BIOMEDICAL ENGINEERING

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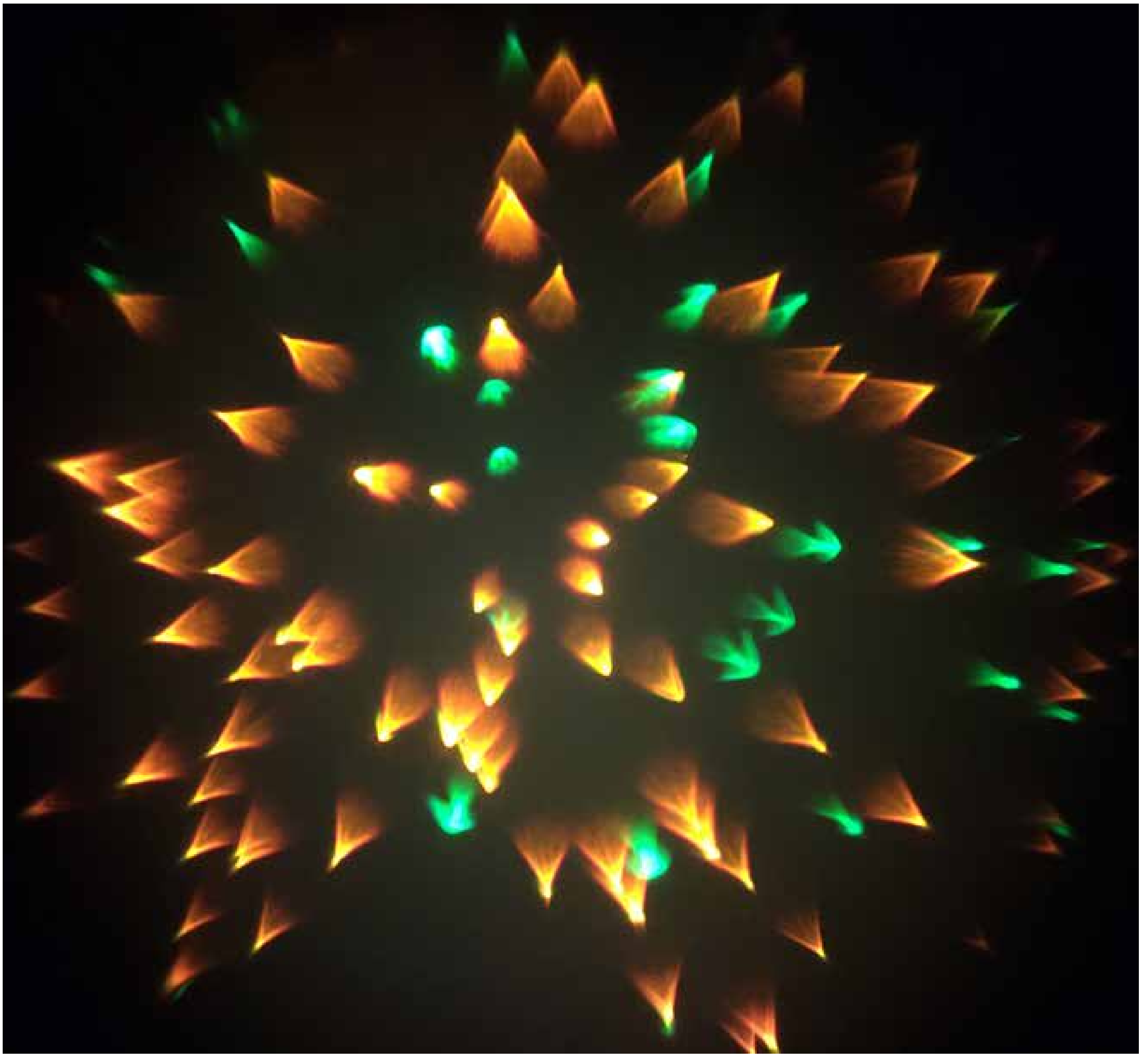

Institute of Biomedical Engineering
UNIVERSITY OF TORONTO

Cover by:
Hongmin Chen, PhD Candidate

Description: Depicted in the picture is a collection of quantum dot infused polystyrene beads imaged on a smart-phone. The beads are fluorescently coloured and can be used in a sandwich assay for diagnosing infectious diseases. The "tails" attached to the beads are imaging artifacts from our custom imaging system.

Cover decided by popular vote by the BME community.

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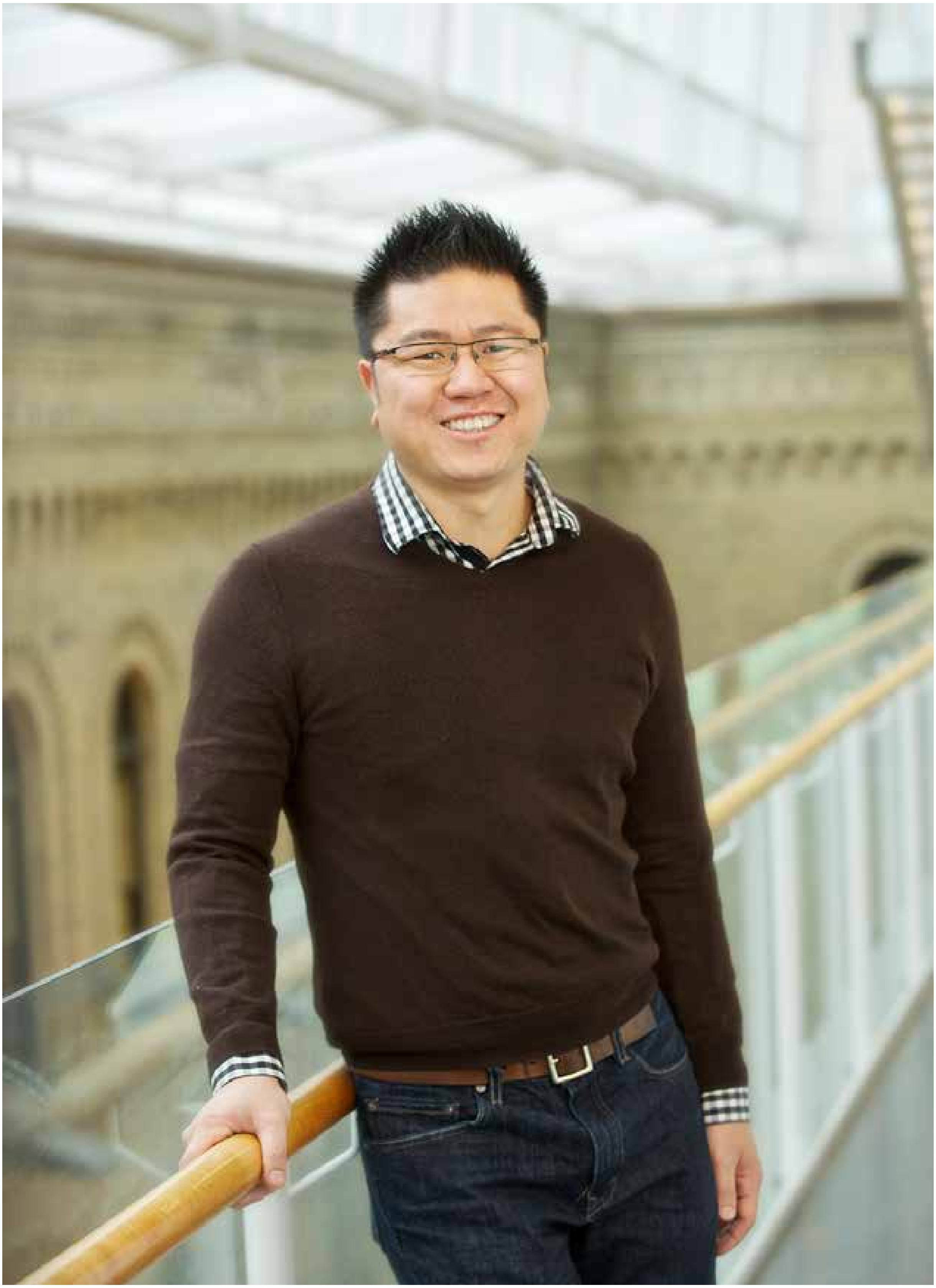


NOTE FROM THE DIRECTOR

Thank you for reading the 2021 edition of the Institute of Biomedical Engineering (BME) annual magazine. Despite the numerous challenges in the past year, we are slowly resuming activities that resembles pre-pandemic: our students are slowly getting back to in-person classes, research capabilities are resuming, and most importantly, we were able to achieve this with everyone's health and safety in mind.

At BME, people are the most important asset. That is the ultimate measuring tape of success at any organization. We have researchers who are growing artificial organs for drug testing; field researchers who are developing disease diagnostic tools; and engineers who work with clinicians on designing assistive and rehabilitation technologies for those in need. Without our students, faculty members, clinicians, and staff members, none of these scientific achievements would be possible. In this volume, we want to highlight some of the research achievements in the field of molecular engineering, cell & tissue engineering, and clinical engineering by our researchers and collaborators.

Many of our students complete their graduate journey with us, however their stories do not end there. We are always proud of our alumni's achievements – big or small – in making a mark in their respective fields after graduation. In this volume, we highlight some of our alumni's impacts in military, healthcare, and academia.

I have no doubt that our students are some of the most talented people out there. While completing their graduate degree – an already arduous journey and a challenging task – they were also involved in many extracurricular activities. Their achievements inside and outside of academia are once again are displayed in this year's feature of 'Faces of BME.'

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

Warren Chan

Warren C.W. Chan
Professor and Director

PAGE CONTENT

A helping hand for neurorehabilitation

↑ A representation of what the egocentric camera captures. The coloured lines represent finger positions estimated through deep learning algorithms (Photo: Zariffa lab).

↑ Dr. Jose Zariffa is the principal investigator for the egocentric neurorehabilitation research (Photo: KITE).

Dr. Jose Zariffa and his research team are developing tools that enable clinicians to evaluate rehabilitation success and track recovery. The goal is to create a personalized process for the improvement of rehabilitation from spinal cord injuries and stroke, accelerating the affected individuals back on the road to recovery.

What's neurorehabilitation?

After a spinal cord injury or a stroke, the neural commands that control movement are often interrupted, and the goal of rehabilitation is to help restore the lost function. In best cases, the individual regains complete recovery to their motor functions, but often the results can be sub-optimal. At this point, any improvement that rehabilitation can provide can have a real impact on independence and quality of life.

"There is a balance of two processes: recovery and compensation," said Dr. Jose Zariffa, an associate professor at the Institute of Biomedical Engineering (BME) and Senior Scientist at KITE, the research arm of the Toronto Rehabilitation Institute – University Health Network. "In recovery, the individual's motor function improves, while in the case of compensation, they maximize what they can do within the constraints of the remaining function by learning to perform tasks in a different way."

During rehabilitation, an interdisciplinary team works with each patient to help them regain the ability to independently carry out activities that are important to them. The process and results can vary greatly based on the nature of the injury, the person's goals, and the treatments available. Being able to accurately assess the abilities of each person over time is key to this process.

The current practice of measuring function in rehabilitation involves direct testing by a clinician. "The shortcoming of this method", said Dr. Zariffa, "is that it is difficult to track function during daily life in the home and community, and therefore to evaluate the true impact of the care that was delivered."

← Members of the Adaptive Neurorehabilitation Systems Lab who are leading the egocentric video research. Clockwise from top left: Dr. Andrea Bandini, Meng-Fen Tsai, Adesh Kadambi, and Mehdy Dousty (Photos: Zariffa lab).

You say egocentric, I say Point of View (POV)

One of the most important determinants of independence after neurological injuries is hand function. Dr. Zariffa and his team are interested in giving clinicians and researchers, for the first time, the ability to measure how an individual is using their hands in real activities of daily living at home.

"Our solution is to equip the injured individual with a wearable camera where they can film their day-to-day interactions with objects at home, with their hands in the field of view." Said Dr. Zariffa, "From these egocentric videos, we can extract information regarding the recovery process, which can then be used to evaluate the impact of a therapy or returned to the clinicians such as physiotherapists to modify their treatment regimen."

While humans can intuitively interpret a grasping motion, translating these actions into an algorithm is a complex topic. For example, recognizing a hand in a complex background is in itself a challenge, and a moving hand further blurs the miniscule detail involved in interpreting the data.

By using artificial intelligence (AI) and deep learning algorithms, Dr. Zariffa and his team are expecting to translate a large set of video footage into biometric data that can be understood by clinicians.

"From the videos, we can get a sense of a person's independent hand use and put their motor function in context." said Dr. Zariffa. "A lot of this information would be extremely valuable to a therapist and can help them decide what to work on with the person in order to either achieve a more functional performance or to help the person work towards reestablishing movement patterns that are similar to what they had preinjury."

This research was the winner of the $100,000 grand prize for the MaRS and Praxis Spinal Cord Rehab Innovation Challenge earlier in 2021.

Challenges and next steps

An issue with the data extraction is the scarcity of information and data available. In order to train a large enough data set using AI for maximum accuracy, a substantial amount of patient information is required. Dr. Zariffa and his team have collected several large egocentric video datasets of individuals with a wide range of hand function in laboratory and home environments, resulting in dozens of hours of video and hundreds of thousands of annotated images.

The future of neurorehabilitation, as imagined by Dr. Zariffa is to improve our understanding of the interplay between all the factors involved, then use this information to determine the best possible treatment for each person.

"If we can make sense of patient data such as their demographics, injury, and use technology to track function in more detail, we can pick the best avenue for this person," said Dr. Zariffa, "Now we're finally at a stage where we're starting to have tools that are going to enable us to make that happen." ■

New method can improve drug delivery in implants

An innovative biomaterial discovery by researchers at the University of Toronto in collaboration with Ripple Therapeutics Inc., has established a method that yields better control over drug release profiles in implants and has the potential to disrupt the classical drug delivery market. Normally, drug molecules are incorporated inside biodegradable or non-degradable polymer shells and slowly release therapeutics, often with difficulty controlling the release profiles. In this study, researchers were able to directly use the drug molecules as the delivery vehicle itself, greatly improving the fabrication process and preparation of therapeutic delivery for the clinic. This study can be found in the 12th volume of Nature Communications.

"The goal of the research and its demonstrated applications is to build a robust system that can be utilized in the delivery of numerous classes of drug molecules", said Dr. Paul Santerre, professor at the Institute of Biomedical Engineering, and the University's corresponding author of this research. "In this study, we used corticosteroids to generate structures which self-assemble on their own to form fibers, rods, nanoparticles and other forms. These robust forms surface erode in a controlled manner,

← Professor Paul Santerre (pictured) is the University of Toronto's corresponding author for this new study, and the first author, Dr. Kyle Battiston, is a recent graduate of Dr. Santerre's lab and BME alumni. The co-industry lead author is a University of Toronto alumni, Dr. Wendy Naimark (Chief Technology officer for Ripple Therapeutics).

delivering drug with near first order control for over weeks to months without the aid of a secondary matrix. This is a paradigm shift for the field."

Corticosteroids are often used clinically to remedy inflammation. For example, they are found in common commercial products such as asthma inhalers, and areas of regenerative medicine such as those in ocular repair, the application described in the article. Aside from inhalation as the route of delivery, these molecules can also be delivered to localized areas in the human body through implants or tissue engineering – where a bio-degradable material traditionally encapsulates the molecules and slowly releases them over time.

In theory this is a great idea, but bringing this idea to the clinic are riddled with barriers.

"One of the greatest challenges that drug delivery faces is the incompatibility of the drug with the carrier, and the resulting inflammatory response from those carriers. The new biomaterials described in this article circumvent both of these issues and provides for a concentrated drug dose that can last from weeks to months. The innovation explains the rapid awarding of patents on the technology, and successful co-development of Ripple Therapeutics' first product, which is in phase II trial, in collaboration with Laboratoires Théa, a leading independent ophthalmology pharmaceutical company in Europe" said Dr. Santerre.

Precise control of the release profile is crucial in yielding efficiency and effectiveness of the therapy. Too little or too much drug release over a specific period could lead to ineffective therapy, or undesirable side-effects.

"The advantage of our system is that it can achieve precisely controlled delivery through tailored designed surface erosion. The Nature Communications study describes different combination of drugs and methods of using the novel biomaterials" said Dr. Santerre.

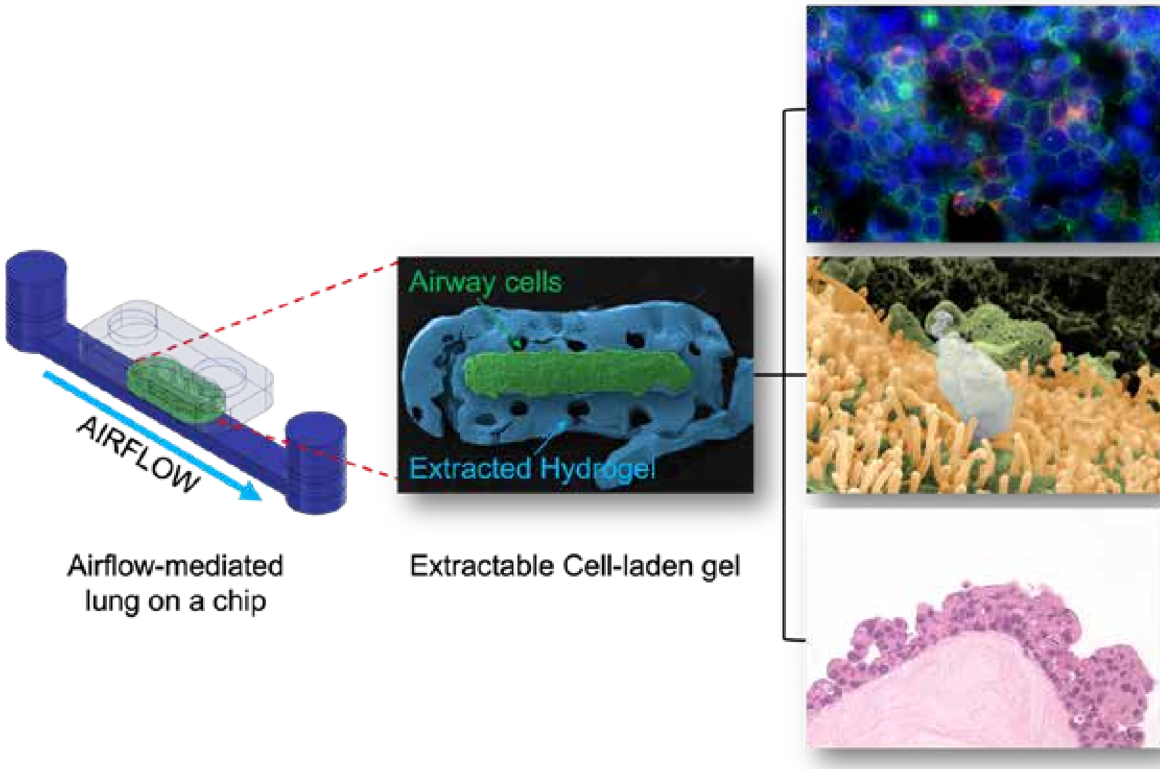
In this work, researchers first linked the corticosteroid molecules into dimer forms using a crosslinker. This type of formulation yields self-assembled systems into not only traditional spherical shapes, but it can also be made into meshes, and even sprayed as a device coating. The study nicely demonstrates the versatility of the technology.

After characterizing these dimer complexes for their stability and drug release profile, the researchers performed pre-clinical studies of these molecules in small rodents and rabbits. Here, the researchers used a disease model for diabetes induced visual impairment, where steroid application is a common treatment.

By injecting the corticosteroid implant into the eyes of the visually impaired animals, the researchers measured the drug release profile and its effects over time. In comparison to the leading commercially available implant, the corticoid-dimer had a consistent drug release profile of up to 12 months with no incompatible by-products released, whereas the commercial competitor's drug profile was below effectiveness by 2 months, and shed a lactic acid by-product from its polymer carrier, a pro-inflammatory agent.

Further analysis using toxicity screening also revealed no negative side-effects.

"If successful in their first clinical studies, these polymer constructs can be utilized in diseases and pathologies, where management of inflammation, tissue regeneration, fibrosis, and drug sensitivity are critical, including osteo arthritis, premature degeneration of soft tissues, vascular pathologies, medical implant associated fibrosis, and many more." said Dr. Santerre. ■



New microfluidic device could become a useful tool to examine the effect of pollutants on the lung

↑ Schematic of the microfluidic device.

A new technology developed by researchers at the University of Toronto provides the first step in mimicking the environment of lung airways, using a microfluidic device combined with a novel airflow system. This technology enables scientists and engineers to perform various particle exposure experiments to examine the pathological effect of air pollutants on respiratory health.

This development was published in volume 6, issue 12 of Advanced Materials Technologies by Siwan Park (BME) and Professor Edmond Young (MIE, BME).

The microfluidic lung airway-on-a-chip, as the authors denoted as E-FLOAT (stands for Extractable Floating Liquid gel-based Organ-on-a-chip for Airway Tissue modelling under airflow), is an easily modifiable system where scientists can grow lung cells in a

← Authors of the study. Left: Siwan Park, PhD candidate. Right: Professor Edmond Young.

suspended hydrogel that mimics lung tissue. Airflow can also be modulated in this system to simulate breathing in the human lungs.

"We showed that lung airway tissue can be micro-engineered in the lab, exposed to various environmental conditions including airflow and pollutants, and then be extracted for further interrogation as if it were a real lung tissue sample," said Professor Edmond Young, corresponding author, and Associate Professor at the Institute of Biomedical Engineering and the Department of Mechanical & Industrial Engineering.

In many existing iterations of the technology, cells grown on the microfluidic device are limited to 'on-chip' analysis to assess the effect of external stimuli – such as airflow – on the health of the cells. This is suboptimal for analysis. While scientists can remove these cells from the device for post-experimental analysis, this process changes the spatial location of the cells in relationship to the tissue mimicry altogether.

"One of the advantages of E-FLOAT is the ability to extract the biomimetic airway tissue that allows us to develop an in-depth knowledge through a wide array of imaging technologies," said Siwan Park, the lead researcher on this study and a 5th year Ph.D. candidate at BME, "We were especially excited to obtain the stunning images of histology sections using the extracted hydrogel. Not only does it look beautiful, we believe that it may also be significant in histological and pathological perspectives. Also, depending on how we design the cell-matrix interactions in E-FLOAT, we may obtain a more physiologically accurate representation of multicellular airway tissue."

The researchers first developed the microfluidic device by micro-milling and bonding the thermoplastic layers. The device incorporates a special channel geometry for growing lung cells on a suspended gel. Lastly, an airflow system was connected to the device that can generate various flow rates of the warm and humidified air.

To put the device to the test, the researchers successfully delivered airborne particles onto the airway cells *via* controlled airflow to mimic how air pollutants interact with lung cells.

The researchers then extracted the entire biological mimic and analyzed particulate and cell interactions using various high-resolution imaging technologies.

"In the future, the plan is to use this technology to study the development of lung diseases like asthma – especially in the presence of air pollution – and to also use it as a preclinical model during drug development. There is obviously a lot more work to be done, but we hope to collaborate with lung researchers and partner with pharma down the road to realize this plan." said Prof. Young. ■

Saving lives – one breath at a time

Derek Watt completed his Master of Applied Science (MASc) degree in Biomedical Engineering in 2007. Now working as the Director of Commercial Products at Thornhill Medical, Derek is part of a team that designs, builds, and supplies a robust line of field-ready respiratory devices. Thornhill Medical's products are specifically designed for military, field hospital, transport medical and first responder teams.

↑ Nurses and medical professionals from around Europe and Africa receive small-group training at Ramstein Air Base, Germany, April 3, 2019 (U.S. Air Force photo by Tech. Sgt. Jessica Hines).

What do you do at Thornhill Medical?

Derek: In my role as Director of Commercial Products, I lead product development and improvement initiatives with an eye towards successful commercialization, with the customer as my primary focus. A major component of my work is what I call field engineering, where I have the opportunity to interact with clients to understand their use environments, getting feedback and information from patient clinical experiences, and bring this information back to our team to address their concerns in future iterations of our products. I routinely partner with and engage our engineering, sales, and marketing teams to ensure we are all aligned in meeting our customers' needs.

What does Thornhill Medical specialize in?

Derek: Foundationally, our technological expertise is in respiratory physiology. Our products include a portable, integrated life support system (MOVES® SLC™), capable of ventilating and generating oxygen to provide on-site critical care. We also offer a mobile anesthesia delivery module (MADM™) for field gas anesthesia applications and a pneumatic rebreather system (ClearMate™) for accelerating the elimination of carbon monoxide from the bloodstream. We have a team of clinicians, researchers, and engineers that specialize in respiratory physiology, and that enables us to innovate and build unique devices that take advantage of that knowledge.

What is the product development cycle like for you? How do you and your team decide on what product to focus on?

Derek: It is all about identifying a need that is expressed by clinicians and end-users, whether in the civilian or military space. Before we bring anything to market, we want to understand how it will make a difference in people's lives in a positive way. The next step is to bring in a complementary team that can provide different viewpoints, from technical engineering staff who can put the hardware together, to clinical researchers that address critical questions and concerns related to patient care. Then it brings us to prototyping and building physical models to validate their feasibility.

Post regulatory approval, long-term success and customer support require addressing parts provisioning, device maintainability, and developing plans for supporting the systems once they are fielded, for example through the development of curriculum for new equipment training.

A big part of the portfolio is your work with the United States and Canadian military. Where do your solutions factor into their operation?

Derek: The requirement for patient treatment in the military healthcare environment can be very different than that of the civilian bricks and mortar hospital. One of the priorities in a military setting is to treat individuals close to potential points of injury, which means being able to address casualties as quickly as possible to improve their chance of survival.

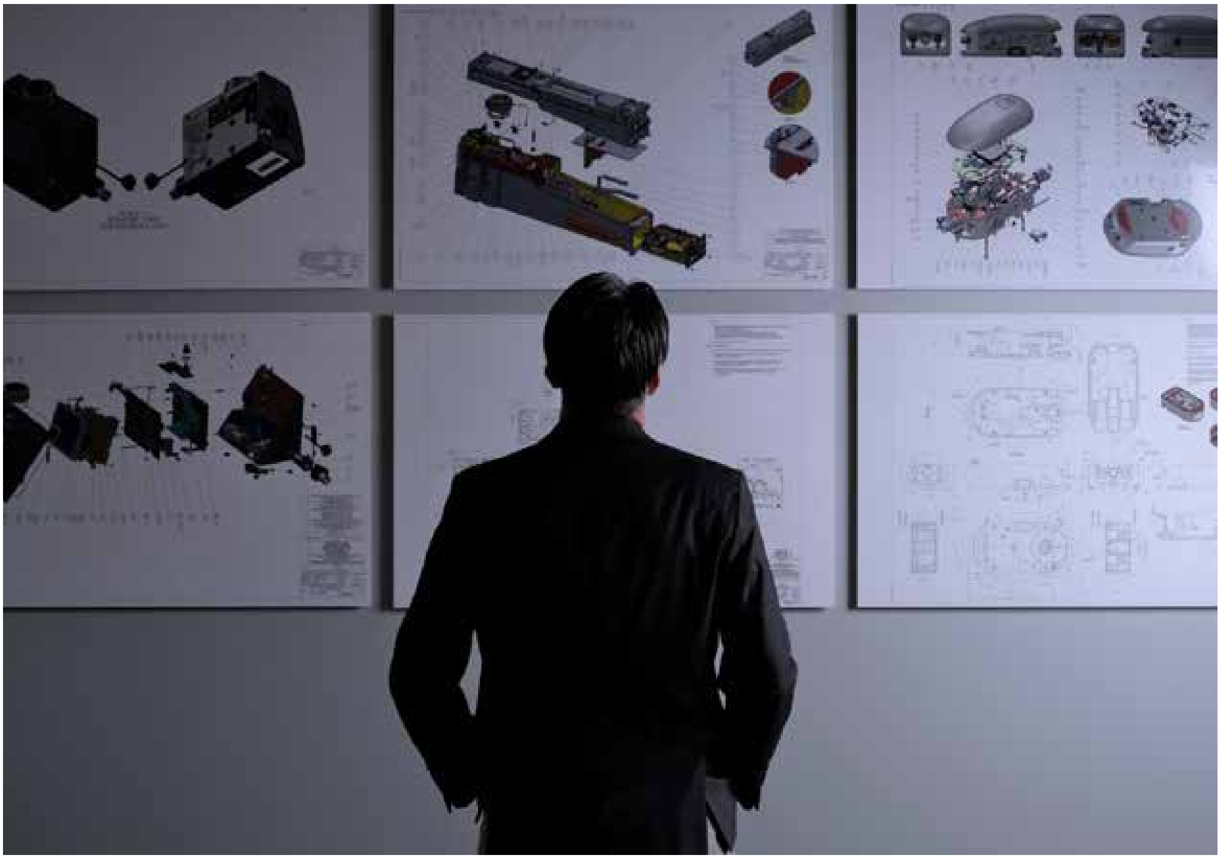
A specific concern of our military customers is to significantly reduce or eliminate the need to carry compressed medical oxygen. In a transport aircraft, you can imagine how dangerous that can be, especially in a combat zone. Compressed oxygen can be incredibly hazardous, and the portable ventilators the military typically use are extremely inefficient with respect to oxygen consumption.

Addressing this concern was the first project for Thornhill Medical; to develop an oxygen-efficient, portable, integrated life support system for the United States Marine Corps. Typical equipment sets consist of a variety of individual devices to sustain life, but our solution produces its own oxygen, does not require an external oxygen source due to its unique oxygen conserving ventilator, and can operate from battery power. The advantage is that the equipment can be taken further downrange, to get closer to the action and address casualties immediately.

The goal with our MOVES® SLC™ technology is to be adaptable to all situations, which I call being both environmentally and platform agnostic. Ideally, the system should be able to function in any condition, whether it is a hot, cold, or sandy environment, in the rain, or even within a helicopter. Supporting air transport requires specialized testing for airworthiness, and having equipment certified for this use is no easy feat. Ultimately, we want to build something that is rugged and robust to support use in all environments.

Part of the portfolio of your company have shifted to COVID-19 work. This is not surprising as the technology is best fitted for the current set of challenges. What kind of problems are you solving with your technology in relationship to COVID-19?

Derek: With COVID-19, we have seen surgical intensive care units that can overwhelm hospitals. If a hospital runs out of space, they may need to set up



temporary field hospitals to accommodate patients, but then you run into infrastructure issues like the availability of power sources and high-pressure oxygen to keep the ventilators running. This is where Thornhill Medical and MOVES® SLC™ come in.

We are proud to have supported Canada's fight against COVID-19. Thornhill Medical answered the call to support the fight against COVID-19, producing and delivering our MOVES® SLC™ devices to help save lives across the country.

Do you have a memorable experience where you have seen the technology in action? How did that change your perspective?

Derek: I have visited an active conflict zone in the past, and frequently talk to soldiers who provide medical support. In the military, there is always a sense of comradery, with the ultimate goal of keeping team members alive and bringing everyone home safe.

I have heard stories where people did not have an on-site ventilator, requiring manual resuscitation via a bag-valve mask for 4-5 hours to sustain life. That really spoke to me and made me realize what kind of difference our devices are making.

What are some of the challenges you are facing with the technology deployment?

Derek: Part of our goal, aside from building the equipment and making sure it is safe to use, is to train healthcare professionals so they have the technical know-how to utilize our devices effectively.

Everyone has a different expectation when it comes to device usage, so the buttons and interfaces on the device must be intuitive to the user. Aside from establishing training modules, we are also building devices with usability in mind, so healthcare professionals can readily use them.

Looking forward, Thornhill Medical will be working with a team of like-minded developers to examine the remote control of medical devices, using MOVES® SLC™ as the platform for this initiative. Enabling remote providers to safely control MOVES® SLC™ locally has the promise to augment the bedside team with the expertise they might not otherwise have.

You graduated from Biomedical Engineering with a Master of Applied Science in 2007, and now you have been with Thornhill Medical for >13 years. How does someone who graduates with an engineering graduate degree get to where you are now?

Derek: In a general sense, coming out of school with an engineering degree, whether it is software, mechanical, electrical and so forth, your first roles are commonly technically focused. In time, that slowly expands into leadership and managerial positions involving a lot of people-people interactions, like what I am doing now.

I completed my undergraduate degree in mechanical engineering, and a graduate degree in biomedical engineering. For me, the undergraduate education gave me a core knowledge base of engineering concepts. Graduate school allowed me the opportunity to apply those engineering concepts in a biomedical engineering context, looking at real problems and working to find solutions. Working in a laboratory group environment exposed me to working as part of a large and diverse team, people with different strengths and backgrounds. That has a lot of similarities to what I am doing on a day-to-day basis right now.

The great thing about my work is that the need for technical skills never really goes away. Even though a big part of my role is to talk to people, having that supporting technical knowledge is a huge advantage.

What does the future hold for Thornhill Medical?

Derek: Thornhill Medical originated through the ability to translate our knowledge of respiratory physiology into real-world applications, for example in addressing medical oxygen availability in austere environments. Forward-looking advancements include an investigational device capable of regulating human blood gas levels of oxygen and carbon dioxide non-invasively, as well as further developing and enhancing our existing technologies in support of our military customers. ■

Giving impact factor a new meaning

Dr. Locke Davenport-Huyer graduated in 2019 with a Doctor of Philosophy (PhD) in Chemical and Biomedical Engineering. During his time at the University of Toronto, Locke has authored over 30 publications and co-founded Discovery, an educational STEM initiative that seeks to bridge the gap between high school and post-secondary studies. He completed a post-doctorate research at Johns Hopkins University. Locke started as an Assistant Professor at Dalhousie University in the Department of Applied Oral Science in July 2021. Here, he shares some of his insights on his path in academia and how he makes an impact outside of his research.

Can you briefly describe your career path from undergraduate to post-graduate?

I did my undergrad at Queen's University, and I majored in biomedical and chemical engineering. Afterwards, I decided to pursue a Master's Degree in biomaterials-based engineering at the University of Toronto under Dr. Milica Radisic. This decision was mainly driven by her bench-to-bedside style engineering solutions that could tangibly be used in the clinic. A couple of years later, I transitioned into a PhD and found my own niche within the lab doing polymer chemistry, helping to push forward their materials design in the biomaterial space with an organic chemistry-based approach. My research was focused on the development of synthetic, mechanically tunable materials in the space of cardiac tissue engineering and on investigating how those materials interacted with the body.

At the end of my graduate studies, there were multiple different career paths I could have taken. But something that's always been important to me is how I can interact with people in a way that pushes a community of practice forward. I really enjoy the practice of mentorship, whether that's in the context of teaching, research in supervision, or talking to people. Mentorship has always been important to me, and I just didn't see a better way to do that than as a faculty member.

I continued down that research path and started as a professor in the summer of 2021 at Dalhousie University. I completed a postdoctoral fellowship at Johns Hopkins University because I think it's important in an academic career to get more experience in different research areas and in different labs. My post-doctoral research interests include investigating the mechanisms behind foreign body reaction and designing biomaterials that work synergistically with microenvironments in the immune system to reduce inflammation. Now, I'm looking forward to balancing the importance of teaching and of research accordingly in a faculty position.

Did you always think that you would end up in academia? If not, when did you make the switch?

I'll be very blunt – absolutely not. For the first three years of my PhD, I thought that I would never be an academic. The reasoning was two-fold. Number one: I didn't think I was cut out for that. I thought it was too hard. How do people come up with these crazy ideas and how do they investigate them effectively? Number two: I don't think I fully understood how important mentorship was.

For me, I wholeheartedly believe that the reason I changed path on that was because of Discovery, an educational initiative that I helped co-found that exposes high school students to biomedical engineering through capstone-style projects integrated in their classes. Through Discovery, I had the opportunity to interact with many faculty members and saw that no one fully knows what they are doing – not even professors. But everyone gets through it, and they figure out ways to do their research or teach their courses. Additionally, my experience of having a novel idea to develop and implement an educational framework for Discovery and then seeing that idea be accepted and executed was very validating. I believe that my research began to thrive afterwards because I realized that I do have ideas that can help and impact people, and other people care about what I think.

On top of that, I realized that I really do love mentorship and the interactions that I can have with others in academia. I'm not sure that I love teaching per se, but what I do like is making impact through driving change. I also think that the interactions with people in academia are different than what you might get in an industry job, which can be hierarchical and regimented. Academia gives you this freedom to talk to whomever you want, whenever. There are no rules governing if I email researchers at another institution and discuss potential ideas.

Why did you start Discovery?

I remember thinking, how could we better prepare the future generation of STEM people? I've always believed that education is what drives society forward. High school teachers especially help shape teens in their late adolescent years before they go out and live life for themselves. However, I saw a gap in which the traditional high school curriculum is more knowledge-based, whereas when students enter post-secondary studies, they must quickly transition into a more inquiry-based model of learning. I wanted to make a difference and leverage tools to try and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← TOP: Locke welcoming high school students to a Discovery session at the University of Toronto.

← BOTTOM: Locke mentoring a high school science student participating in Discovery.

↑ Locke started his new role as an Assistant Professor at Dalhousie University in the Department of Applied Oral Science in July 2021.

impact the way people think and solve problems in a more systematic way. Thus, we created a learning community where we can collaborate with high school teachers to provide opportunities for students to develop problem-solving and inquiry skills in STEM and in biomedical engineering.

Biomedical engineering just doesn't exist for students in high school. It's not something they understand, and by providing them with capstone-style projects around biomedical engineering, we can give them really cool opportunities. They know what cancer is, they know what cells are, and they think microscopes are awesome. Through Discovery, we can further inspire that curiosity, but we can also build concrete skills on top of that. Beyond building the next STEM generation, I also believe that Discovery is about building people who can think critically about the world as they come out of high school. The people that we impact through this program might eventually make a better decision on, for example, how to design the next cure for cancer.

What advice would you have to current graduate students at BME?

The biggest advice that I have is to get involved in activities outside of your research. Sometimes, there will be months of experiments not working, and even though it's part of the whole research journey, it can be frustrating. But if you have other extracurricular activities to do, whether it's getting involved in something like Discovery, a student club, volunteering, sports, or doing anything where you can feel valued and useful, they can help you get through those times. It's finding the thing that you love that may be a minor inconvenience when you're busy because your research is working, but when your research is not working, it's the crutch that gets you through it. And you can develop your personal and professional skills along the way. ■

Rethinking surgical safety as a culture as opposed to the end outcome

Recently completing her graduate degree at BME, **Amalia Gil** continued her career path as a clinical implementation engineer, aiming to help improve surgical safety in operating rooms (ORs). By capturing videos, sound, and other data from the OR during operations – akin to a black box on an airplane – these technologies enable hospitals to gain insights into how to improve quality and safety in their ORs. Here she describes her role, and what the future holds for safe surgical practices.

What do you do as a clinical implementation engineer?

My main role is to collaborate with hospitals to ensure a successful implementation of the various platforms offered by Surgical Safety Technologies (SST) including the OR Black Box® and Black Box Explorer®. I work with different departments at the hospital to implement these systems, including project planning, biomedical and clinical engineering, perioperative services, hospital facilities and engineering, integrators, and IT and networking departments. After the implementation is completed, I also support the hospital site by monitoring and addressing any issues that may arise. Outside of implementation, I also work in research and development (R&D) to continuously improve the SST platforms.

What's a typical day at work?

The first thing I do in the mornings is to check on all active sites for any issues. If any issues are identified, I work with the SST team to address them. The rest of the morning is usually filled with client meetings, usually 2 or 3 clients to address designs, plan for implementation, or update on testing and go live. I also have meetings with the implementation team to update on the status of upcoming sites. In the afternoon I focus on either completing implementation designs, configuring hardware for shipment to a site that is ready for installation, remotely configuring a site that has been installed and is ready for testing, or performing testing to prepare for go-live. If time allows, I also work on R&D projects to better understand and address issues that arise in the field or find hardware improvements for the platforms.

What does a client interaction look like for you?

I most often interact with clients through phone calls and virtual meetings. I work directly with the project manager who identifies the leads at the hospital of the many required departments. We then organize various meeting to first identify the client needs, then to obtain all engineering specifications and drawings to provide the implementation design, and finally organize the


OR BLACK BOX

installation and testing prior to go-live. Due to the pandemic all these discussions have been done through virtual meetings, but I look forward to visiting future client sites for more face-to-face interactions.

How do you help improve surgical safety?

I am a small piece of the puzzle on how SST helps to improve surgical safety. SST is composed of many groups that include software developers, data analysts, AI engineers, surgical analysts, surgeons, designers, project managers, finance, operations, sales, and of course the implementation team. We all work together to provide hospitals with a method to better understand what is happening in their ORs, to develop initiatives that can help improve OR quality and safety.

Why is surgical safety important in the operating room?

I would say surgical safety is a culture for continuous improvement to ensure the required outcome. Those providing patient care work tirelessly to ensure a successful outcome for the patient. A safety culture is a method to assess and develop systems that support health care providers in their efforts to help achieve successful patient outcomes. This type of culture also empowers people to raise concerns that can help continuously improve safety in the operating rooms without fear.

It should be noted that it is difficult to prevent all negative outcomes, there's comorbidities and other unexpected issues, but if there is a safety culture, even if unexpected events occur, the systems surrounding health care providers can still provide enough protection for a successful outcome. And if the systems fail, then a safety culture can analyze the root causes without blaming people, and rather focus on how to improve support and processes to ensure a successful outcome the next time around.

What are some of the challenges in improving surgical safety?

I would guess that the biggest challenge to improve surgical safety is that of obtaining data during operations to identify areas of improvement. Before the OR Black Box®, the most common processes to understand what could have led to an issue was to do an analysis post incident. But the problem with this approach is that this analysis often occurred days or weeks after the incident which made it difficult to put together exactly what happened to identify what could be improved. This is the gap that we hope to fill with the OR Black Box®; to provide a method that can help identify areas of improvements for hospitals to develop systems to help improve surgical safety.

Did your research in graduate school contribute to what you are doing now?

My graduate research was supervised Dr. Teodor Grantcharov at the International Center for Surgical Safety (ICSS), Li Ka Shing Knowledge Institute of St. Michael's Hospital. My research focused on developing a method of identifying distractions with eye-tracking technology and the OR Black Box® system. I would have to say that my research contributed to what I am doing now. For my thesis, I had the opportunity to work with various departments at St. Michael's Hospital to successfully integrate the eye-tracker into the OR. I worked with biomedical engineering, facilities, electrical, environmental services, perioperative services, and nurses, surgeons, and patients. This gave me the experience required to do the work I do now as a clinical implementation engineer.

What is the next step in improving surgical safety?

I would say the next step is to integrate a safety culture in hospitals that can help identify areas of improvement that does not focus on blaming but rather continuously improve the systems and processes that can support health care providers in ensuring successful patient outcomes. The other steps are to share this knowledge across hospitals to create open discussions about surgical safety and develop new ideas. The more players there are working towards a change in safety culture the easier it will become, and the closer we will come to creating this required systemic change. ■




FACES OF BME

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

Doris Adao | PhD Candidate | Craig Simmons Lab

My father worked as an industrial engineer in the Philippines, and my brother is a U of T mechanical engineering alum. Growing up, I was fascinated by their incredible work and abilities. Biomedical engineering gives me the opportunity to continue my passion for biology while learning from and collaborating with the people I've always admired.

As an undergraduate student, I was heavily involved in the Filipino McMaster Student Association (FMSA), where we organized fundraisers to support students pursuing higher education in impoverished areas like the Philippines. Currently, I volunteer with various outreach and mentorship groups within Filipino-Canadian communities, such as FAMS and POP. I am also a founding member of FiCARs, a community of support for researchers and scholars throughout various sectors across Canada.

↓ Photo courtesy of Doris Adao.

→ Photos courtesy of Doris Adao.

I was born and raised in Taft, Eastern Samar, a very small town in the Philippines. My father was the first-ever in his family to attend college. Pursuing higher education, a graduate degree, or being a scientist, was something I could never have imagined. I'm extremely fortunate to have this opportunity now, but I also acknowledge the barriers in pursuing a career in the sciences: a lack of resources, educational opportunities, and mentorship. Advocating for underrepresented groups is more important than ever.

My favourite meal to cook is Green Thai Chicken Coconut Curry. It's the best comfort food and has an amazing blend of flavours. For family gatherings, my go-to dish is lumpia, a Filipino-style spring roll. It's simple, delicious, and perfect for any occasion. Bonus: it reminds me of home!

Cooking is a science, and the process is a lot like conducting an experiment. First, you find a trusted protocol/recipe and familiarize yourself with it. Next, you gather your materials/ingredients, and follow the recipe/protocol to the best of your ability. Results are analyzed/eaten, and we discuss the outcomes to draw conclusions. There is always room to optimize your experiment/dish! ■

Maryam Mahjoob | MASc Candidate | Azadeh Kushki Lab

My family came to Canada as refugees in the early 2000's. I was four years old at the time, so all that financial and social stress of being a refugee in a new country, was put on the shoulders of my parents. My parents always used to tell me with education, I could become anyone or do anything I want to in life. While they were working multiple jobs to make ends meet, in addition to learning English, they constantly stretched themselves to make sure I had the resources to pursue my studies.

While I feel extremely grateful and privileged today, I don't want parents to have to feel this type of burden, so my sister and I began 'The School Bag Project' which is an initiative that aims to empower newcomers and refugee Afghan youth in their education. We provide pre-packed school bags filled with stationary items and personal health staples to these youth.

We believe every child should be equipped with sufficient school and health resources to be able to tap into their full potential. We want to knock down these barriers for refugees and newcomers in providing these educational and health resources for their children.

We began our initiative in June 2020, and we were really blown away by the support of friends, family, and even internet strangers since then! Additionally, we recently received a generous project grant from the Afghan Youth Engagement and Development Initiative (AYEDI), and #RisingYouth to help further develop and support our initiative. With their grant, we were able to begin an additional campaign called "Project Bloom". Project Bloom is a subproject made with the aim to encourage mental health awareness in the Afghan community. For this campaign, we equipped our bags with a mental health resources and held mental health seminar for Afghan youth.

I feel my research and extracurriculars have mutually inspired each other – and will continue to do so. Health and education inequity are systematic problems. My past and current extracurriculars (in addition to some inspiring mentors) have built my interest in wanting to change, address and educate others on these inequities. This brings me to my current thesis project, where I am learning more about the intersectionality that certain sociodemographic groups face in health, and how this effects neurodevelopmental disorders. It's unbelievable to me that in a society advanced enough to receive a video from Mars, we have been unable to create equitable opportunities for everyone to pursue an education or achieve their full health potential.■

← All photos courtesy of Adam Koebel.

Marta Overchuk | PhD | Gang Zheng Lab

I grew up in Ukraine in a family of artists, so it seemed natural that I too would become an artist. At the age of 12, I even took up a job that involved drawing illustrations for a 500-page or so children's book and spent the next two years drawing hundreds of illustrations for that book. I didn't enjoy that very much! But it did teach me a valuable lesson. Nothing of value in life comes easy, so I better find something I am truly passionate about and enjoy doing.

When I wasn't glued to a Harry Potter book, I often found myself venturing into the non-fiction section of the local library and became quite fascinated with science and the sort-of grandeur of discovery. I dived headfirst into quite a few biology and chemistry textbooks, and as early as grade ten I began auditing undergraduate lectures and shadowing a graduate student at the local research institute. Since then an entire piece of my life has revolved around research, but because I get to work towards a cause I believe in while doing something I love, it has never felt out of place!

My research is centered around photodynamic therapy (PDT). This is a cancer treatment modality, which uses light in combination with non-toxic light-activatable molecules to generate reactive oxygen species that can kill cancer cells in a process that is somewhat analogous to radiation therapy. More specifically, my research explores how a PDT approach could be combined with nanomedicine to improve tumour uptake of chemotherapeutics with the goal of reducing systemic toxicity in patients while promoting tumor remission.


OLYMPUS

My extracurriculars are generally centered around two themes. The first involves science communication, I challenge myself to try to explain cutting-edge science in a way that is both fun and easily understood by most people. And the second theme centers around empowering others, especially international students, to pursue a career in science.

My motivation to start doing science communication on social media was to show as many people as possible that real-world science can be fun and interesting and that contrary to popular opinion you do not need to be a genius to understand it. Unfortunately, scientific research is still shrouded in mystery for most people. And sometimes we as scientists perpetuate this stereotype by not adapting our explanations to a broader audience. When I think of a complex scientific concept, I like to challenge myself to find a way of explaining it in a very short period of time, like 30 s. Surprisingly, most of the time, I can find a way of explaining it in an interesting way without sacrificing scientific accuracy. By incorporating these basics of storytelling, I have found that I've started to change the way I even approach my more professional talks. So in a way science communication is making me a better scientist!

I plan to stay in academia, but while on the path to professorship I plan to continue my science communication work. By being present on social media, I hope I can share my journey, help others, and try to break a few stereotypes along the way. 2020 really cemented social media as a tremendous force capable of change for both public health and social issues. By having more scientists' voices on social media, we can hopefully bridge the gap between the public and the scientific community, build trust, and incorporate scientific principles into peoples' decision-making. Also, as a woman in science, I want to share my academic journey so that any young girl out there can see if I did it they can as well. ■

Samantha Stuart | MASc Candidate | Frank Gu Lab

Ultimately my goal is to build a career in innovation through data, so I am thrilled this summer to be working as a data science intern with Amazon Web Services, as part of the Professional Services team. I entered my graduate studies with an interest in both biomaterials science and data science. My project is focused on understanding and predicting macromolecular polymer-protein binding interactions, towards the aim of improving the clinical translation of drug delivery systems.

← All photos courtesy of Youth Science Canada and Samantha Stuart.


Ambassador


CWSF
ESPC

While this past year has been anything but typical, my project requires a mix of laboratory work and computational work through programming with Python. With some careful scheduling and COVID-19 preparedness last semester, I was often in the laboratory performing experiments 2 days a week, helping build a library of raw data. In the remainder of the time, I have been focused on writing re-useable and maintainable Python modules for processing experimental data into a labelled format for machine learning, and building initial modelling pipelines.

As someone who benefitted hugely while in high school from participating in outreach programs, paying it forward to lift the next generation has always been important to me. Since 2014, I have planned dozens of STEM outreach events with various organizations, given an outreach TEDx talk, volunteered, and mentored students who came my way to help them find what they are looking for.

When I first started doing outreach, it was the disconnect between high school student ambitions and the actuality of engineering careers that really surprised me. Outdated professional stereotypes, and a lack of early visibility into career opportunities on the other side of an engineering degree can turn young students, particularly those from underrepresented or disadvantaged backgrounds away from engineering unnecessarily. I struggled with this too when starting out, and it was great mentors and positive role models that helped me find my way. I hope my outreach work helps do the same for others.

Having a place to explore and celebrate science and creative ideas without bounds unleashes some incredible projects from the students who attend. There is nothing in your way as a student researcher – you can take bigger risks, ask bigger research questions, the downside is low if you fail, and the incentives for creative iteration are all there. The result is a vibrant nexus that inspires attendees to think big and believe in the power of self-learning. The finalists will carry this mentality with them for the rest of their careers – and I believe they will innovate relentlessly because of it. ■

INCOMING CLASS OF **2021**

In September, BME welcomed 100+ students into our graduate programs. We asked some of these students why they chose our programs, and what they are looking forward to in this unusual year. Here's what they have to say.

Saba Abtahi, MEng Stream

I decided to come to UofT because of the unique curriculum offered by the MEng program.

I hope to bring this skill set to the workplace.

Shana Alexander, PhD Stream

I chose BME at the University of Toronto because I was attracted to its location in the heart of a biomedical and biotechnological advanced city. Additionally, the flexibility to work and collaborate across multiple disciplines, hospital partners, and start-up companies.

I'm looking forward to meeting like-minded individuals, expanding my professional network, and creating lasting memories, all while conducting meaningful research.

Vanessa Cristini, MEng Stream

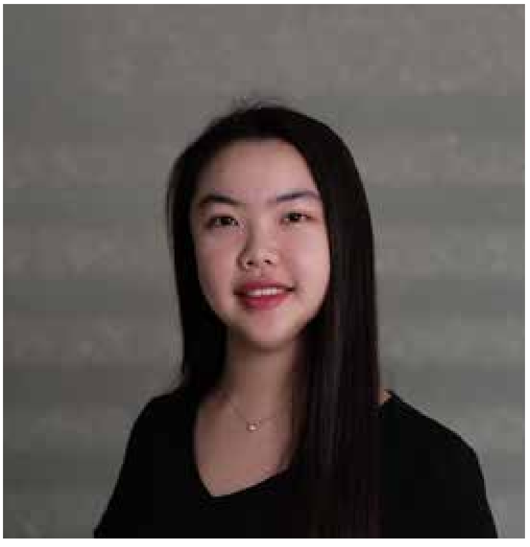
There were many reasons I chose UofT! Firstly, each and every course offered piqued my interest! From Regenerative Medicine to Clinical Instrumentation, I wanted to take them all. I also love how UofT values practical experience and incorporates a one-term internship into the degree!

I'm most looking forward to building on my undergraduate engineering knowledge and learning more about the endless opportunities in the biomedical engineering field. I'm also excited to make connections with peers and professors!

Shaurya Gupta, PhD Stream

The intersection of two fields often provides various avenues for growth and innovation. Knowledge from one field is used to solve problems encountered in another – ultimately leading to the advancement of each individual field. Choosing to study at the University of Toronto provides me with access to world-class faculty and state-of-the-art research facilities. Combined with great peers and a rigorous curriculum, graduate studies at UofT provides the best environment to conduct independent research and opportunities to grow as a scientist.

I look forward to further developing my professional skills and making significant contributions to the scientific and social community.



Yaji Ke, MEng Stream

I was in Chemical Engineering at the University of Toronto and I chose bioengineering as my minor. I always had an interest in biology and wanted to make the world a better place. After having my PEY in the bio-field, I wanted to study more about biomedical engineering and decided to pursue a master's degree.

I look forward to learning new techniques in the field of biomedical engineering.

Shawn Khan, MD/MEng Stream

As a medical student, I am constantly brainstorming ways in which we can improve aspects of patient care. While I have recognized the way that technology is rapidly transforming medicine, I felt limited in my own capacity to enact change and to innovate. As such, I concurrently enrolled in the M.Eng program to gain a sense of agency in my ability to develop new solutions to old problems. I hope to explore methods of designing and implementing biomedical devices, with a focus on incorporating artificially intelligent systems.

I am really looking forward to learning as much as I can from my colleagues. In particular, I am excited to be learning about AI and robotics where my group is conceptualizing an autonomous colonoscopy system that can identify suspicious colorectal polyps. In doing so, we hope to increase accessibility to colorectal cancer screening and push the boundaries of what is considered possible in medicine.

Anchana Kuganesan, MASc Stream

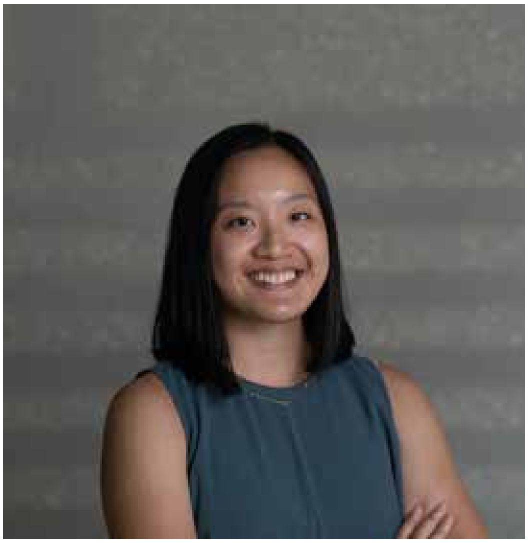
While completing my undergraduate degree in Life Sciences, I knew I wanted to pursue research in graduate school. I chose Biomedical Engineering at the University of Toronto because I saw that I could use my background and experiences to take a more technical approach to solve problems in medicine. The endless opportunities for collaboration with all of the different institutions in the city led me to select UofT.

I am looking forward to so much this year! I am hoping to learn more about my research focus, work with other BME students and my lab team, and explore the city.

Benedikt Licht, MASc Stream

I am strongly connected to the University of Toronto through family, which includes current students and alumni, as well as the varsity volleyball team. My experience at this university throughout my undergraduate career in the Life Science program has really inspired me and made me excited about being able to contribute to scientific knowledge and progress. BMEoffers research opportunities that allow me to apply my knowledge and creativity while working on developing therapies for important diseases. Furthermore, the positive environment at this institute with all the extremely helpful and friendly staff, fellow researchers and PIs encourages me to want to learn, ask questions, and get involved.

I am excited about the opportunity and challenge of contributing to developing new therapies for important diseases. I am hopeful that this will have an impact on clinical treatment and improve the lives of patients and their families. I am also looking forward to developing my research skills and becoming an expert in my field of study.



Janice Pang, PhD Stream

The Institute of Biomedical Engineering offers a network of scientists and clinicians conducting leading research in the field of nanomedicine. This program is also in close proximity to accelerator programs that will enable me to commercialize my biomedical innovations.

During my Ph.D., I look forward to interdisciplinary learning and networking with scientists and clinicians in nanotechnology and beyond.

Megh Rathod, MASc Stream

I am fascinated by the intersection of engineering and medicine at BME. I am really curious about the various projects going on at the University of Toronto and its close collaboration with clinicians, scientists and engineers within Toronto and beyond. I felt that as long as I put the work in, there would be a higher ceiling at UofT, and that's exciting.

I'm really looking forward to furthering my scientific training, developing niche skills, and really being able to dive deep into a project and chase my curiosity. Also, just being a sponge and soaking up all this unique experience has to offer.

Danielle Ribeiro, MEng Stream

I first became interested in engineering to learn more about designing and developing solutions to assist my uncle who has cerebral palsy and is quadriplegic. Living with someone who has a disability makes you think more about the design, usability, and accessibility of devices to aid individuals. After completing years of education and extra-curricular projects in assistive device research and design, I realize my passion is building solutions to create opportunities for individuals with chronic diseases and disabilities. Through the Biomedical Engineering program at the University of Toronto, I hope to learn how to take a human-centred approach to design and develop assistive devices for improved quality of life.

I am looking forward to learning more about medical device design and development with the goal of becoming a Clinical/Rehab Engineer and an innovative leader. I also hope to meet new people and make new connections during my time at UofT.

Meghan Rothenbroker, PhD Stream

I chose UofT because of the faculty, the research, and the city!

I'm looking forward to conducting impactful research and making great friends.

Darshpreet Sangha, MEng Stream

UofT is a world-renowned university with professors that have connections around the world. They have amazing industry partners that would really help propel my career forward.

I'm looking forward to developing real-world skills that I can apply to my internships.

Morteza Sarkari, MEng Stream

I've always been fascinated with medical technology and see this as a way to help improve the health and lives of people through scientific innovation.

I'm looking forward to networking with people in the field and getting introduced to real-life examples of biomedical engineering in action.

Danielle Serra, MASc Stream

I chose BME at the University of Toronto because it allowed me the perfect opportunity to combine my research interests in regenerative medicine with the upcoming field of synthetic biology. Grateful to work with world-reknown scientists, the university allows me to learn from the best as well as provides opportunities to embark on entrepreneurial ventures within the institute.

I am looking forward to meeting like-minded people as well as generating meaningful networking connections. Additionally, I am excited to grow as a person and scientist to become an expert in my field.

David Taylor, PhD Stream

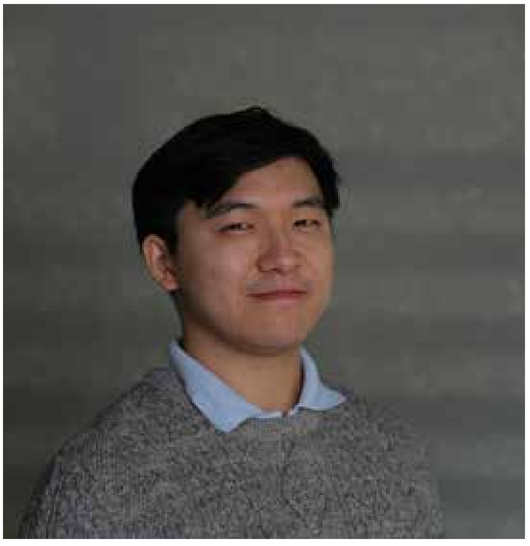
I was born and raised in Toronto. Whenever I had the opportunity to visit a research facility at UofT, I was always inspired. I chose the Biomedical Engineering program because I feel that training at the institute will allow me to make an impact in the biomedical research community and form long-lasting relationships with like-minded people.

I want to expand my research abilities that can contribute impactful new information to the research community, and I hope that my training will provide me with a variety of potential career paths in the future.

Laura J. Wheeler, MASc Stream

The quality mentorship, courses, and interdisciplinary collaboration available compelled me to choose Biomedical Engineering at the University of Toronto.

I am looking forward to collaborate with skilled and passionate academics.



Jonathan Wu, MASc Stream

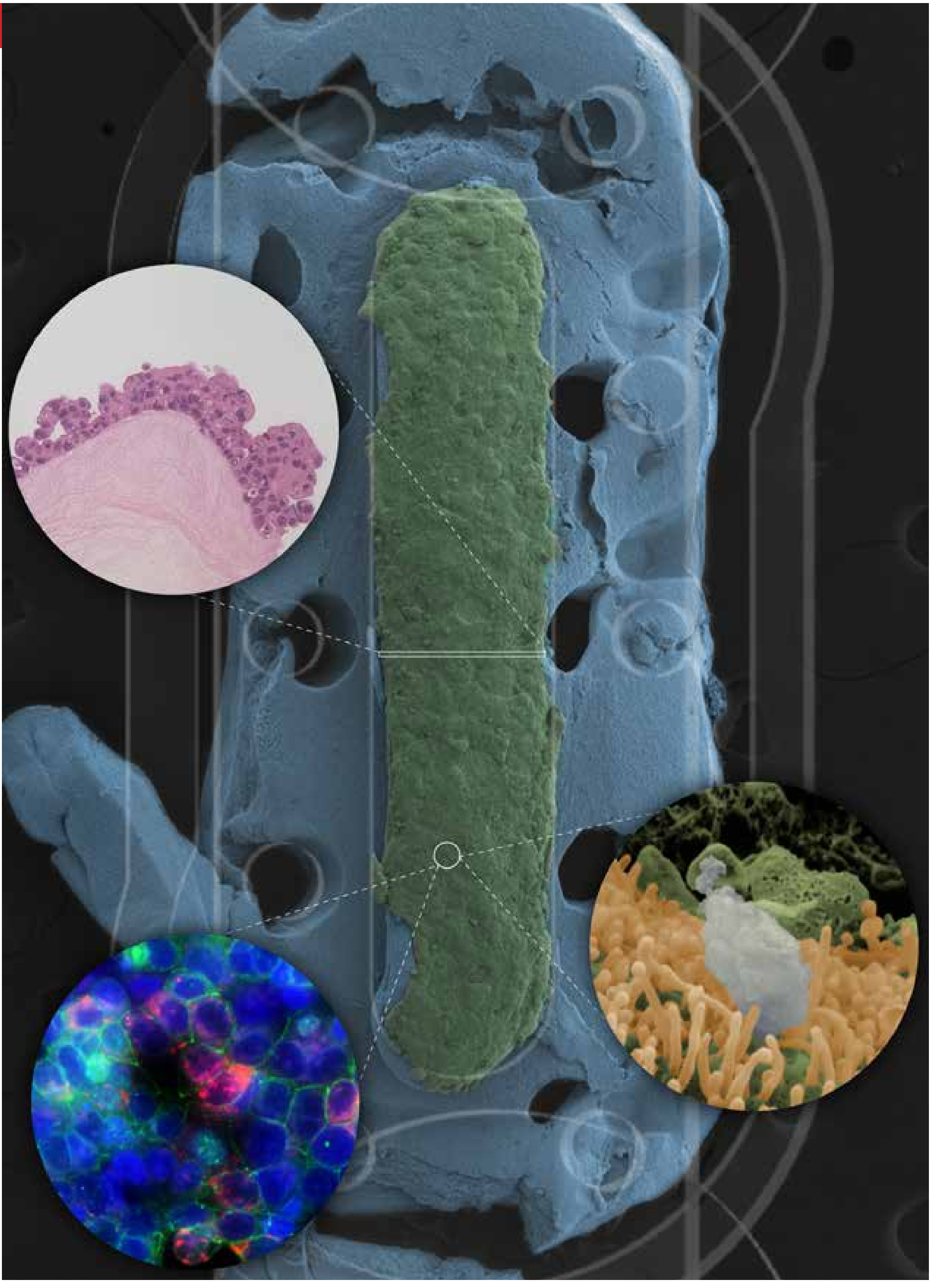
I want to expand my technical knowledge with medical devices and take advantage of UofT's entrepreneurial environment to embark on a start-up.

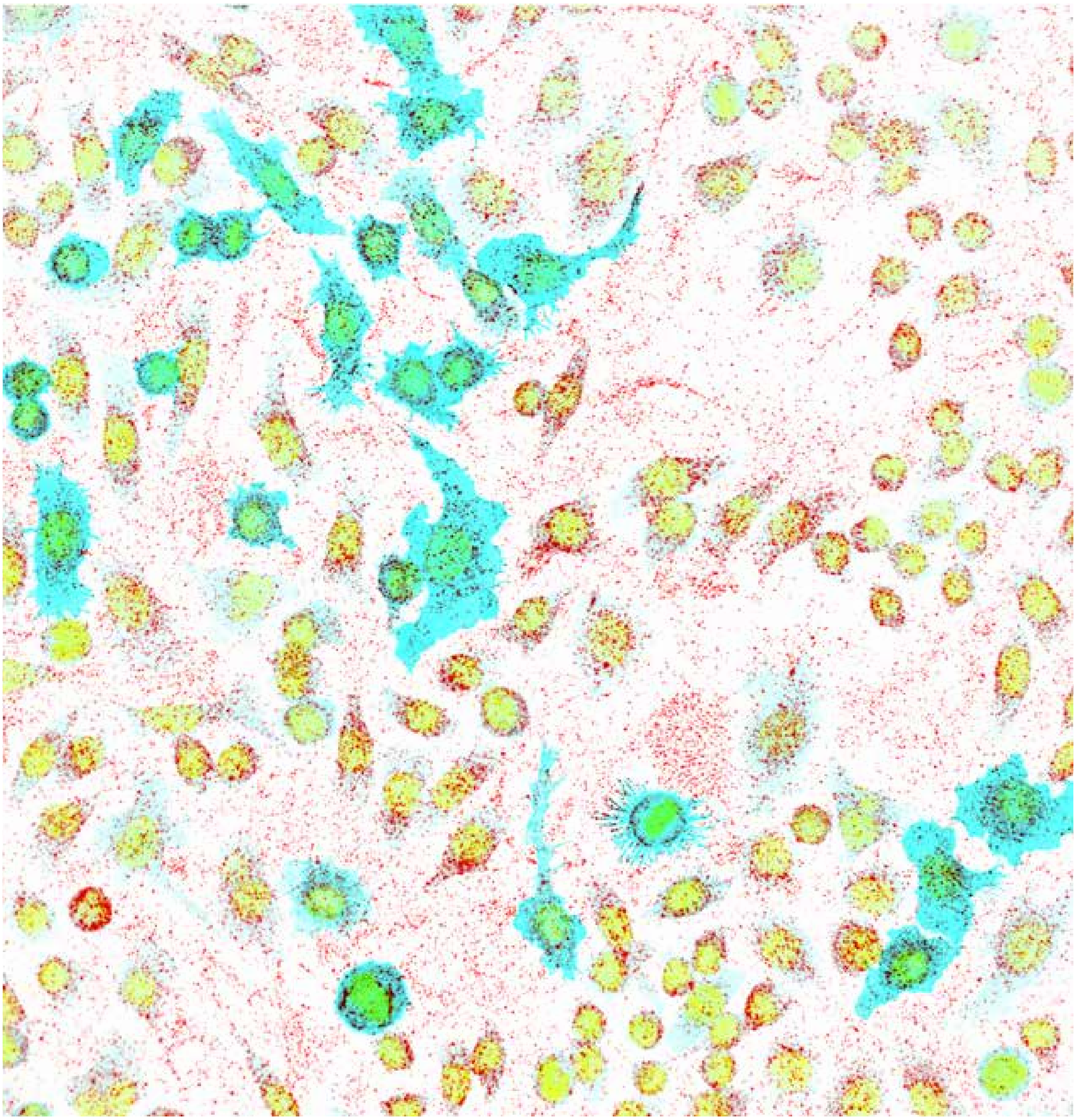
I am hoping to expand my network and getting my hands dirty with some research work!

Zi Xuan Zhang, PhD Stream

I completed my undergraduate degree at the University of Toronto, so it was an easy choice to continue my academic career in the same supportive, nurturing, yet intensive environment.

I'm looking forward to growing as an independent researcher and making meaningful connections with like-minded peers!



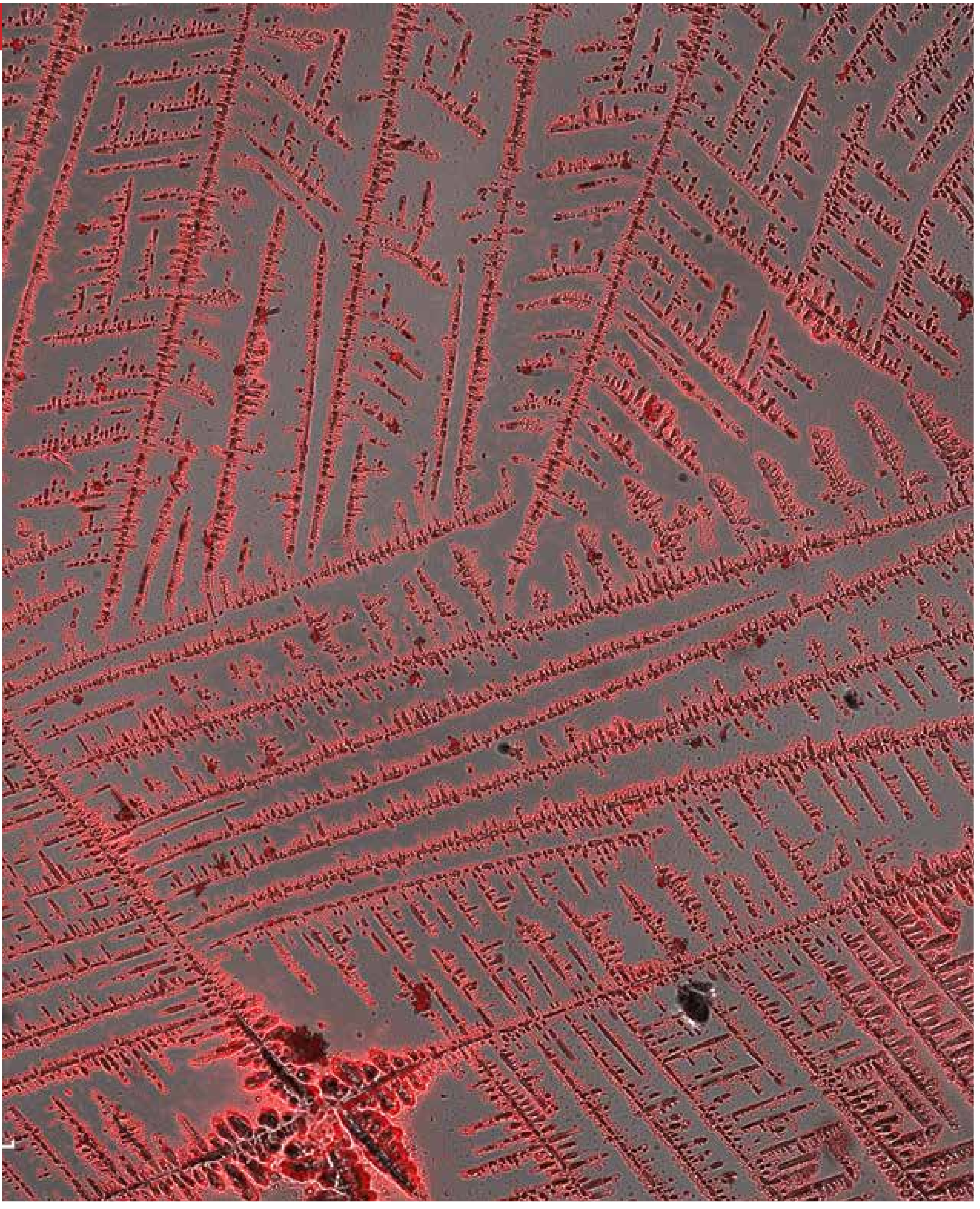


SIWAN PARK, PHD CANDIDATE (LEFT)
EDMOND YOUNG LAB

We have developed a lung airway-on-a-chip consisting of an airflow system combined with airway epithelial cells cultured in a biodegradable floating hydrogel. This microfluidic system enables the delivery of particulate matter to the live epithelial cells, which can then be extracted from the chip for various biochemical characterizations. This system represents a promising in vitro platform to study the effect of air pollution on lung airway epithelial cells.

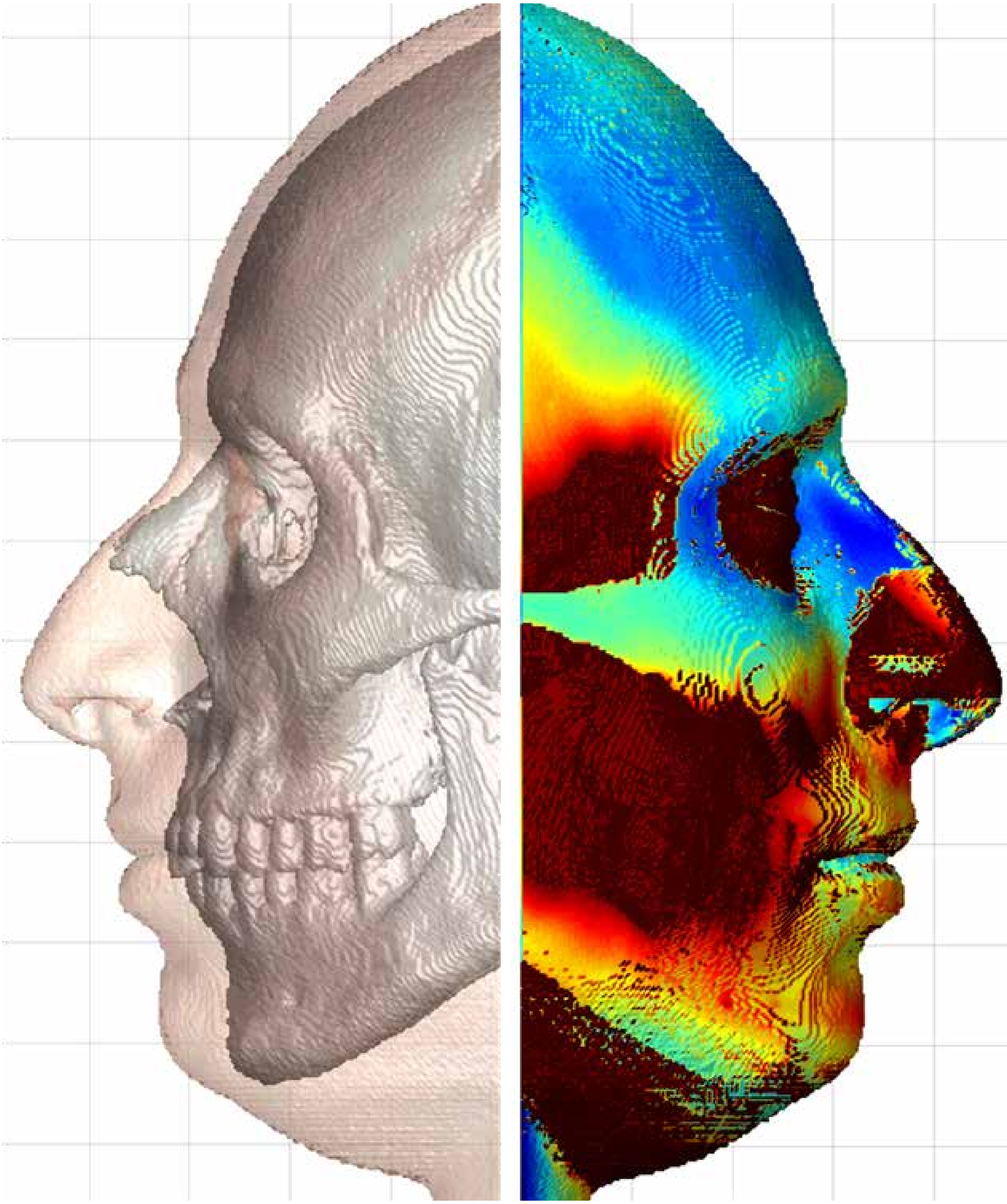
WENDY WANG, POSTDOCTORAL FELLOW (TOP)
LEO CHOU LAB

Nanodevices created out of DNA (red) were introduced to macrophages (cyan) in culture. Cell nuclei are labelled in yellow.



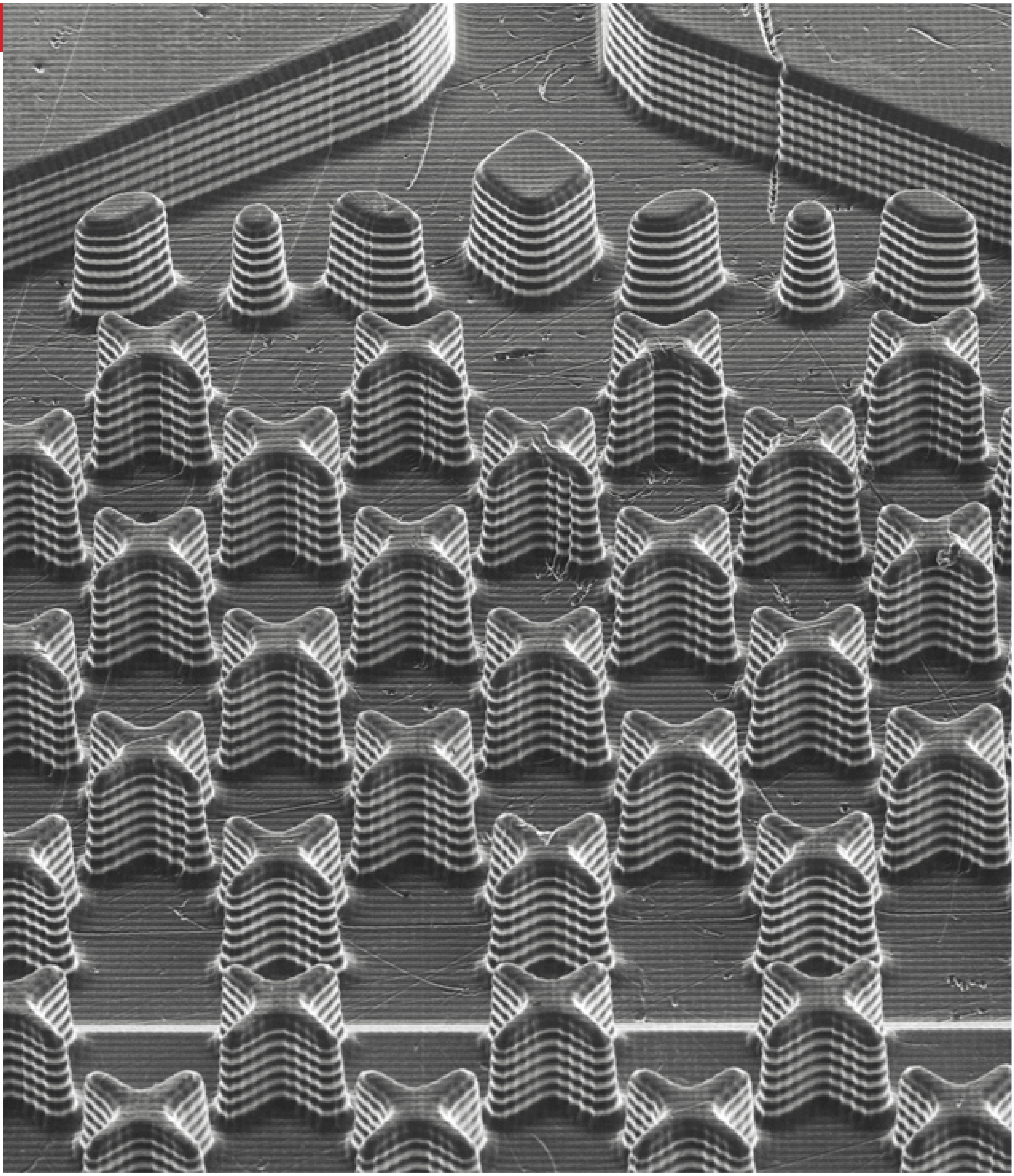
CHANTAL TREPANIER, MASC CANDIDATE
PAUL SANTERRE LAB

Nanoparticle crystalline lattice.



ZACHARY FISHMAN, POSTDOCTORAL FELLOW
CARI WHYNE LAB

On a 3D head CT scan, the facial soft tissue thickness is visualized between the segmented skin surface and the skull (0 to 20 mm scale).

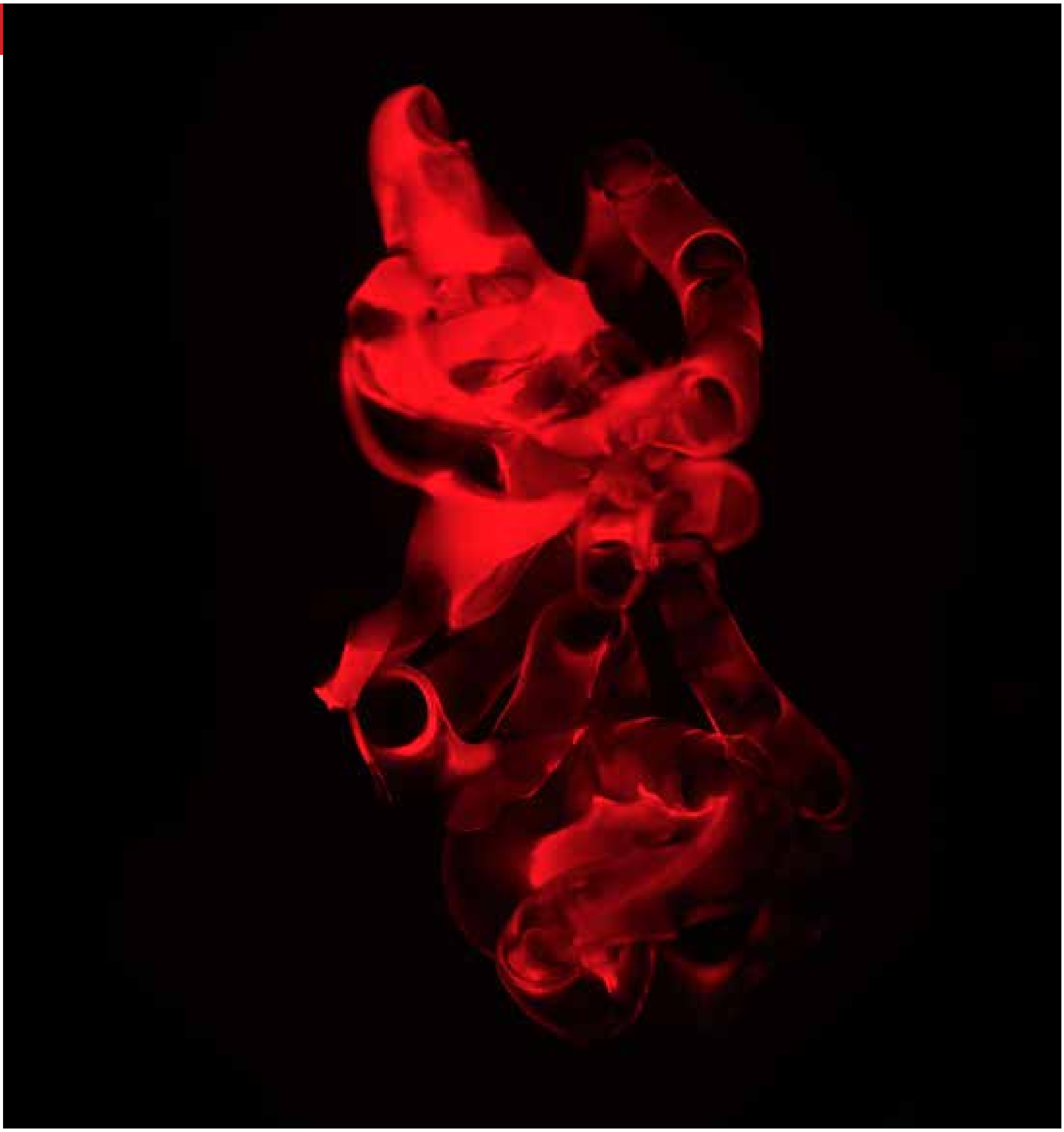


ZONGJIE WANG, PHD CANDIDATE
SHANA KELLEY LAB

This SEM image reveals the 3D-printed microstructure of a microfluidic system which has been applied to early cancer diagnosis and cell enrichment for immunotherapy.

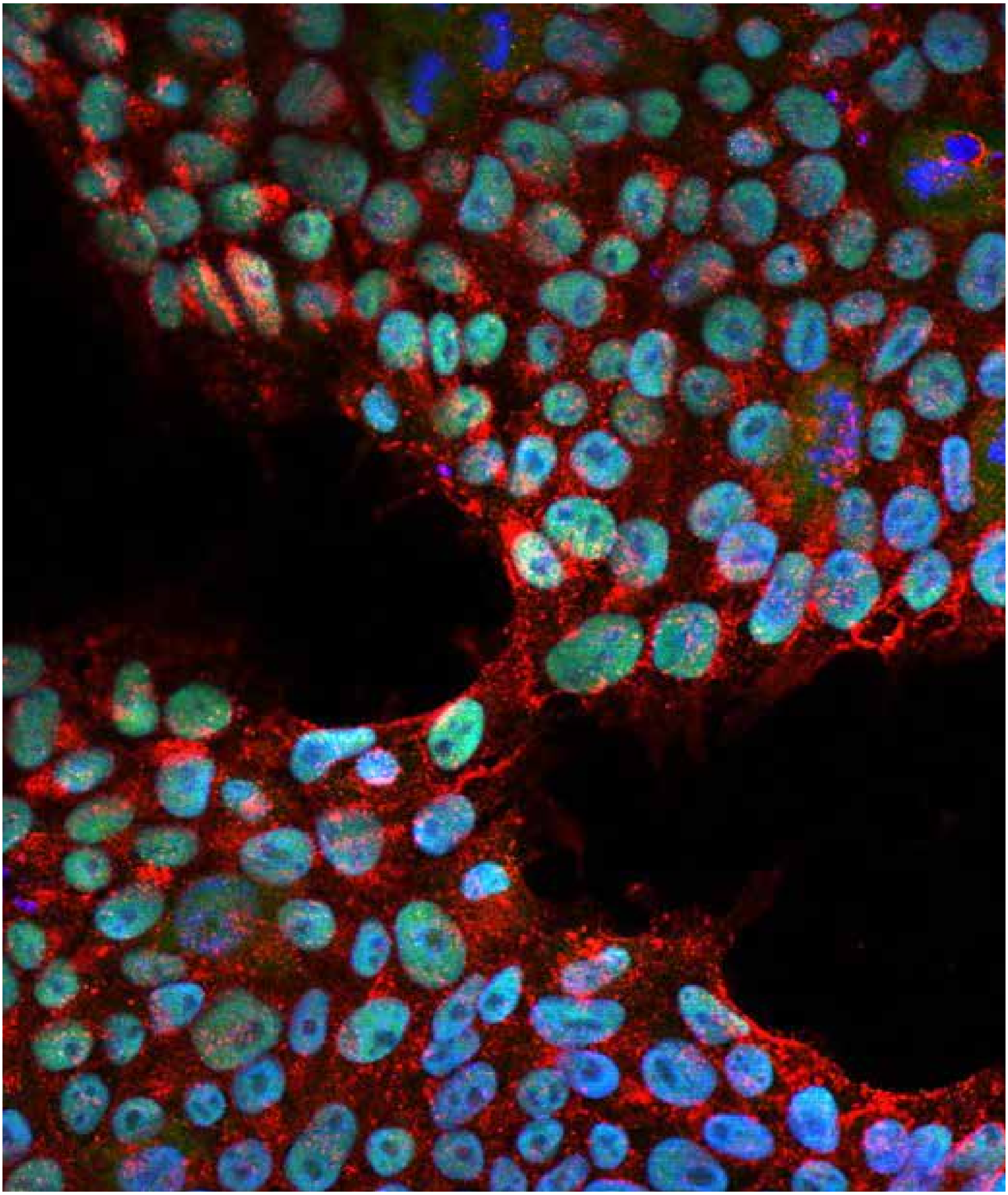
ZI XUAN ZHANG, PHD CANDIDATE
ELI SONE/SOWMYA VISWANATHAN LAB

Transmission electron microscopy is an indispensable tool used by the Sone lab to image collagen fibrils on the nanoscale.



CHUAN LIU, PHD CANDIDATE
MILICA RADISIC LAB

Scaffolds fabricated by 3D printing of bioelastomers have the ability to mimick both the structures and mechanical properties of native tissues, which are ideal for organ-on-a-chip and tissue engineering applications. When printed via coaxial extrusion in a stochastic manner, this artistic three-dimensional structure made of rhodamine-embedded poly(itaconate-co-citrate-co-octanediol) was created.



KEYU ZHUANG, PHD CANDIDATE
HAI-LING MARGARET CHENG LAB

Immunofluorescence images of human embryonic stem cells, staining for pluripotency markers OCT4 (green), SSEA4 (red), and cell nuclei (blue).

YEAR IN NUMBERS

Enrollment Trend

BME graduate student body has been experiencing steady growth in the past 5 years. At the beginning of 2021 academic year, the graduate body experienced a 2.5% growth compared to last year. The enrollment represent the number of students registered in our programs as of September of every year. Data was collected on November 22, 2021.

YEAR	ENROLLMENT
2021	366
2020	357
2019	332
2018	291
2017	303

Enrollment Breakdown

BME is one of the leading research intensive units within FASE. Approximately 60% of BME's graduate population consists of PhD students in 2021. Data was collected on November 22, 2021.

PhD	MASc	MEng & MHSc
60%	25%	15%

Gender Distribution

BME has a balanced female to male graduate student body ratio. All data is self-reported by candidates during registration. Data was collected on November 22, 2021.

47% Female

53% Male

Female Population in Individual Programs

53%	MEng
50%	MASc
45%	PhD

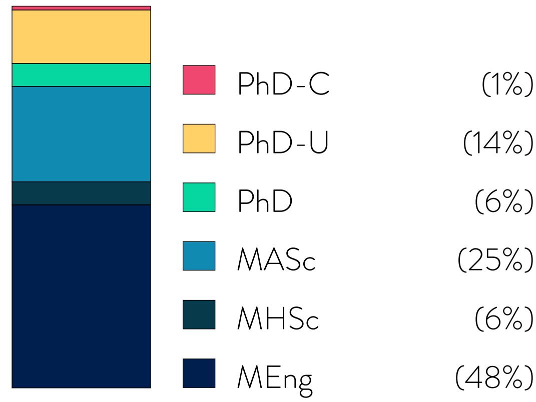
Graduation Summary

The graduation number is similar to the last academic year. The numbers indicate the students who have met all program requirements and are eligible to graduate. The numbers from the 2020-2021 academic year was calculated from adding 2020 September, 2021 January, and 2021 May sessions. Data was collected on November 22, 2021.

YEAR	GRADUATED
2020-21	111
2019-20	90
2018-19	97
2017-18	63
2016-17	47

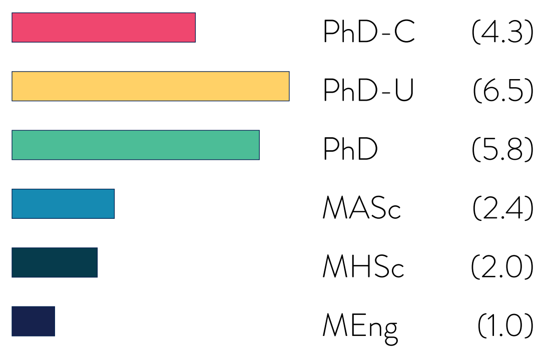
Graduation Breakdown

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 111 total graduates in 2020-2021. PhD-C: Clinical stream. PhD-U: Direct-entry. PhD: students who had previously obtained a masters. Data was collected on November 22, 2021.



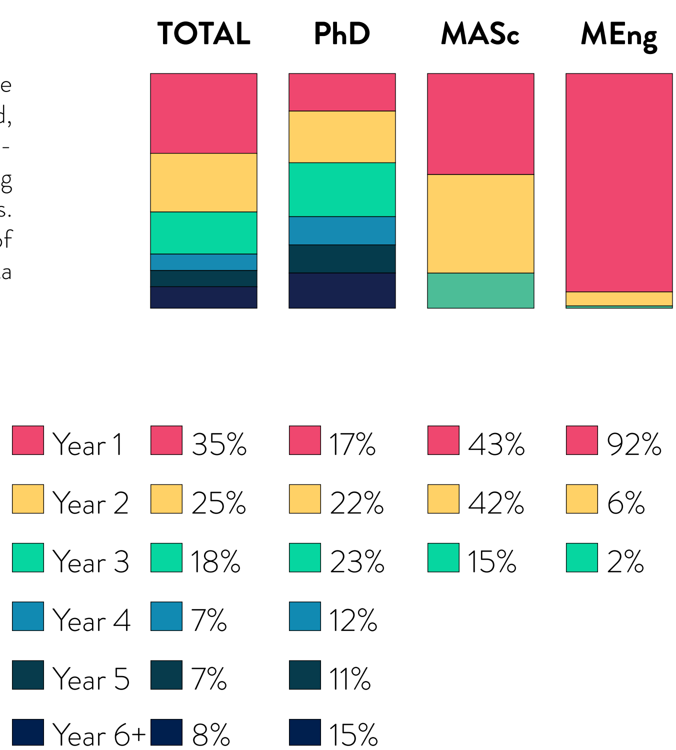
Graduation Time

Graduation time is dictated by degree type in 2019-2020. PhD-C: Clinical stream. PhD-U: Direct-entry. PhD: students who had previously obtained a masters. The number of years was calculated as an average. Data was collected on November 22, 2021.



Year Distribution

First year students are the most prevalent in the student body. Within the 366 students registered, 126 are first year students. While the student distribution is balanced in PhD and MASc 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. Data was collected on November 22, 2021.



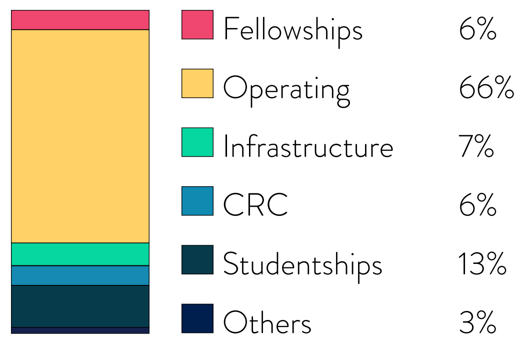
Research Funding Trend

BME have received $9.31 million in research funding amongst 40 core faculty members. On average, funding per faculty member was approximately $0.23 million between September 2020 – August 2021.

YEAR	FUNDING
2020-21	$9.31M
2019-20	$11.13M
2018-19	$10.51M
2017-18	$12.02M
2016-17	$7.82M

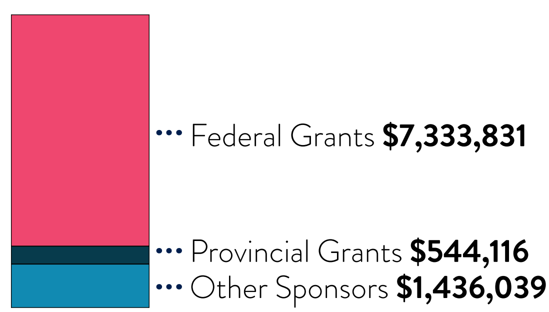
Grant Distribution

There were 117 funding packages for the September 2020 - August 2021 period. Majority of the funding packages were operating grants for research activities. CRC: Canadian Research Chair funding. Others include: equipment, clinical trials, and title funding.



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 $9.31 million from the September 2020 – August 2021 period.



Publication Record

BME has published 170 peer-reviewed papers during January 2021 - December 2021 from our core faculty members. The data on the right was aggregated via SciVal, an Elsevier subsidiary. The data was collected on December 15, 2021.

YEAR	PUBLISHED
2021	170
2020	191
2019	203
2018	192
2017	229

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)
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WARREN C. W. CHAN | PhD, FAIMBE | Molecular
Professor (BME, ChemE, CHM, MSE, DC) | Director, BME
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