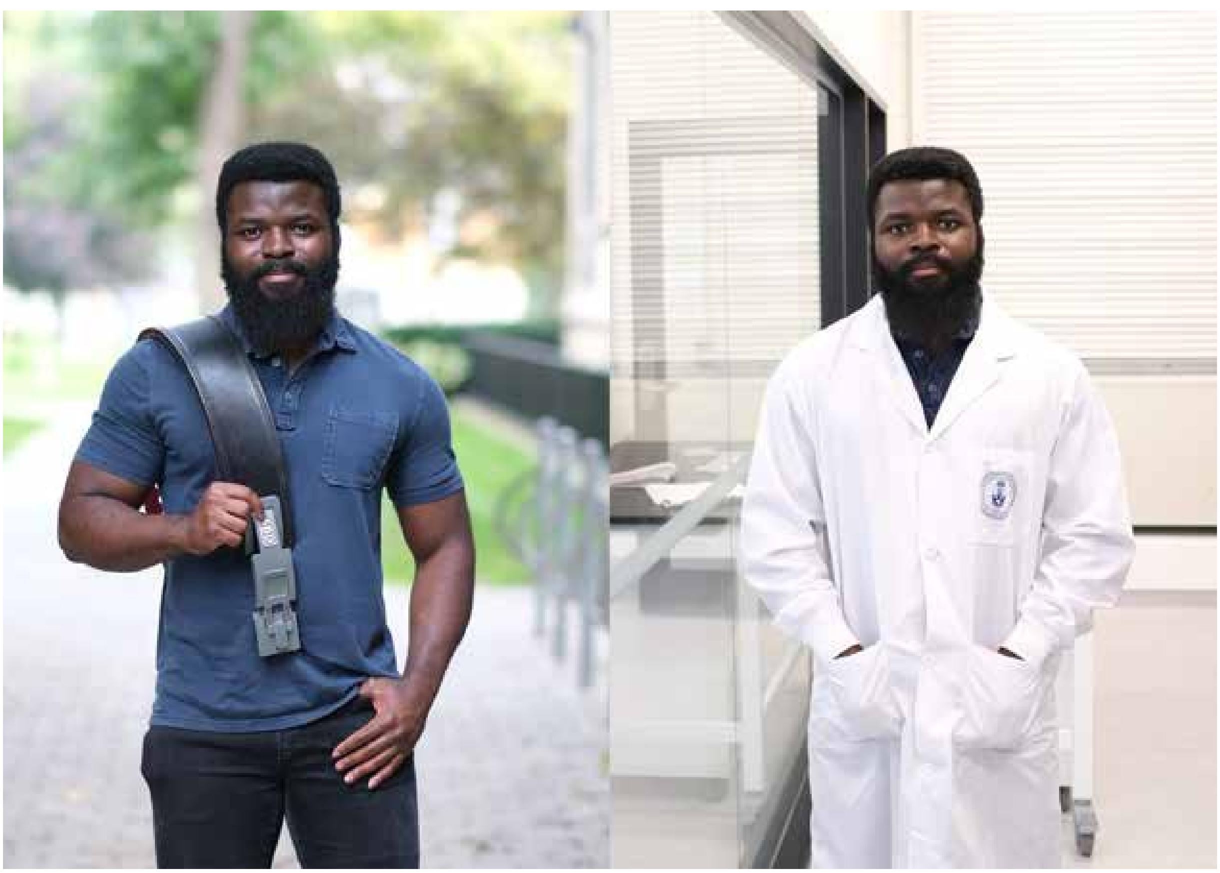
↓ Photo courtesy of Davis Tang


SBD

Strength training and research are similar because they are both methodical and there's a progression system. In weight training, most people start off with a linear progression, adding maybe five pounds each week, but at some point, they stall because the stimulus just isn't sufficient for their body to adapt and getting stronger. I'll then have to find ways to condition the body to respond to the same stimulus. That often takes quite some effort.

Powerlifting is very detail oriented, and it's similar in science as well. Note taking, writing out protocols, recording data and everything is emphasized to notice sometimes significant but non-obvious trends. These are things required in both lifting and science.

With lifting, if you really want to succeed at the highest level, you have to pay attention to the details. Things like technique, sleep, nutrition, and training load are all important factors to consider. For example, we would track the exact poundage that I was lifting per week, the level of exertion it required per set, and how these variables changed over time in order find the right combination of stimuli to increase my strength.



Sayeh B. | PhD Candidate | Alex Mihailidis Lab

My grandmother was diagnosed with dementia around the same time that I started my research career at the Toronto Rehabilitation Hospital. It made my research more personal.

For my PhD thesis I'm developing an assistive system that uses artificial intelligence to enhance the lives of people with dementia. People with dementia, even at early stages, often get disoriented or lost. I am developing intelligent navigation assistance to help them navigate safely and independently in the outdoor environment. What we want to do with this is predict future mobility patterns, and in case they unintentionally diverge from their original destination we can provide some form of intervention to guide them.

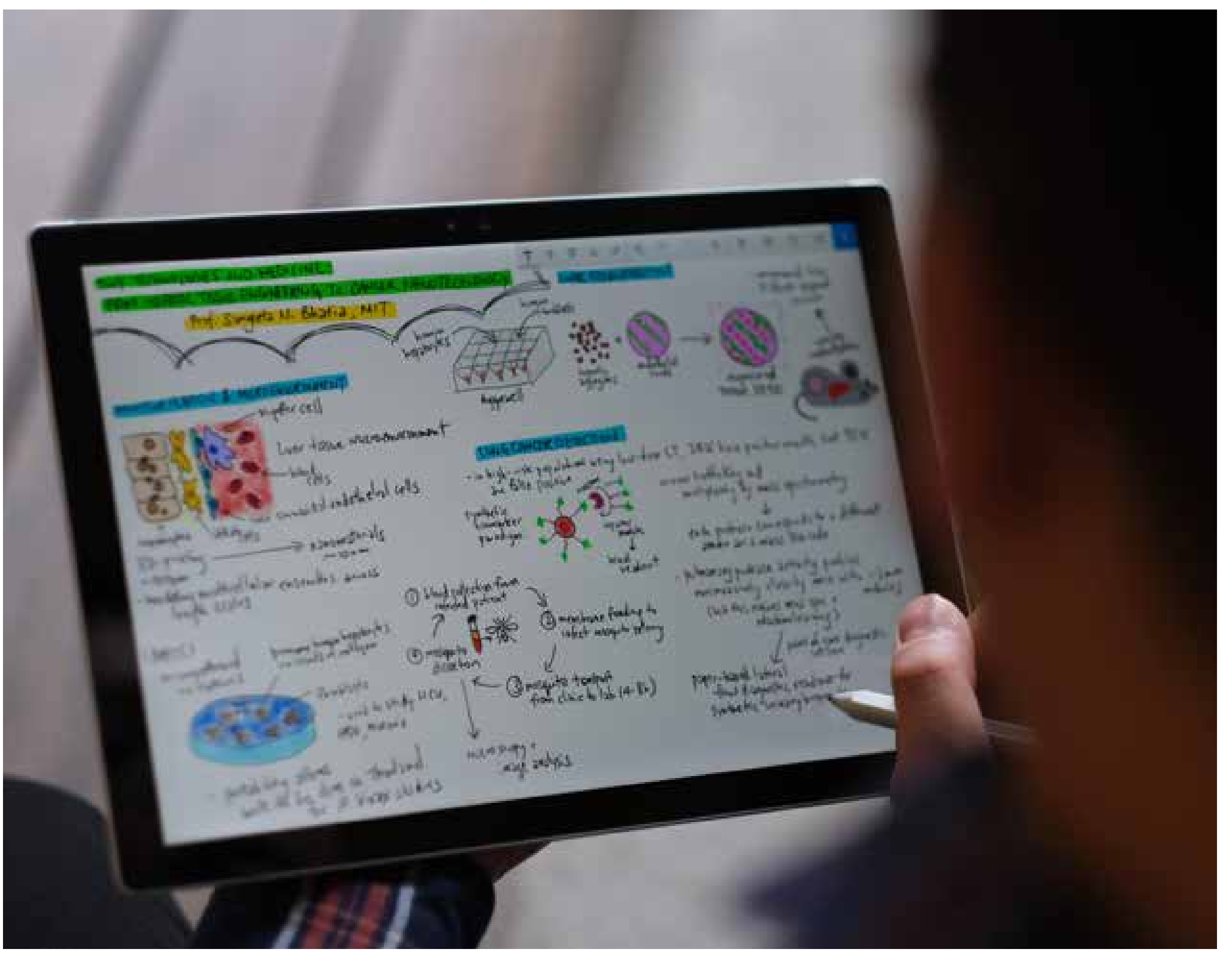
Growing up, I was always ambitious and competitive; perhaps that's what got me interested in engineering in the first place. Engineering is exciting and challenging. It affects all of our lives in a form, whether it's biomedical engineering during a surgical procedure, or aerospace engineering when travelling to another continent. That's why we need greater diversity in the field; we need to better represent society.

There's a lot of implicit bias about a female engineer. I think it's important for the younger children to have diverse role models that they can look up to, to see what the next stages of their lives can look like.

For me, the most rewarding part of my research is working with people. We work with doctors, patients, and researchers from different disciplines. Understanding the needs of each party allows us to design better technologies.

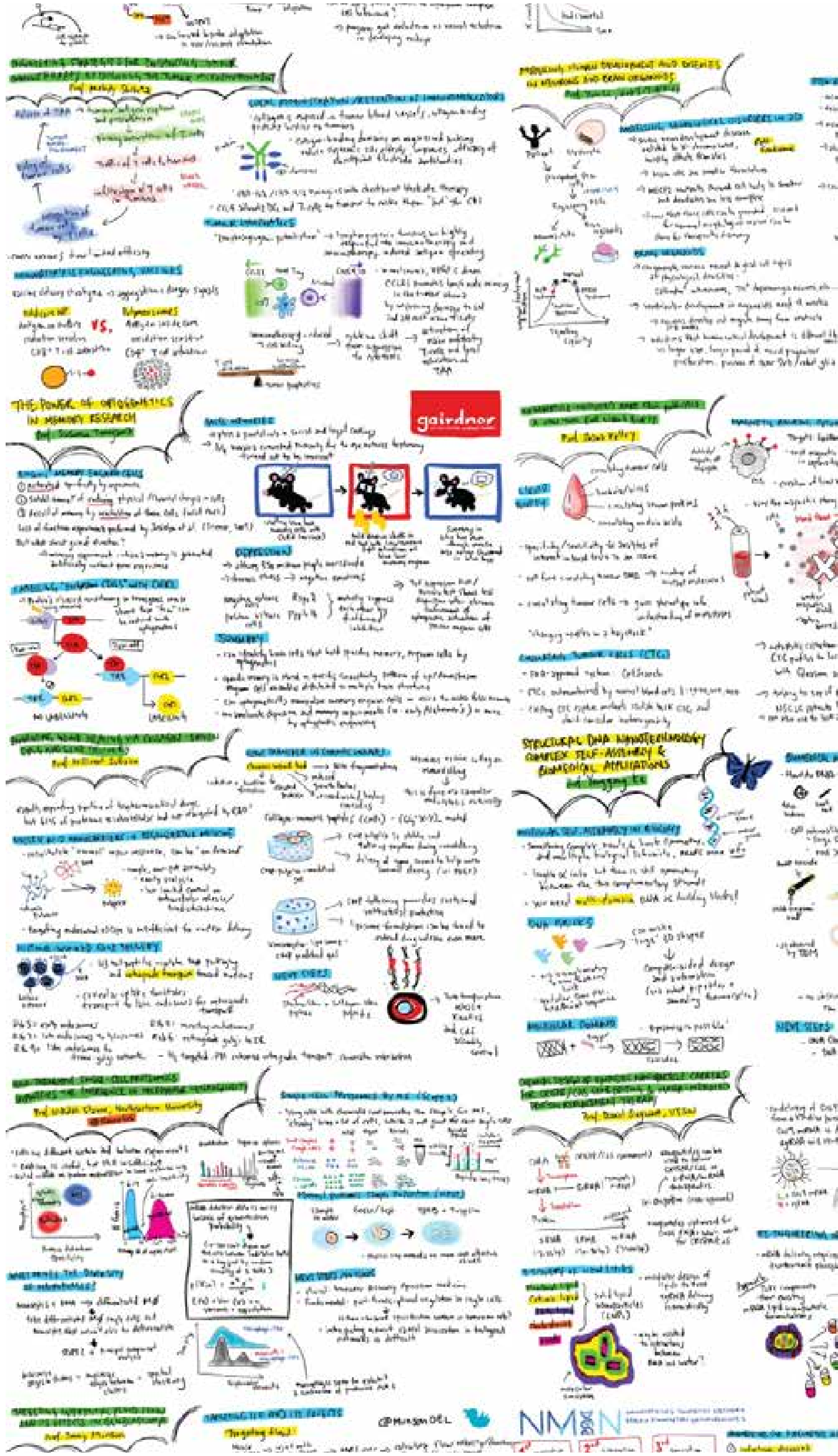
Wilson P. | PhD | Warren Chan Lab

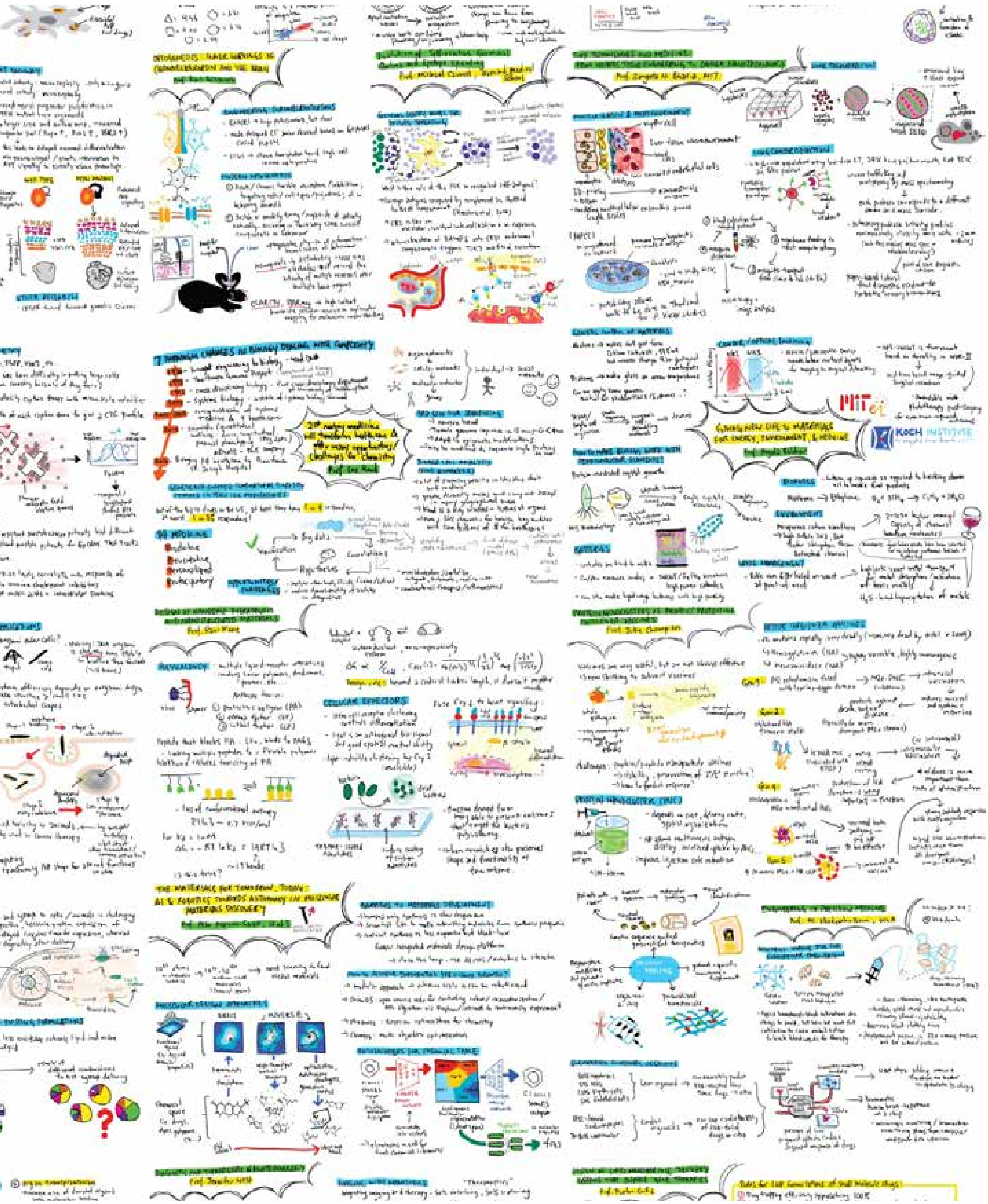
I first saw this type of scientific communication on social media, like Twitter. I thought it would be an interesting tool to summarize someone's research talk in a graphic format.



We are living in the information age, and there's really no shortage of information out there. A research talk is typically about an hour long, and my goal here is to condense that into an informative summary. Hopefully that makes it more digestible to the audiences.

Science communications comes in many different forms. Some utilizes social media, some writes editorial pieces, and I summarize research in infographics. The ultimate goal is to bring awareness and educate the public about scientific research. There's no rigid formal format to present science only in peer-reviewed articles.





KOCH INSTITUTE

Melissa & Melanie R. | MEng Candidates

We're best friends. We have similar personalities, which is why we both ended up in BME. We were drawn to the MEng program at BME because, unlike most master's programs, it was project-based. The internship allows for course-based knowledge to be applied practically.

We're trying to live our best life in Toronto. It's not like the East Coast, but there's a lot to do here.

With our positive psychology course, we had to go on adventures every week and then write about them and bring it back to what we're trying to improve in ourselves. So we did different things. I [Melanie] did an improv class at Second City, we went to the Christmas market, we saw the Nutcracker and we went to eat in the dark at Onoir, you know, that's just a bunch of things that you wouldn't really get to do so we're just trying to do that here.

Denis M. | MASc Candidate | Gang Zheng Lab

I made a name for myself on the Junior Grand Prix circuit. It's an international competition before the senior stage of top-level skaters. Once I started competing on the Senior world circuit, I was making grand strides and making the podium at international competitions, landing all the triple revolution jumps including the triple axel. This allowed me to qualify for the World Championships in 2016 which would be crucial to help with the Olympic qualification process.

I was born in Argentina, where obviously figure skating is not a popular sport. If I stayed down there all my life, soccer would have probably been my main athletic passion. But at the age of three I moved to Canada, and with my parents' rich athletic background, they put my brothers and I in all kinds of sports to stay active and teach us good life habits. My mom came to the eventual realization that since we were now in Canada, one of the sports we had to learn was skating. Especially since it was considered a hockey country after all.

When I am on the ice, it feels as if I am flying. Where I can glide effortlessly through the air and just escape my worries for a short while. The ice is a place that allows me to be complete, and always has, and always will be, a home away from home.

I decided that I wanted to take a bolder step and actually get into a field of research where I could apply, make and discover something that could be utilized in the real world. That was my main incentive for stepping out of my comfort zone from my physiology background and applying to grad school in biomedical engineering.

Academia was always a big part of my life, as I treated it just as important as my athletics. That's why it was difficult when I had to decide whether to accept my university offers after competing at the World Championships, as it would mean an end to my Olympic dream. However, a devastating ankle injury was my tipping point in making my choice to hang my skates away from the international competitive scene and focus onto the education route. But because of this decision, I ended up learning

many valuable life skills, develop into the leader I am today, and meet many great people who I now get to call some of my closest friends. Looking back, I can definitely say I don't have any regrets.

Coming from Western University, it was a bonus for me that the University of Toronto had a figure skating team here as well, and a strong one at that. I feel like I still have a little bit left to give to the sport of figure skating, so I decided that I would try out again for another season or two. When will my drive to skate competitively end? I'm not sure. All I know is that for the time being I will let skating continue in being my peaceful escape and let the skating arena be the place where I hope to make more art on the ice.

A good lesson I've learned through my experience with research that connects well with what I've learned with skating is that, whether you start a sporting season, or a research project, you prepare both with a set of goals in mind that you aim to accomplish by the end. Although you hope for that path to go smoothly, most of the time it won't, as there will be bumps and obstacles in the road. Whether that's an injury, if we're talking about sport, or a series of unsuccessful experiments, if talking about research, it's important to know that it won't always be straight forward. Setbacks give us a chance to learn from such an experience, to take a moment and reevaluate before proceeding further with a different approach and a different mindset. This then ultimately grows our confidence and our character, leading us to that end goal and glory that we have long desired from the start.

← (BOTTOM) Photo courtesy of Danielle Earl.

Shabnam H. | PhD Candidate | Alex Mihailidis Lab

I studied Electrical Engineering in undergrad abroad. Contrary to the representation we have in BME, we had only two female faculty members in my university's department at the time. So, each time I hear about a success story of a women in STEM, I get genuinely happy – it reinforces my sense of belonging, which is something I might have lacked during undergrad.

When choosing my undergraduate major, I was torn between Software and Electrical Engineering. Most advices I got to help with this decision was that "Software Engineering is more suitable for a girl". So, I chose Electrical Engineering. Certain stereotypes should never stop anyone from pursuing something the enjoy.

I could have not predicted that I will be working with automated vehicles as a biomedical engineer. At the same time, my notion of biomedical engineering has always been about using "engineering" to improve human health and quality of life. So after all, it makes sense that my PhD project is about using one of the most sophisticated achievements of the field of engineering to improve older adults' quality of life.

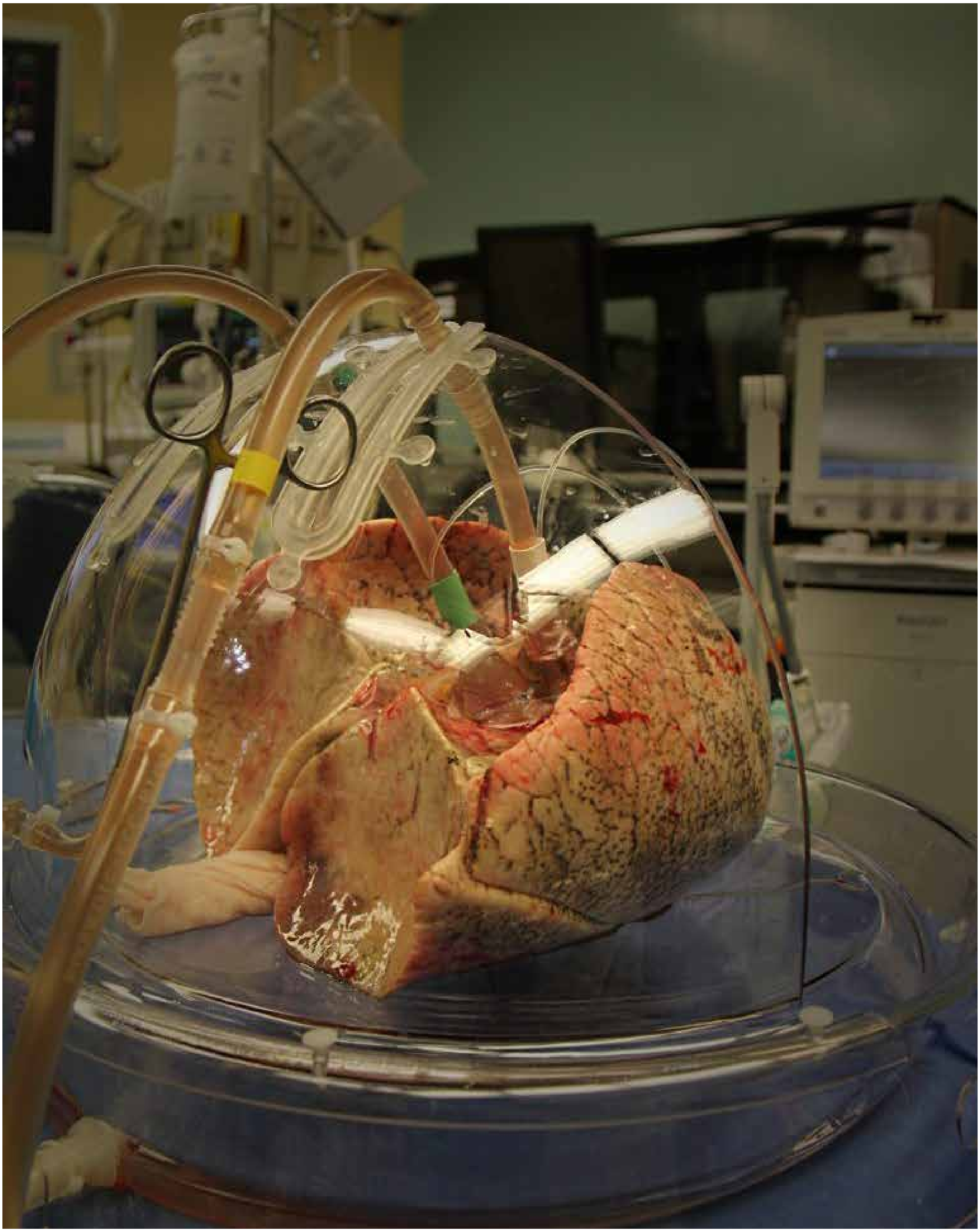
I work in a lab that is all about assistive technologies, using assistive technologies for older adults or individuals who may have impairments. The idea behind my project is about using automated vehicles as an assistive technology that can potentially improve the quality of life experienced by older adults living with cognitive impairments. The idea is to use a sophisticated technology not just as another awe-inspiring piece of tech, but to do people good.

Sometimes as a scientist what you talk about may sound like science fiction – my project certainly does sound so to some. But I think such "high-risk" projects are not that high-risk and are/should be a critical part of research. If nothing works out and we realize that these automated vehicles cannot generally be used by individuals with cognitive impairments, then we have a cautionary tale to tell that, and this in turn may make future designers of such vehicles think about solutions. At the end of the day, these vehicles may just not have been designed for the individuals with cognitive impairments, so we need to start by identifying those areas of mismatch to build on them.

For me science has always been about contributing to something more than yourself to make a change. ■

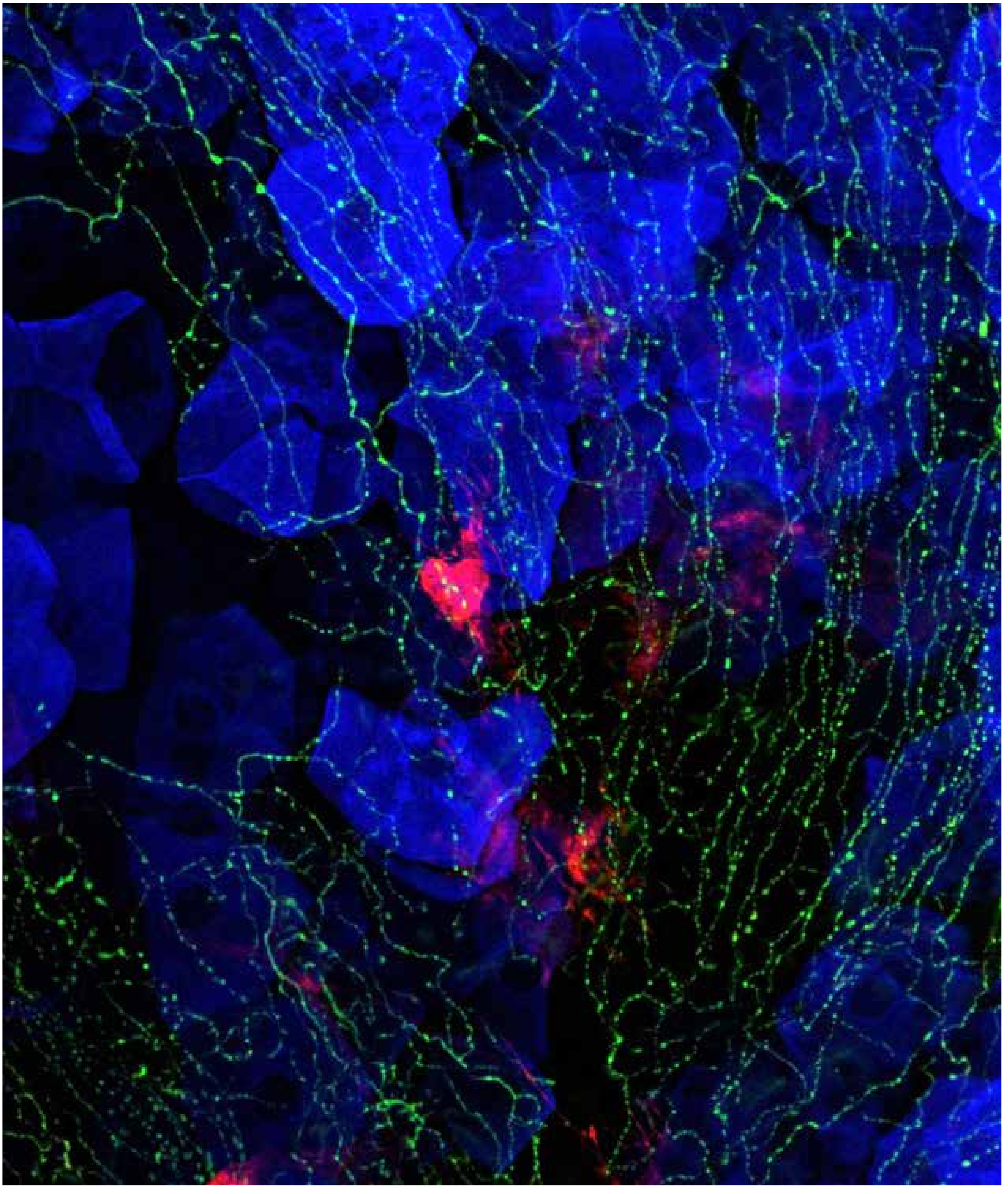
Research Gallery

Here we curated some research image submissions by researchers within our community.



BONNIE CHAO
SHAF KESHAVJEE LAB

From Concept to Clinic.

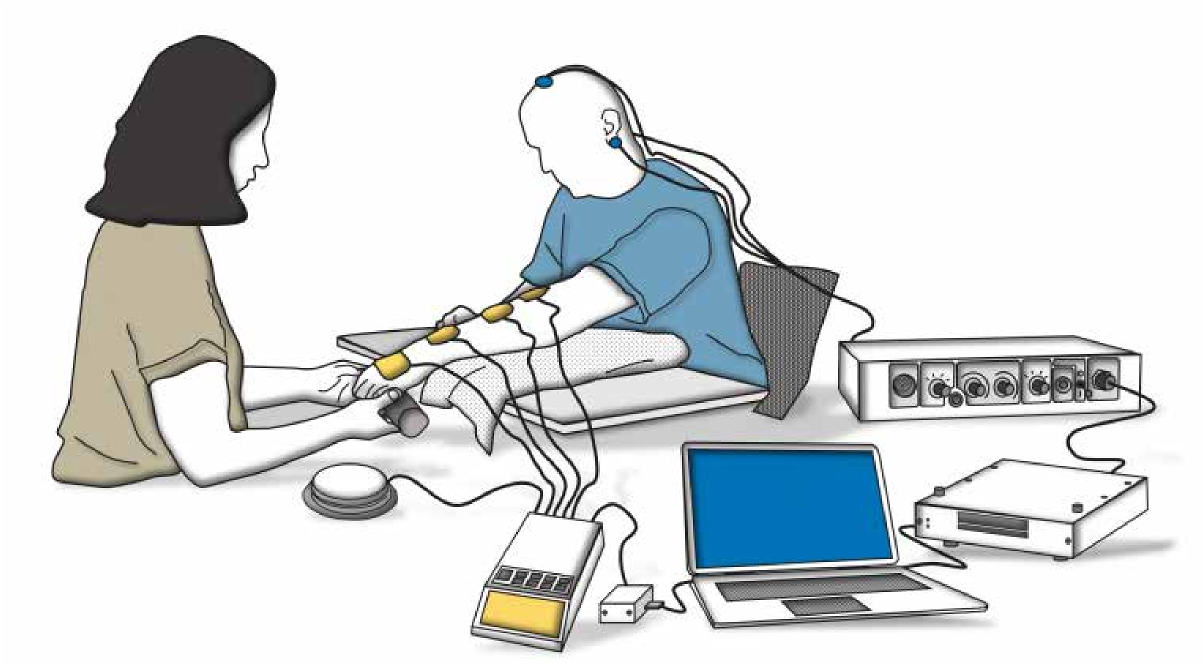


SEYED KAVEH MIRMOEINI (TOP)
GREGORY BORSCHEL LAB

The image of center of cornea. color green is axons, blue is stem cells, red is Schwann cells.

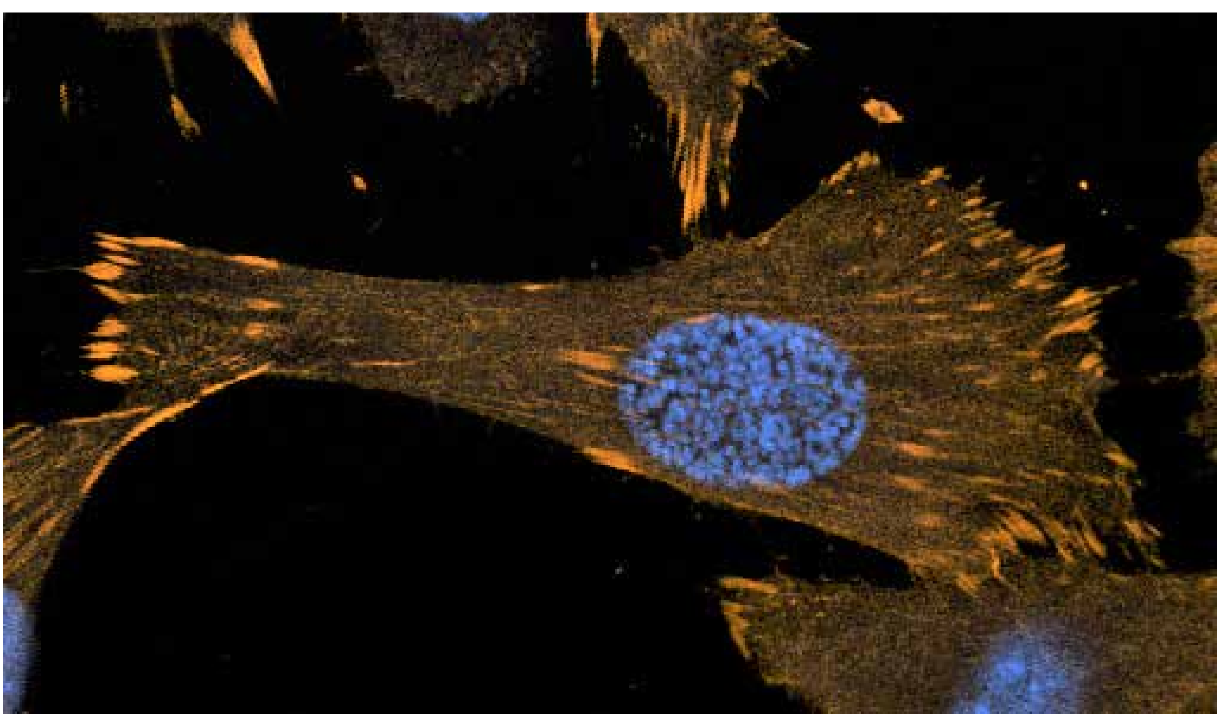
JO NGUYEN (BOTTOM RIGHT)
PENNEY GILBERT LAB

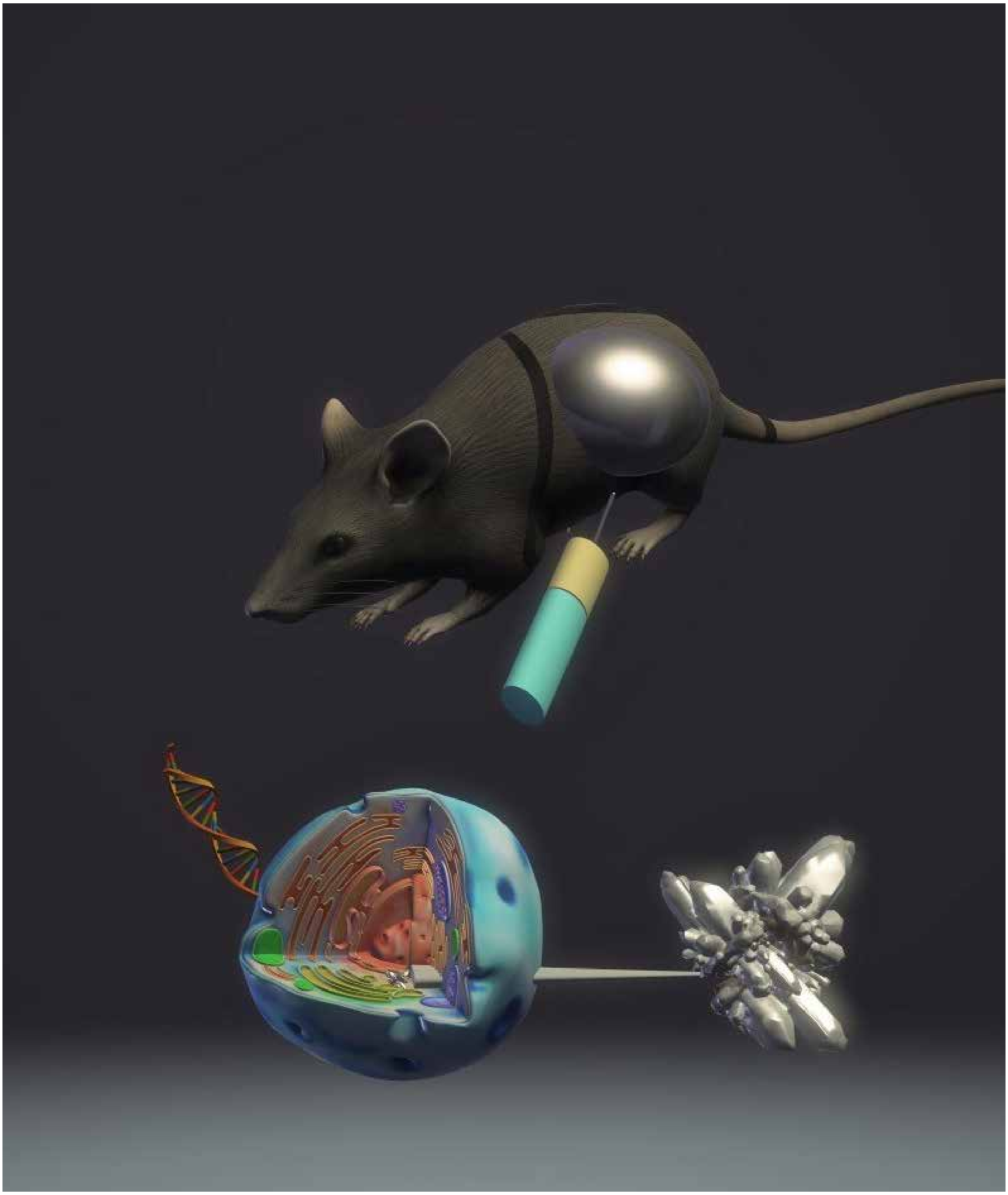
Mouse muscle stem cell focal adhesions (orange) and nucleus DNA (blue).



LAZAR JOVANOVIC (TOP)
MILOS POPOVIC & CESAR MARQUEZ CHIN LAB

The concept illustration of the brain-computer interface-controlled functional electrical stimulation therapy, or BCI-FEST for shorter. BCI-FEST is a novel rehabilitation strategy for the recovery of voluntary arm and hand motor function after stroke or spinal cord injury. The therapist (left) guides the patient (right) in performing functional movements assisted by electrical stimulation. During therapy, the patient uses the BCI to control the stimulation with their electrical brain activity.



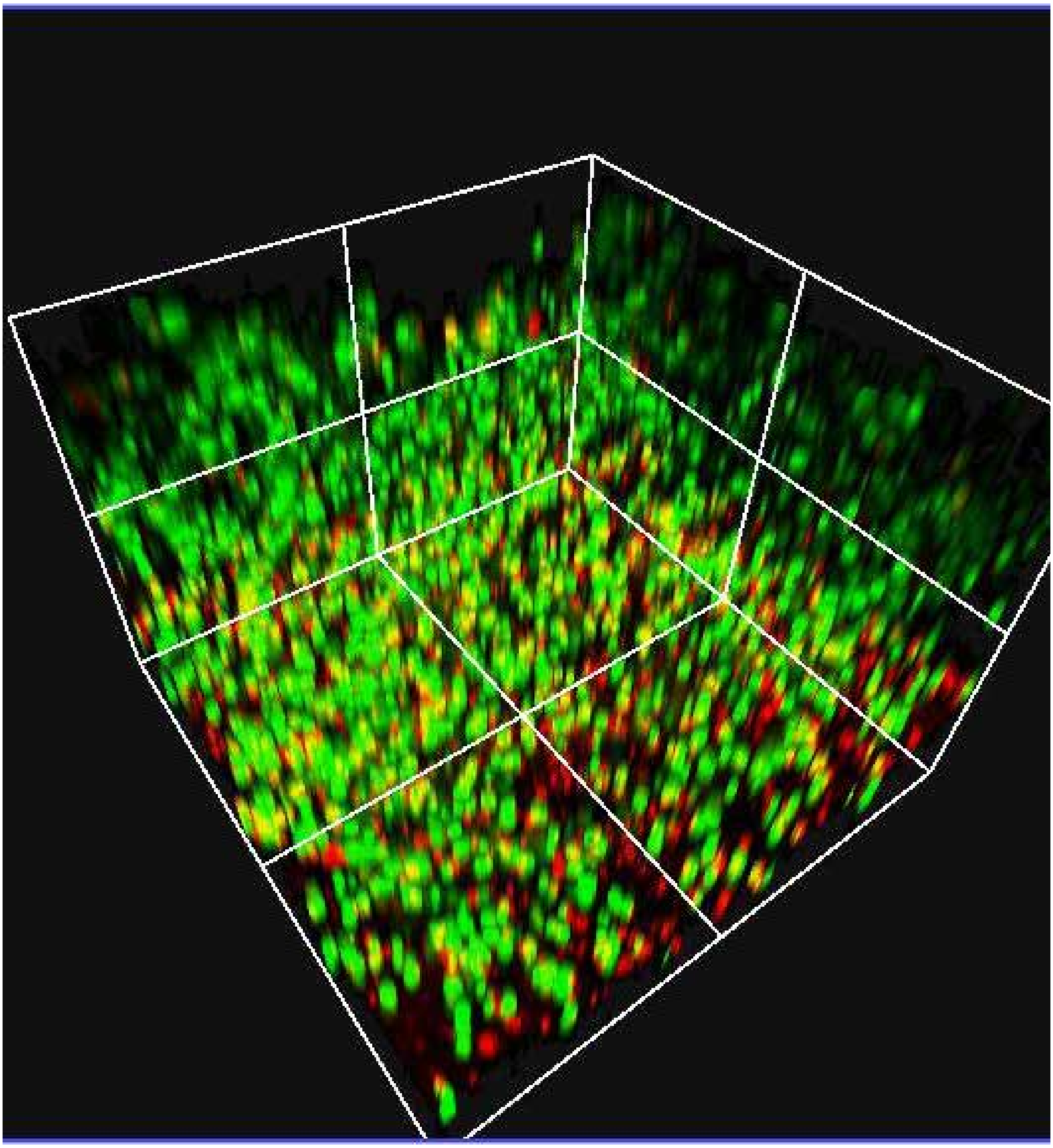


MARGARET HAI-LING CHENG
MARGARET HAI-LING CHENG LAB

In-vivo cellular assembly of magnetic particles for bright-contrast cell tracking on MRI.

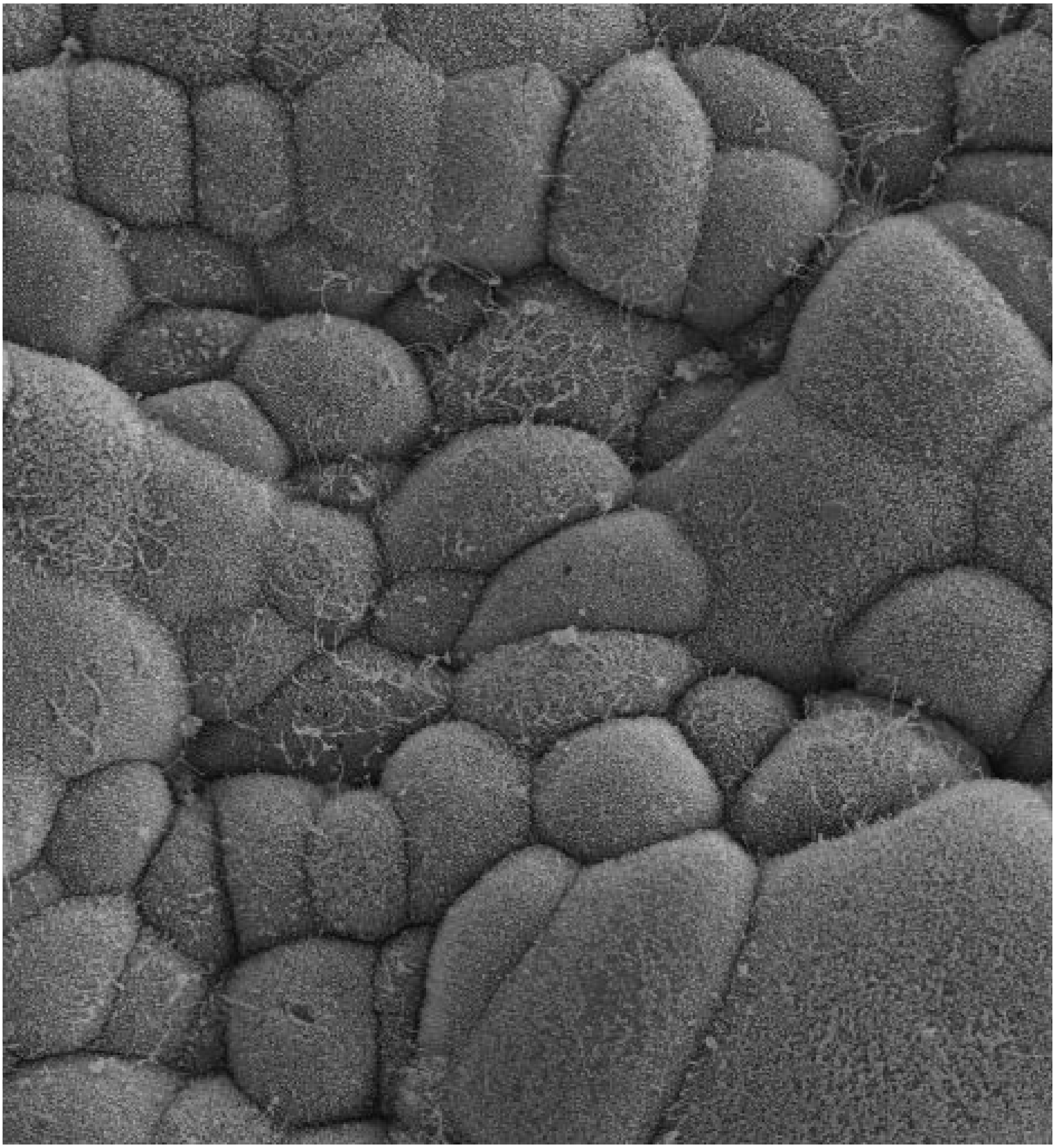
JAMIE WU
WARREN CHAN LAB

Gold nanoparticles are taken up by an immune cell inside a tumour microvessel. We are looking at the cross-section of a microvessel inside a mouse melanoma tumour. The image was acquired using an electron microscope that provides sub-nanometer resolution, so that we can visualize where our gold nanoparticles (the black dots) are located. Here, the nanoparticles have been "eaten" by an immune cell and are stored in organelles called lysosomes. Around them are endothelial cells forming the vessel wall, outside of which is the cancer tissue. Techniques such as electron microscopy help us study how nanoparticles interact with the biological system.



SADI LOAI
MARGARET HAI-LING CHENG LAB

A 3D bioprinted cellular scaffold that can be detected through non-invasive MRI imaging post-implantation. The green dots represent live cells and the red dots represent dead cells. The scaffold is labelled with a contrast agent that gives off a bright signal when imaged by MRI.



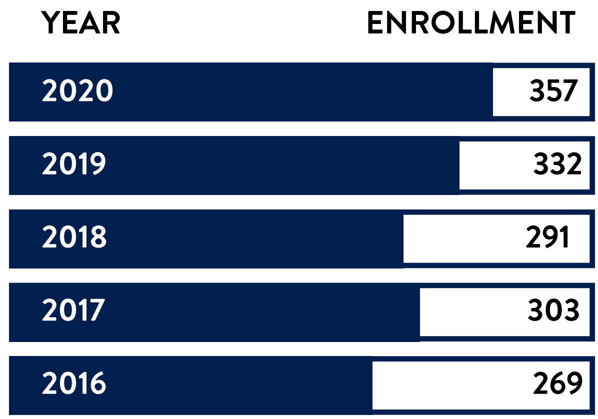
SIWAN PARK
EDMOND YOUNG LAB

Airway epithelial cells were cultured on a suspended hydrogel that is integrated into a channel of a microfluidic device. After precisely controlled airflow was exposed on the cells, cells began to grow cilia that mimicked the native airway epithelium. The image was taken with a scanning electron microscope. (Magnification: 5000x)

YEAR IN NUMBERS

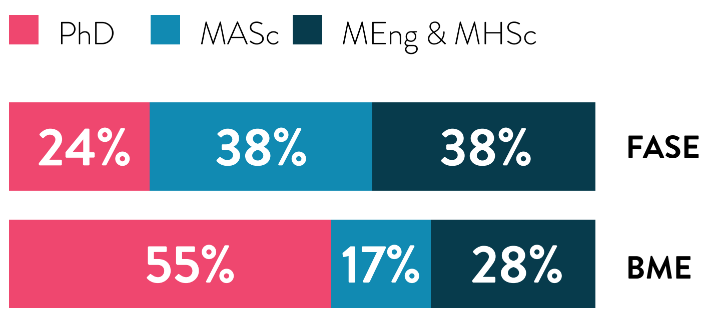
Enrollment Trend

BME graduate student body has been experiencing steady growth in the past 5 years. At the beginning of 2020 academic year, the graduate body experienced a 8% growth compared to last year. The numbers shown represent the number of students registered in our programs as of September of every year. The numbers were collected on December 7, 2020.



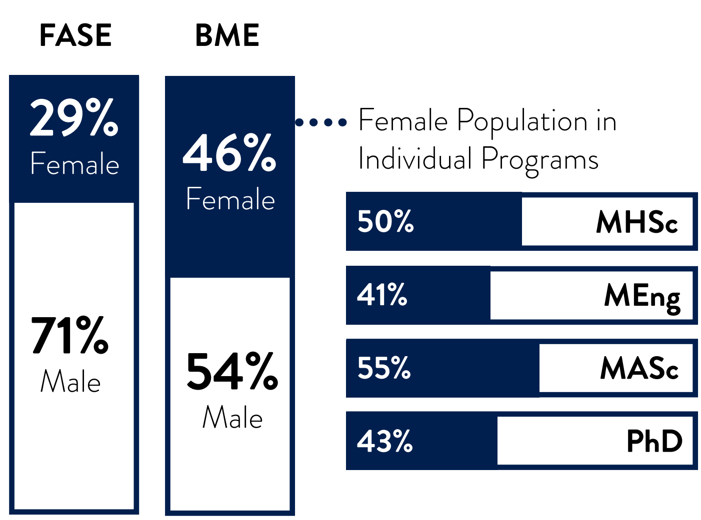
Enrollment Breakdown

BME is one of the leading research intensive units within FASE. Approximately 55% of BME's graduate population consists of PhD students in 2020. Comparatively, FASE averages 24%. The BME numbers were collected on December 7, 2020.



Gender Distribution

BME has a balanced female to male graduate student body ratio. All data is self-reported during registration. The numbers from BME was collected on December 7, 2020.



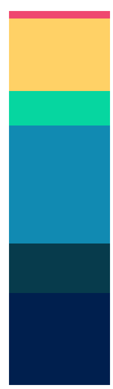
Graduation Summary

The graduation number is similar to the last 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. The numbers from the 2019-2020 academic year was calculated from adding 2019 September, 2020 January, and 2020 May sessions. The numbers were collected on December 7, 2020.

YEAR	GRADUATED
2019-20	90
2018-19	97
2017-18	63
2016-17	47
2015-16	43

Graduation Breakdown

Graduate proportion is similar to the current student body breakdown, indicating a balanced exit rate amongst students within each program. Bracketed percentages indicate the proportion of students out of 90 total graduates in 2019-2020. The numbers were collected on December 7, 2020.

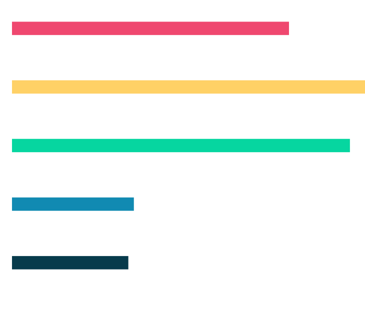


PhD - Clinical Specialization	(2%)
PhD - Direct Entry	(19%)
PhD - Transfer from MASc	(9%)
MASc	(31%)
MHSc	(13%)
MEng	(26%)

Graduation Time

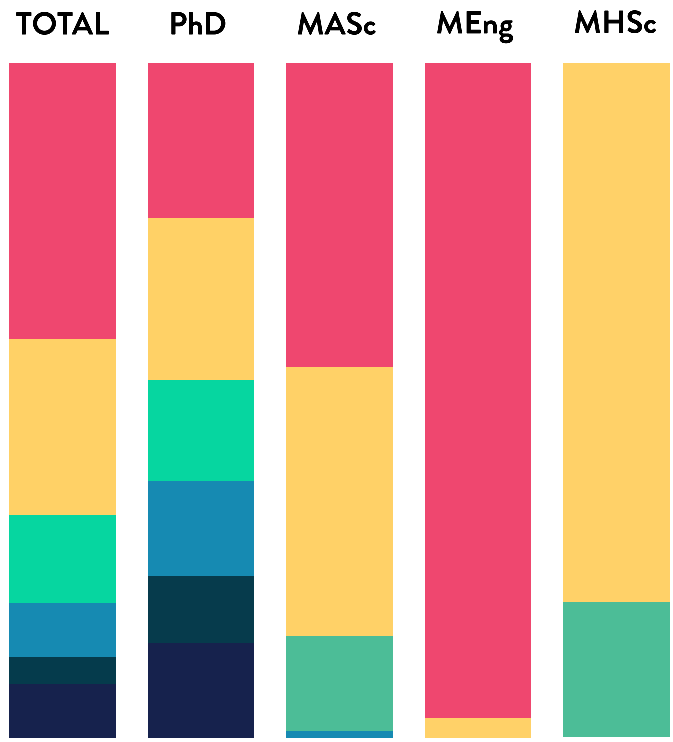
Graduation time is dictated by degree type in 2019-2020. PhD-C: Clinical Specialization. PhD-U: Direct-entry. PhD: students who had previously obtained a masters. The number of years was calculated as an average. The numbers were collected on December 7, 2020.

PhD-C	(5.0)
PhD-U	(6.6)
PhD	(6.1)
MASc	(2.2)
MHSc	(2.1)
MEng	(1.4)



Year Distribution

First year students are the most prevalent in the student body. Within the 357 students registered, 145 are first year students. While the student distribution is balanced in PhD, MASc, and MHSc programs, MEng had the highest proportion of first year students. Since this is one year program, the proportion of second year and above is expected to be low. The numbers from BME was collected on December 7, 2020.



LEGEND

Year 1	41%	23%	45%	97%	
Year 2	26%	24%	40%	3%	80%
Year 3	13%	15%	15%		20%
Year 4	8%	14%	1%		
Year 5	6%	10%			
Year 6+	8%	14%			

Research Funding Trend

BME have received $11.13 million in research funding amongst 39 core faculty members. On average, funding per faculty member was approximately $0.3 million between September 2019 – August 2020. The numbers shown below represents the number of funding package that is active during September 2019 – August 2020.

YEAR	FUNDING
2019-20	$11.13M
2018-19	$10.51M
2017-18	$12.02M
2016-17	$7.82M
2015-16	$8.04M

Grant Distribution

BME continues to thrive with research funding from all sectors. Amongst all funding packages, approximately 56% are new funding initiatives. Out of total funding, 81% are operating grants. The numbers represent the September 2019 – August 2020 period.

79 New

63 Ongoing

Selected Grants

Warren Chan
Connaught: A quantum dot portable diagnostics device for COVID-19

Milica Radisic
NSERC: Additive manufacturing of organs-on-a-chip

Tom Chau
MITACS: Effect of Music on Interbrain Synchrony

Funding Breakdown

Majority of the research, equipment, and personnel funding originate from the federal government of Canada. 'Other Sponsors' are categorized as funding from education bodies, foundations, hospitals, international organizations, and societies. The numbers represent percentages of $11.13M from the September 2019 – August 2020 period.

Federal Grants **$8,318,951**

Provincial Grants **$1,284,451**

Other Sponsors **$1,526,898**

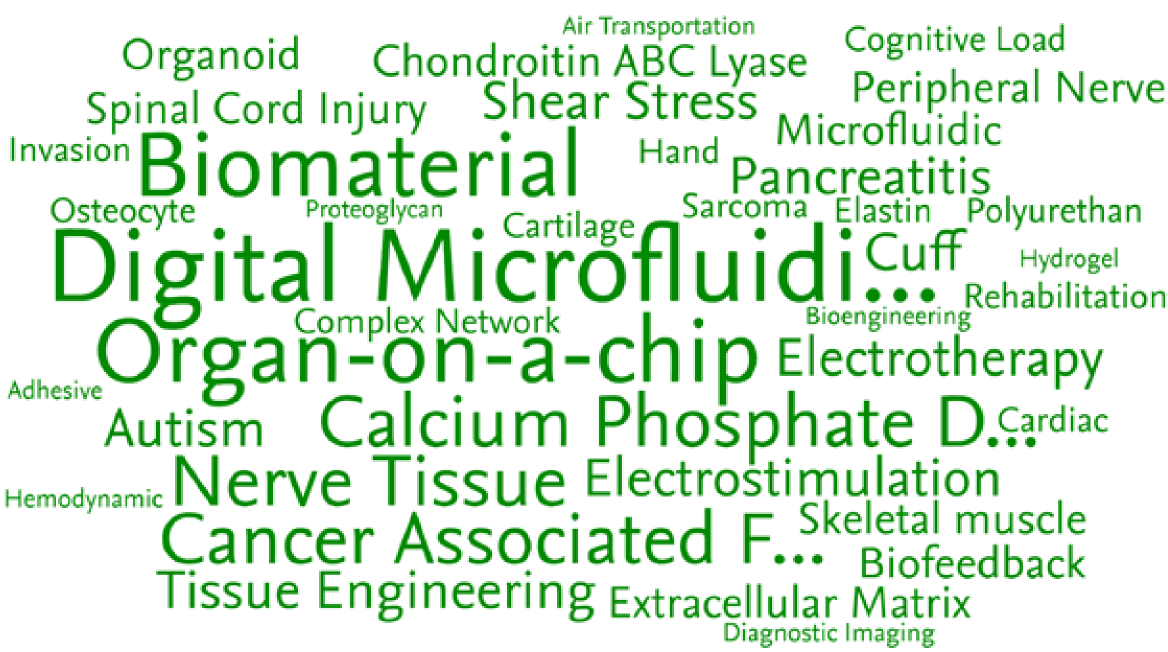
Publication Record

BME has published 151 peer-reviewed papers in 2020 from our core faculty members. The data on the right was aggregated via SciVal, an Elsevier subsidiary. The data was collected on December 7, 2020.

YEAR	PUBLISHED
2020	151
2019	186
2018	181
2017	214
2016	210

Keyword Identifiers

BME has a diverse set of research topics. Publications produced by BME core faculty members from 2020 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.



YEAR IN
PEOPLE

CORE FACULTY

JAN ANDRYSEK | PhD, PEng | Clinical
Associate Professor (BME) | Senior Scientist, Holland Bloorview
Email: jan.andrysek@utoronto.ca

JULIE AUDET | PhD, PEng | Cell & Tissue
Professor (BME) | Vice Dean, Graduate Studies, Faculty of Applied Sciences & Engineering
Email: julie.audet@utoronto.ca

BERJ L. BARDAKJIAN | PhD, PEng | Clinical
Professor (ECE, BME)
Email: berj.bardakjian@utoronto.ca

ELAINE A. BIDDISS | PhD | Clinical
Associate Professor (BME, Rehabilitation Sciences Institute) | Senior Scientist, Holland Bloorview
Email: ebiddiss@hollandbloorview.ca

CHRIS BOUWMEESTER | PhD, PEng | Clinical
Assistant Professor, Teaching Stream (BME, ISTEP)
Email: chris.bouwmeester@utoronto.ca

WARREN C. W. CHAN | PhD, FAIMBE | Molecular
Professor (BME, ChemE, CHM, MSE, DC) | Director, BME
Email: warren.chan@utoronto.ca

TOM CHAU | PhD, FAIMBE, FCAE, PEng | Clinical
Professor (BME, ECE) | Vice President of Research, Director & Senior Scientist, Holland Bloorview
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We are saddened by the passing of Professor Michael Joy. Mike was a wonderful person and great colleague. It is a tremendous loss for the University and the Institute. His family said that "he died at the farm in the living room, looking out the window at the wild roses. He passed on his own terms, at his own time."

Professor Michael Joy was born in 1940. He completed his undergraduate studies in mathematics & physics at the University of Toronto in 1963, a MASc in electrical engineering at the University of Toronto in 1967 and a PhD in electrical engineering at the University of Toronto in 1970 (with N.F. Moody – the pioneering director of the Institute). Between 1969-1970 he was a lecturer at the University of Toronto, before joining as an Assistant Professor in 1970 in the Departments of Electrical and Computer Engineering (ECE) and the Institute of Biomedical Engineering (IBME). He became Full Professor in ECE and IBME, was cross-appointed to the Department of Physics and became a Scientist at Sunnybrook Research Institute. Mike Joy led IBME, serving as Associate Director (1986-1989), Associate Director, Graduate Studies (2003-2005) and acting as Chair of the Biomedical Research Group in ECE.

Mike's research combined his skills in physics and electrical engineering towards the, then emerging, field of biomedical engineering. Together with Greg C. Scott, and Mark Henkelman, Michael Joy was a pioneering researcher in the development of current density imaging (CDI), a technique that measures electrical current density distributions in a volume of material or tissue in order to create an image, in 1988 at the University of Toronto. Today this imaging technique is performed by applying an electrical current to the material/tissue during a magnetic resonance imaging (MRI) acquisition in order to generate magnetic fields that are mapped onto the phase image of the MRI acquisition. Mike Joy's research throughout his career focused on advancing CDI and impedance imaging. He worked with a number of researchers through collaborations in order to translate basic research into practice.

We will miss him immensely as he was a big part of the Institute.

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