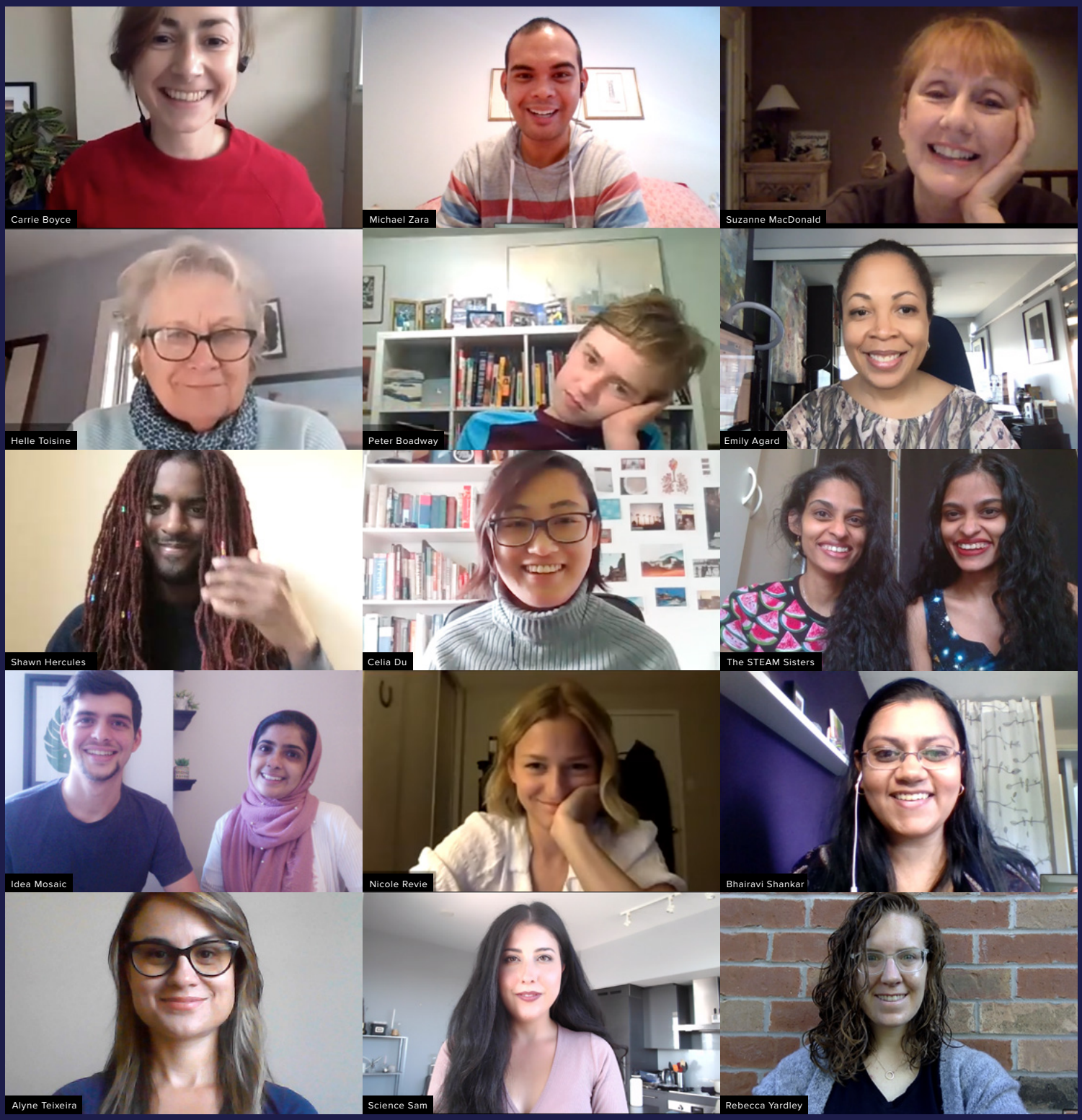
RCIScience

2020 ANNUAL

MAGAZINE



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THANK YOU FOR JOINING US IN 2019-20

for the most exciting program season we can remember!

More than 3,000 people attended 35 programs in person before the pandemic required us to move online. While this was a challenge, it is truly wonderful to be able to regularly engage with people from all across Canada, something that was only starting to happen before the pandemic. By designing programs that actually work better online than they would in person, we now have a suite of events that can continue, even after we can meet in person again.

We are also very proud of how our platform blossomed this year to feature events like *Science is a Drag*, praised for its inclusivity and noted for attracting people who would not normally attend a "science" event.

This magazine is one way that RCIScience fosters science communication in Canada. Articles are written by volunteers, many of them students, who meet the scientists behind the stories and receive feedback and guidance on their work. This year, we also launched the SciCommTO Conference and a science communication certificate in partnership with the University of Waterloo for undergraduates who attend RCIScience events and submit a written piece about one of them. One is featured in this magazine.

We hope that you will continue to attend RCIScience events and support us in our efforts to strengthen Canada's science culture through the promotion of science and of excellence in science communication.

If 2020 has taught us anything, it is that a society that values and listens to science is vital to our future.

RCIScience Editorial Team

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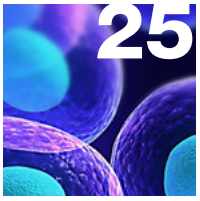

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COVER PHOTO: Like many, RCIScience embraced the video call in 2020, staying connected with our members, volunteers and partners across Canada, and continuing our 170-year-old mission to build a stronger science community.

RCIScience Magazine is a publication of the Royal Canadian Institute for Science

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Message from the Chair

DR. REINHART REITHMEIER

THE 2019-20 SEASON HAS BEEN ONE OF CHALLENGES and opportunities for RCIScience. We were on track to have our largest event attendance in recent memory. After COVID-19 restrictions began, RCIScience quickly pivoted to remote programming. Our first priority was to use our online platform to amplify good information sources for COVID-19, which you can find on our website.

We then took advantage of the growing interest in social media not just as a tool to promote programs, but as a program itself, engaging people with science in particular on Instagram and YouTube, and increasing our reach. This has been incredibly successful and I thank everyone who has helped us grow and blossom on platforms like Instagram.

Online programming will be RCIScience's "new normal", at least for the near future. We are experimenting, trying programs that we hope will continue even after we can safely gather in person once more. These include a science book club, using gaming to explore science, and cook-along events revealing the science lurking in the food we eat.

About the time this Magazine is published, RCIScience will announce the recipient of the 2020 Fleming Medal. This award, in place since 1985, is one of few recognitions of great science communication in Canada. Congratulations to Dan Falk, the 2019 recipient, whom we welcome to this exclusive group of Canadians.

Our support for good science communication was on display at the February *SciCommTO Conference*, hosted in partnership with Ryerson SciXchange and supported by NSERC PromoScience, Ryerson University and Science Rendezvous. Welcoming 150 delegates and presenters, we worked to ensure that more people can communicate science effectively. You can watch a highlight video here.

One hundred years ago, as the world emerged from the 1918 Flu Pandemic, a discovery was taking place in Toronto that would change the world. RCIScience will celebrate the centenary of the discovery of insulin throughout 2021. Working in partnership with the Banting Research Foundation, the Sir Frederick Banting Legacy Foundation and the Charles H. Best Foundation and with support from Sanofi Canada and the University of Toronto, we are presenting a series of programs called *Insulin to Innovation*, and a book, *100 Lives of Insulin*.

As the 1918 flu pandemic tore through Canada, the Institute shut down. There are no records of talks from late 1918 through to 1921 and the Council did not meet. During the current pandemic, technology that was enabled by science has allowed us to not just continue, but flourish. And it is very important that we do so. As some have said, science is the path out of the pandemic. Trust in science is critical to our society's future. Building trust happens through communication. We are proud to have created a strong platform to connect Canadians to science and build a community of science supporters in this country.

These are exciting and uncertain times, and we know this coming year will not look like years past. Further, the economic situation has created personal hardship for many. Given this, the RCIScience Board decided to extend membership through to June 30 2021 at no cost.

But our expenses remain even if our events look different. For those who can, please consider paying your membership fees for this year. Any money received will be counted as a donation for 2020-21 and you will receive a tax receipt for the full amount. For those who can contribute more, please send a note to donate@rcisicence.ca to learn about how you can support our efforts.

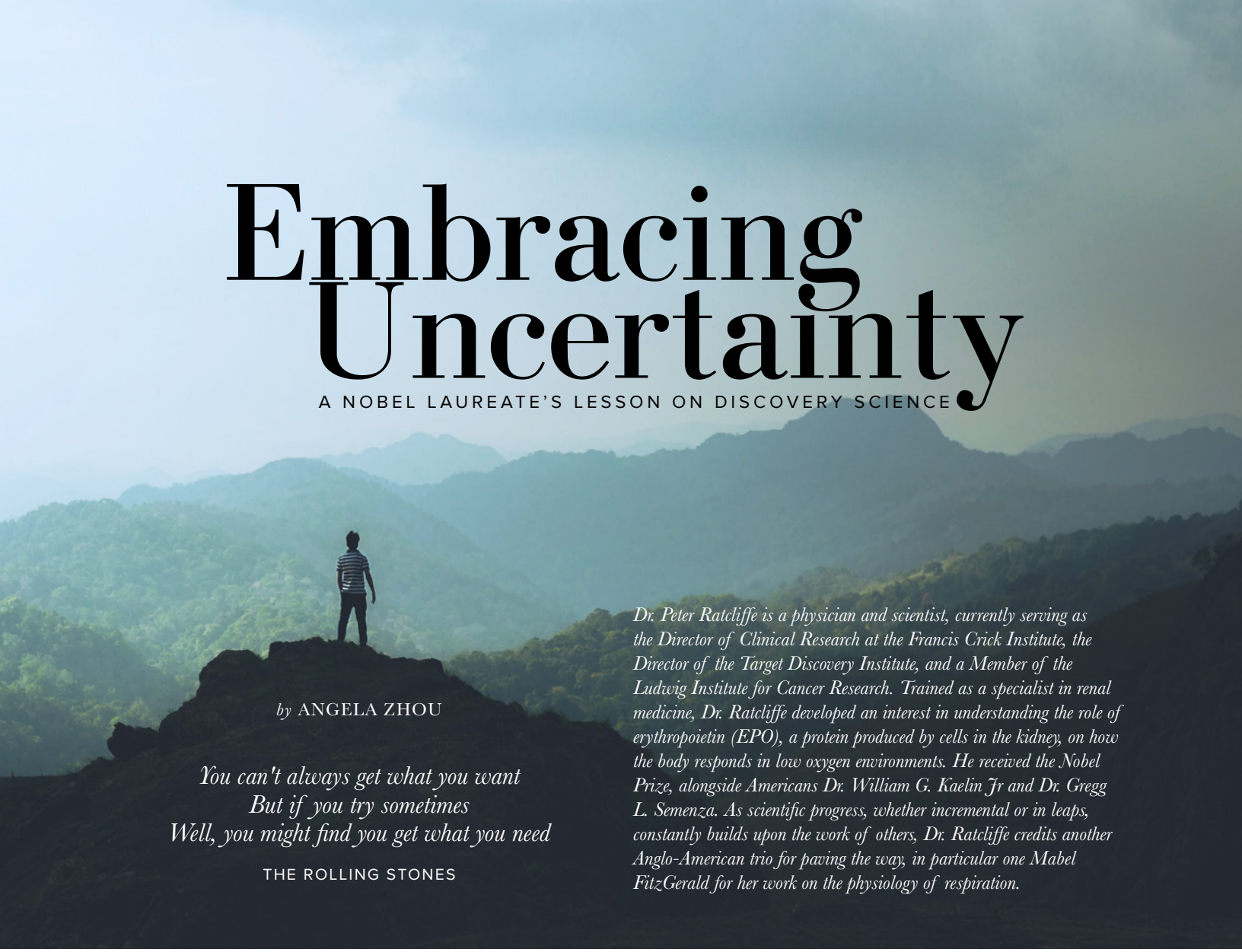
As my term as Chair ends, I would like to thank the volunteer board trustees and the past Chairs who will now sit with me on the Advisory Board. We were all deeply saddened by the untimely loss of our long-time supporter and Board Trustee Dr. Deborah Zamble, a faculty member at the University of Toronto and leading expert in metallo-proteins. Deborah's enthusiasm for our mission and her willingness to help will be very much missed.

The Board and the staff have worked hard to bring my vision for RCIScience to life. That vision includes this magazine, which I hope that you enjoy. It is made possible through the efforts of an incredible group of volunteer writers, many of whom are students, along with managing editor Angela Zhou, who started as a volunteer writer, and designer Yianni Tong, who began her association with RCIScience in the Youth Science Academy in the 1990s. I would also like to thank the Executive Director Kirsten Vanstone, Programs Manager Carrie Boyce, and our regional Event Coordinators Jenessa Doherty and Celia Du for keeping RCIScience running and our programs sharp and relevant.

I look forward to continuing my involvement with RCIScience and promoting its mission to bring science to the public.

Embracing Uncertainty

A NOBEL LAUREATE'S LESSON ON DISCOVERY SCIENCE



by ANGELA ZHOU

You can't always get what you want
But if you try sometimes
Well, you might find you get what you need

THE ROLLING STONES

Dr. Peter Ratcliffe is a physician and scientist, currently serving as the Director of Clinical Research at the Francis Crick Institute, the Director of the Target Discovery Institute, and a Member of the Ludwig Institute for Cancer Research. Trained as a specialist in renal medicine, Dr. Ratcliffe developed an interest in understanding the role of erythropoietin (EPO), a protein produced by cells in the kidney, on how the body responds in low oxygen environments. He received the Nobel Prize, alongside Americans Dr. William G. Kaelin Jr and Dr. Gregg L. Semenza. As scientific progress, whether incremental or in leaps, constantly builds upon the work of others, Dr. Ratcliffe credits another Anglo-American trio for paving the way, in particular one Mabel FitzGerald for her work on the physiology of respiration.

When Mick Jagger and Keith Richards penned their 1969 hit song, *You Can't Always Get What You Want*, little did they know that they were describing the scientific journey of 2019 Nobel Laureate, Sir Peter J. Ratcliffe. Dr. Ratcliffe's ground-breaking work on how cells sense and adapt to oxygen availability was awarded the 2010 Canadian Gairdner International Award and the 2019 Nobel Prize in Physiology or Medicine. He took us through the twists and turns of his illustrious career at a mid-winter lecture hosted by RCIScience and the Gairdner Foundation, revealing the often serendipitous nature of science.

KNOWLEDGE BUILDS ON KNOWLEDGE IN UNEXPECTED WAYS

In 1911, John Scott Haldane and Claude Gordon Douglas embarked on the Oxford-Yale expedition to Pike's Peak just outside of Colorado Springs to study altitude and oxygen adaptation. Mabel FitzGerald was invited on this trip, but was not allowed to join the men on the summit due to concerns of her being an "unchaperoned" female. Instead, she took measurements at intermediate altitudes in nearby mining towns. Although others had documented how the human body adapted to varying oxygen levels, FitzGerald was the first to show how extraordinarily sensitive the body's physiology is. She did this by measuring changes in breathing and in the blood.

It was this incredible sensitivity that spurred Dr. Ratcliffe to search for the body's oxygen sensor. To do this, his team identified oxygen-sensitive cells in the kidney that produce a protein called erythropoietin (EPO) in low oxygen conditions. They planned to transfer genes from these cells into others with the goal of determining if the oxygen sensing property could be transferred. To his surprise, they had trouble finding any oxygen-insensitive cells. It turned out that oxygen-sensitivity is not a property only of specialized kidney cells, but rather a property common to all cells of the body. "This idea made my career," Dr. Ratcliffe recalls.

PHOTO: Alfred Aloushy/Unsplash

A FIELD OF YOUR OWN

Excited by these findings, Dr. Ratcliffe and his team submitted a paper to the prestigious journal, *Nature*. The journal sent back a rejection letter, stating that they had great difficulty finding reviewers who were expert enough to assess the paper. Rather than being disheartened, Dr. Ratcliffe saw an opportunity. "This means you're in a field of your own," he explains. His advice to trainees and early career scientists is to "carve yourself a niche." Too often, he explains, PhD graduates feel like they have to go to a big, established lab after completing their degrees, but in those labs, they become just another postdoctoral fellow in a crowded field. "We believed what we were doing was important," Dr. Ratcliffe reflects. Their persistence paid off and the team was able to work on piecing together the oxygen sensing pathway, building the foundation for a small field that quickly grew around them.

What Dr. Ratcliffe's group, together with those of Drs. Kaelin and Semenza (co-Nobel recipients for this discovery) uncovered is the step by step process of how cells respond to hypoxia. Described briefly, in the presence of oxygen, hypoxia-inducible factors (HIF) inside a cell are kept inactive by a suppressor protein called Von Hippel-Lindau (VHL). When oxygen is low, HIF is allowed to access the cell's DNA, working with other mechanisms to switch on genes that allow the cell to change its activity. For example, the cell can start producing EPO, which then stimulates more red blood cell production to help deliver oxygen more efficiently throughout the body.

This work is exciting, not just because it describes a fundamental physiological process, but because it can also lead to drug therapies for common medical conditions by blocking certain components of the oxygen-sensing pathway. For example, a drug that prevents the suppressor protein VHL from acting allows genes to switch on that induce more red blood cell production in patients with anemia. Similar concepts exist for some kidney diseases and cancers.

COMPETITIVE SYMBIOSIS

Science is a global endeavour where the curious pursuit of knowledge, often from seemingly unrelated research topics by different groups around the world, finds ways of fitting together to complete different puzzles. The exploration of the oxygen-sensing pathway was no different. As Dr. Ratcliffe was trying to piece together this puzzle, Dr. Christopher Schofield at the University of Oxford published a paper in 1995 about an enzyme involved in antibiotic synthesis. This enzyme was in the same family as the oxygen sensor that regulates HIF activity, helping complete the picture of how it worked.

In a more unlikely coincidence, a 1983 study on mutant worms provided another piece of the puzzle. Dr. H. Robert Horvitz's group at MIT studied 149 different mutations of the *C. elegans* worm to learn about genetic control in the worm's egg-laying. They found that mutant #9 had no oxygen-sensitivity. Further investigation revealed that mutant #9 lacked the very oxygen sensor the group had been studying. Along with previous work showing that this same oxygen sensing pathway is also present in fruit flies, Dr. Ratcliffe's team demonstrated that the mechanism they had uncovered exists across the animal kingdom.

Plants, on the other hand, seem to have a completely different set of proteins to regulate oxygen sensing. Dr. Francesco Licausi from the Max Planck Institute of Molecular Plant Physiology in Germany discovered this and a chance meeting with Dr. Licausi spurred a new collaboration in which the two scientists and their respective teams investigated what would happen if a plant's oxygen sensor was replaced with the human version. The startling result was that the plant could still function and respond to changing oxygen levels using the human sensor. This strange research uncovered another fundamental piece of the puzzle. That a common system—one in which the oxygen sensor is a type of molecule known as a G-coupled protein—exists in plants as well as animals, getting at the heart of what defines something that is alive.

Dr. Ratcliffe describes the work of scientists as competitive symbiosis. You want to be the best in your field, but at the same time, collaboration and the sharing of information must happen in order to make true and important discoveries.

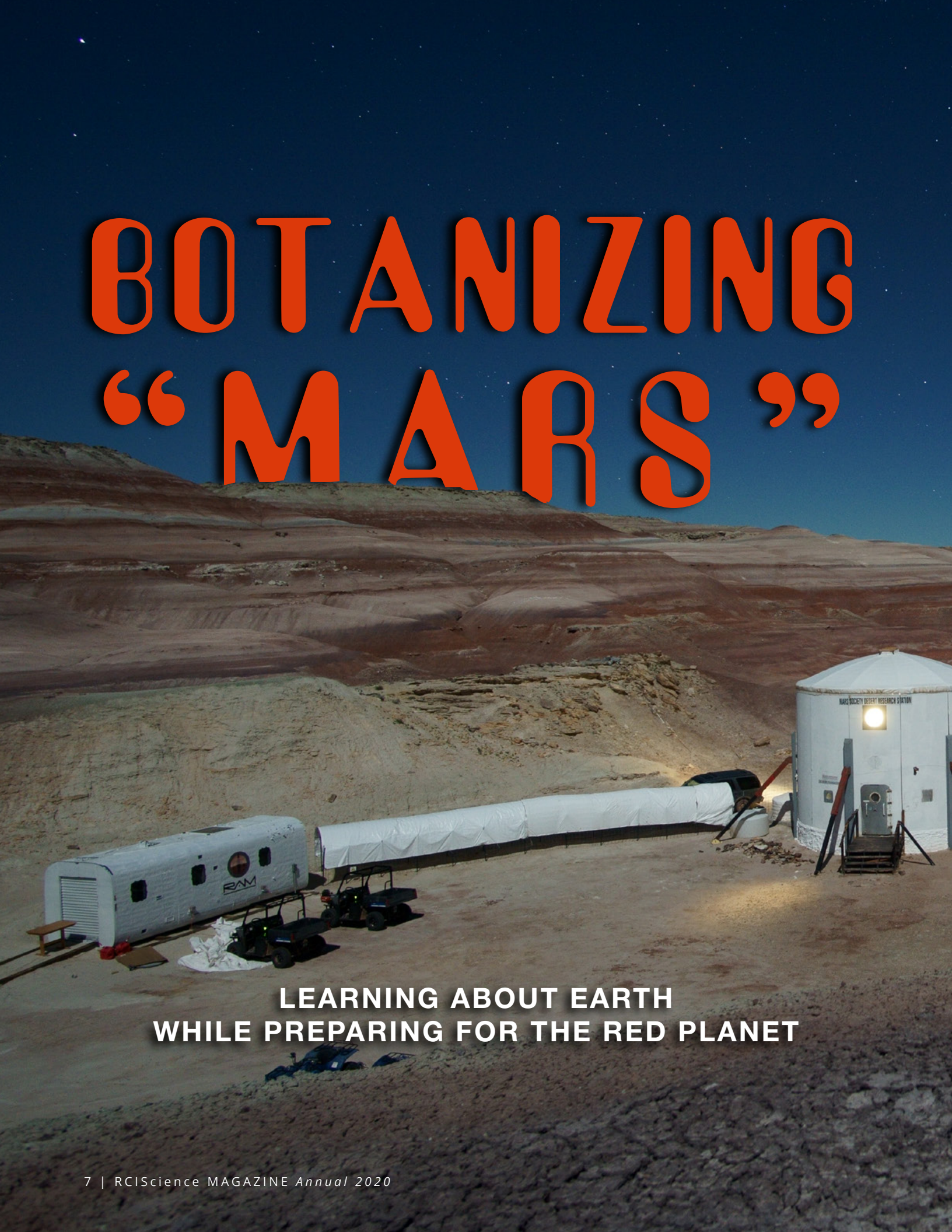
YOU GET WHAT YOU NEED

Quoting the Rolling Stones about getting what you need, Dr. Ratcliffe emphasized the importance of embracing uncertainty. Research science and drug discovery benefit from the same risk-taking and trial and error that produced this Nobel Prize winning research. "Molecular genetics will give you [drug] targets," Dr. Ratcliffe says. "Failure to appreciate [molecular sciences] will cost the pharmaceutical industry millions of dollars."

Indeed, as drugs targeting the oxygen sensing pathway show promise in preclinical and clinical trials for various diseases, it is worthwhile to remember the endless persistence and the happy accidents that got them there. ●

Click here to watch "Adventures of a Physician in Discovery Science | Sir Peter Ratcliffe, 2019 Nobel Prize Winner" in full on RCIScience's YouTube channel now.

Dr. Peter Ratcliffe, RCIScience lecture in Toronto.



BOTANIZING "MARS"

LEARNING ABOUT EARTH WHILE PREPARING FOR THE RED PLANET

PHOTO: Paul Sokoloff/Canadian Museum of Nature

PAUL SOKOLOFF, a Senior Research Assistant in botany at the Canadian Museum of Nature in Ottawa, humorously describes his everyday workspace as a "plant morgue". But Paul's work documenting plant diversity extends beyond the walls of his laboratory. As a member of the Arctic Flora of Canada and Alaska Project, he focuses on collecting specimens and cataloguing plant biodiversity by looking at similarities and differences across different taxa (the grouping of different plant species) in Canada and beyond. His work in understanding biodiversity in the most remote and extreme environments on Earth not only helps us understand our own planet, but also gives us a peek into another, unraveling what life could be like on Mars.

A DAY IN THE LIFE

A typical field day for Paul might involve a 12-hour hike covering roughly 10 km while collecting plant specimens in the Canadian Arctic. To preserve these specimens for study, Paul uses a plant press to flatten and dry samples, a technique that's been around for hundreds of years. These samples are then stored in an herbarium within the museum where they are locked up tightly to control for pests and can last indefinitely. Other aspects, such as date and location of collection are also recorded, which can be useful for scientists looking at the definition and distribution of different plant species. Currently, there are more than one million samples in the herbarium at the Canadian Museum of Nature documenting the vast biodiversity of Canadian plants.

However, Paul's love for extreme environments does not stop at the Arctic. To conduct a series of "Earth-based, but Mars-focused" experiments, he became involved with the Mars Desert Research Station in Utah, where crews from around the world can conduct research in an environment similar to the surface of Mars. In these microcosms that simulate Mars expeditions, groups work to solve problems like how a team will not kill each other while working and living in inescapably close quarters? What will they eat when they get to Mars? And how can space helmets be prevented from fogging up?

In 2014, Paul traveled to the desert research station just outside of Hanksville, Utah, to spend two weeks living in an 8 m diameter hub—slightly bigger than a typical downtown Toronto condominium alongside 6 other scientists. While indoors, the team spent their time cooking shelf-stable food (refrigeration is reserved for storing samples) and keeping active with yoga and dancing. This was all in addition to completing mission tasks, such as writing meticulous reports for Mission Control, growing vegetables and conducting long-term scientific experiments. They even tested whether urine could be used as a fertilizer in Martian soil (verdict: it's not great) and made a cast for a broken arm from local resources! However, the more important aspects of their mission came from the time spent outside.

EARTH-BASED, MARS-FOCUSSED

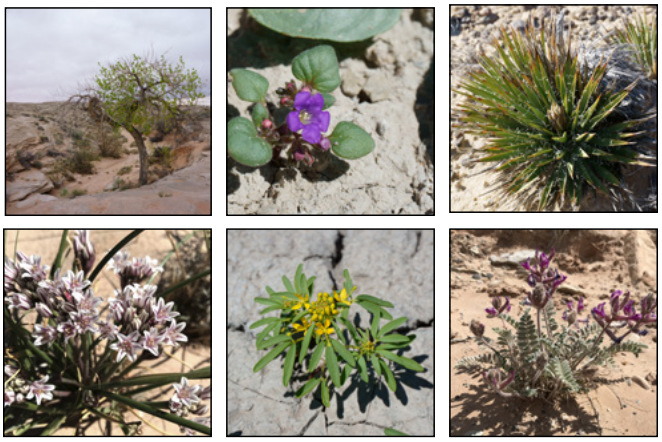
To simulate what it would be like working outside on Mars, Paul and his colleagues wore simulated space suits paired with helmets and thick gloves. Outdoor tasks included habitat maintenance, exploring the land with rovers and taking soil cores and geological samples. Being a botanist, Paul took part in collecting 69 different specimens from locations near the station. These collections included shrubs, cacti, and lichens and 58 of them were new records for the area "I like the idea of bringing this really old-fashioned kind of science to this space age simulation," he shared.

Paul believes that doing Earth-based research on the kind of science we need to conduct when we arrive on Mars provides us with valuable information for Mars while also teaching us new things about our own planet, particularly about its extreme

Paul's team at the Canadian Museum of Nature has spent the last 10 years collecting and documenting plant diversity across the Canadian Arctic, alongside many community members from Inuit Nunangat—the Inuit homeland—which is composed of four regions: the Inuvaluit, the Nunavut, the Nunavik, and the Nunatsiavut. "**It is important to remember that we are in somebody's backyard**," Paul emphasized. These relationships are extremely important to ensure that northern perspectives are present in the work, and to ensure that research results are communicated back to these communities, in one of the most rapidly changing ecosystems on Earth.

Spacesuit selfie. (Photo: Paul Sokoloff)

The Mars Desert Research Station (MDRS) is a Mars-simulation campus set in a Martian planetary analogue in southern Utah. Teams include people like scientists, engineers, medical practitioners, journalists and artists, where they work to understand and mitigate the technical and psychological challenges that will come with crewed Martian exploration and conduct field research to better understand this site as an analogue of our planetary neighbour (Photo: Paul Sokoloff)



"Martian flora": new plants discovered during a research mission to record new botanical species. (Photos: Paul Sokoloff)

environments. Studying, for example, endolithic cyanobacteria, a blue-green algae that lives inside rocks, can give clues as to where to look for life on Mars because, as Paul notes, "we know that if we find life on Mars, it will be typically deep underground, inside rock and in the extreme."

Paul returned to the station in April 2019 for his most recent mission, one with a strong focus on Earth-based life. "We wanted to show off the fact that a station that simulates Mars is still an Earth-bound research station," Paul explained. "We can still do really cool biology and earth science outside of space." This time, the team was composed of a group of biologists and communications professionals who concentrated on outreach, as well as plant collection and ecological surveys examining what drives diversity across the desert landscape. During this mission they collected 65 taxa, which included desert lilies, desert onions and yuccas, to name a few. According to Paul, many of the specimens are endemic to that part of the world, making the Mars Desert Station an incredibly interesting area with an astounding diversity of species not found elsewhere on the planet. This research is also important for understanding and documenting the spread of invasive species, which can inform mitigation efforts by local authorities working to protect the desert ecosystem.

The research conducted by Paul and his colleagues tries to answer basic questions about biodiversity here on Earth, in contrast to the complex questions that arise when we consider what life on Mars looks, or looked, like. The complex systems around us can tell us much about our place in the universe. A botanist from a nature museum might seem like a strange fit for a mission to Mars, but as Paul puts it, "Our mission is to increase appreciation for the natural world and that does include things like space." Perhaps one day the museum will be just the place to house exhibits and samples collected from the Red Planet and beyond. For now, our biggest worry should not be what we will do when we arrive on the Red Planet, but rather what we can learn about it by conducting experiments close to home. ●

Click here to watch "Botanizing "Mars": Learning about Earth while preparing for the Red Planet" in full on RCIScience's YouTube channel now.

LEFT TO RIGHT: Kasia Majewski (CMN), Reinhart Ruthmeier (RCIScience), Paul Sokoloff (CMN), Kirsten Vanstone (RCIScience)

The Canadian Museum of Nature (CMN)'s National Herbarium houses 1.25 million dried and pressed plant specimens. Mundane disturbances from drips to high humidity to dreaded insect infestations can cause damage and destroy entire collections that make up a researcher's life's work. Such sensitive pieces need to be constantly monitored and protected from harm.

What happens then if the museum is forced to shut down (for who one knows how long) and access to these specimens is restricted?

The COVID-19 pandemic saw governments around the world mandating stay-at-home orders to contain the spread of the virus. The CMN closed its doors to all visitors in mid-March. For its entire 23-year residency in the Gatineau facility, CMN has never been left so vacant for this long. The indefinite wait is enough to stir all sorts of anxieties over the state of these precious samples. Scientists have taken to making weekly visits to their labs to check in, making sure to maintain physical distance and not run into others in the building doing the same.

In addition to the National Herbarium, other facilities also took precautions to ensure that the CMN's collection of 14.6 million specimens is kept safe. The National Biodiversity Cryobank, a genetic library of 30,000 animal and plant tissue samples, moved chunks of its collection into liquid nitrogen deep freeze at -160°C. At this temperature, movement of molecules and atoms is dramatically slowed, thus reducing degradation over time.

Live animal exhibits present a greater challenge. Keeping animals fed and habitats clean required a consolidation of exhibits spread across three floors since only one employee was allowed inside the building at a time to take care of all of them. The museum also had to look for new food suppliers because physical distancing meant that you could not just walk into a few stores and grab crickets and fish pellets for the hungry inhabitants.

While the pandemic mounted immense challenges for the CMN, many researchers embraced silver linings and took the time to catch up on paperwork, documenting and keeping the collection's records up to date.

canadian museum of nature
nature
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VOLUNTEERSPOTLIGHT

NICK DEMERS

Nick Demers is a PhD student in the Department of Biochemistry at the University of Toronto, studying the molecular basis of neurodegenerative diseases. Outside of the lab he enjoys running, cycling, rock climbing and playing hockey.

Nick volunteers with RCIScience as a scientific writer, contributing articles to RCIScience Magazine, and lending a helping hand at events. He strongly believes that science communication is important for everyone to enjoy and appreciate science, and that as a scientist he has a responsibility to inform the public of scientific advances and findings.

Nick's most memorable experiences to date were meeting Nobel Laureate Dr. Peter Ratcliffe and astronaut Dr. Robert Thirsk. To anyone considering joining RCIScience, he suggests, "You should absolutely get involved! It is a wonderful, fun team to be a part of, and the work that RCIScience does is so important in growing the scientific community in Canada."

GUIDED TOUR INCLUDED

by ANGELA ZHOU

The moai statues of Easter Island stood tall, the final vestiges of a lost society gazing towards the horizon, as darkness fell over the land for almost 5 minutes. These silent mystical stone monoliths, lit only by the wispy ring of the sun's corona, was a sight that had not been seen in this remote location for 13 centuries. When the moon had finally passed and the total solar eclipse was over, Dan Falk had captured the shot of a lifetime. This iconic photo—now framed and hung in the Falk house living room—was one of many in a captivating photo series documenting Dan's eclipse-chasing journey in 2010 for *New Scientist*.

Almost a decade later, Dan remains adventurous and curious, finding science in unexpected places and bringing them to readers and listeners around the world. An award-winning author, journalist, and broadcaster, Dan Falk now adds the 2019 Fleming Medal of Excellence in Science Communication to his long resume of achievements. Dan joined RCIScience for a fireside chat with long-time friend, *BookLab* podcast co-host and science journalist, Amanda Gefter. Reminiscing on his career and the changing landscape of science journalism, they traded stories about Stephen Hawking, life as a freelancer and everything in between.

Dan Falk is a freelance journalist whose award-winning work has spanned many media formats, including countless articles for renowned news outlets, three acclaimed books, numerous radio documentaries and a podcast. Dan sees himself as a combination of educator, entertainer and translator. "We're not here to do public relations work for scientists," Dan explains, "We're independent." Instead, he likens his job to that of a tour guide at an art gallery or a museum. "You'll get something out of it if you're there alone, but you'll get more on the tour." On Dan's "tours," you get context and history for science, narratives that engage audiences and help them understand why research, innovation and discovery are important. Over the course of his career, Dan has guided the public through a comprehensive list of topics, covering everything from morality to Stonehenge to dark matter.

The last solar eclipse Dan Falk witnessed was in 2010 from Easter Island, in the middle of the Pacific Ocean. (Photo: Dan Falk)

A science enthusiast at a young age, Dan obtained his undergraduate degree in physics before taking a year off to contemplate his career interests. During that time, he audited courses in statistics and Shakespeare, the latter of which came in handy when he penned his 2014 book *The Science of Shakespeare: A New Look at the Playwright's Universe*. Dan eventually enrolled at Ryerson University to study journalism. As a freelancer, he built a list of both national and international clients. "I wish there was more of a budget for science journalism," Dan laments, contemplating the reduced resources for freelance hires from many news outlets, especially as print media continues a tough fight to stay alive in a field of ever-growing and newly-emerging digital platforms.

Despite the uncertainty, independent freelancing comes with a freedom that Dan appreciates. In addition to sleeping in, there is the option to travel and attend conferences whenever he likes, as long as he is willing to pay out of pocket. In fact, it was at a conference on cosmic theory in 2003 where Dan and Amanda first met. Rubbing shoulders with the, "who's who of the first few seconds of the universe's existence," Amanda recalls sneaking into a group photo with Stephen Hawking while Dan was, regretfully, on the outside looking in as the photographer.

As the two talked about how science journalism has changed over their careers, one can easily point to *BookLab* to see how renowned journalists have adapted to embrace new platforms of communication. Through their podcast, the two have produced episodic, digital content featuring conversations about new science books and in-depth discussions about hot topics in the press. The switch to digital recording is a remarkable technological shift from the old days, back when Dan used his handy Sony Pro Walkman—which he claims "never malfunctioned"—and razor blades to edit for radio.

Yet when it comes to advancements, it is the progress of the science itself that has been the most exhilarating for Dan. He recalls covering stories on the Sudbury Neutrino Observatory, the Large Hadron Collider and the Laser Interferometer Gravitational-Wave Observatory (LIGO) back when these projects were in their infancy, and witnessing their respective rises to prominence in discovery and then recognition with the Nobel Prize. Dan recalls covering LIGO back when finding gravitational waves was just an idea. He reflects, "It was cool seeing these things from the ground up."

Looking back on the many stories that he has covered in print and on radio, Dan remembers his most rewarding project to be one called *Looking Up*, a series of episodes exploring the history of astronomy for CBC Radio's *Ideas* in 2009 to celebrate the International Year of Astronomy. For this assignment, Dan conducted on-location journalism in Italy to visit Galileo's birthplace and the site of The Inquisition, among many other historically and scientifically relevant destinations. "Nothing beats being there, if you can pull it off," Dan explains, acknowledging that money is often a barrier to extensive travel projects. However, there's a certain intimacy that comes out of in-person interviews on-site that cannot be captured over a phone or Skype call.

"I almost always say okay," Dan says, elaborating that he believes there is a story anywhere if you can get a good interview with people who have interesting things to say. Collecting these interesting soundbites, Dan crafts a story for his audiences. "Give it time, give long interviews, and then edit for the pieces," is his advice. Like a true tour guide, he takes his readers and listeners down a path filled with intrigue alongside the information. Whether he's chasing eclipses on Easter Island or exploring the cosmos through Shakespeare, Dan brings all of us—both scientists and non-scientists alike—along on the journey. ●

LEFT TO RIGHT: Dan Falk, Jock Fleming, the Honourable Elizabeth Dowdeswell, Dr. Reinhart Reithmeier

As an Honorary Vice Patron of RCIScience, the Lieutenant Governor of Ontario, Elizabeth Dowdeswell, opened the Sanford Fleming Medal ceremony with a speech celebrating science communication and Dan Falk's contribution to the public understanding of science. She revered Dan's work for its "capacity to spark imagination, and inspire future scientists" and acknowledged the collective efforts of science communicators, who help build "Canada's international reputation as a hub for innovation." She highlighted the need for science to be supported by a healthy democracy, which in turn must use science to better serve people through evidence-based decision-making.

ANATOMY OF A BLACK HOLE

A black hole is an immense quantity of matter compressed into a small region of space. Imagine stuffing a few trillion rabbits into a magician's top hat. Then, the mutual gravity of the rabbits pulls them together until they eventually reach infinite density. Quite a trick! On paper, you can turn any mass into a black hole by calculating its *Schwarzschild Radius*. This is basically the object's mass times the *Gravitational Constant*, which is a very small number. Then divide the whole thing by the speed of light squared, which is a very, very large number. In other words, to make a black hole of any appreciable size requires a huge amount of mass. Our rabbits aren't going to cut it.

In nature, the *Schwartzschild Radius* of a non-spinning black hole marks a border region called the event horizon. This is the point of no return: anything within the event horizon needs to move faster than the speed of light to escape the black hole. Making escape, regrettably, impossible.

At the centre of the black hole lies the singularity, the pinnacle of a black hole's twisted physics. This is where matter is condensed into an infinitely small space, curving space-time infinitely. The implications of this environment are not yet fully understood, or even acknowledged by some.

BLACK HOLES

SEEING THE

by ANNOJ THAVALINGAM

They are voracious consumers. Anything, from matter to light, that gets too close gets caught in their gravitational web, adding the terrifying quality of invisibility. Black holes. Are they horrifying monsters, or fascinating portals to the unknown? However you perceive them, as Dr. Avery Broderick put it, black holes fulfill our desire to, "to step out from where we are," and explore realities beyond our reach.

ILLUSTRATION: M. Kornmesser, European Southern Observatory (ESO)

How do you find a black hole without the Event Horizon Telescope?

Find a star that appears to orbit something really massive, but which is invisible. Easy? Not really. There are literally hundreds of billions of stars at which to point your telescope.

Black holes are wildly popular, but public perception of them is largely informed by science fiction and pop culture. According to York University Post-Doctoral Fellow Dr. Christina Smith, black holes are often portrayed in movies as doing one of three things, each designed to introduce peril to the characters.

First, they are depicted as, "massive, massive vacuum cleaner[s]," sucking everything in. While black holes do have huge gravitational pull, this is not how they work. You have to get close enough to a black hole to be affected by it. If, for example, the Sun was replaced by a black hole of the same mass, the effect on Earth would simply be to grow dark and cold. It would not get "sucked in." It's worth noting that we'd all still be dead, however.

Secondly, pop culture black holes create weird time distortions. This plot device, as used, for example, in the TV show *Stargate SG1*, is inspired by the idea of time dilation. Described by General Relativity, as you approach a very large and dense object with immense gravity, time moves at a different rate for you than for those farther away from the object.

Lastly, due to the invisibility and general mystery of black holes, directors and writers use them to pelt all sorts of odd and interesting things at their protagonists. Usually based on very little or, in fact, no actual science. These movies are fun, but they do a disservice by ignoring the actual science behind these enigmatic forces of nature.

HOW TO HUNT FOR BLACK HOLES

"How do you discover black holes if you can't see them?" The question, plainly laid out by University of Toronto professor Dr. Suresh Sivanandam, does not offer any simple solutions. However, he reveals innovative, albeit indirect, methods of detection that make use of black holes' greatest asset: gravity.

Dr. Sivanandam presents three different ways of inferring the existence of black holes. The first is by studying the motion of any stars appearing to orbit an invisible, highly dense entity.

A second method concerns matter that succumbs to a black hole's gravitational field, but accelerates and just misses the mark. This matter may fly outwards at near-light speed as jets, releasing detectable emissions in the process. It may also get trapped in a disk near the event horizon in something known as an accretion disk. The matter here superheats as it swirls around and around, emitting X-rays.

The last way to find a black hole involves ripples in space-time called gravitational waves. Any accelerating object produces gravitational waves, but most are too weak to be detected. If two black holes in orbit around one another eventually smash together in one of the most violent gravitational events imaginable, the resulting gravitational wave will be of unparalleled amplitude and intensity. The Laser Interferometer Gravitational-Wave Observatory (LIGO) detected its first gravitational wave in 2015, created by just such an event, adding another item to the strange scrapbook of black hole lore.

THE IMAGE THAT ROCKED THE WORLD

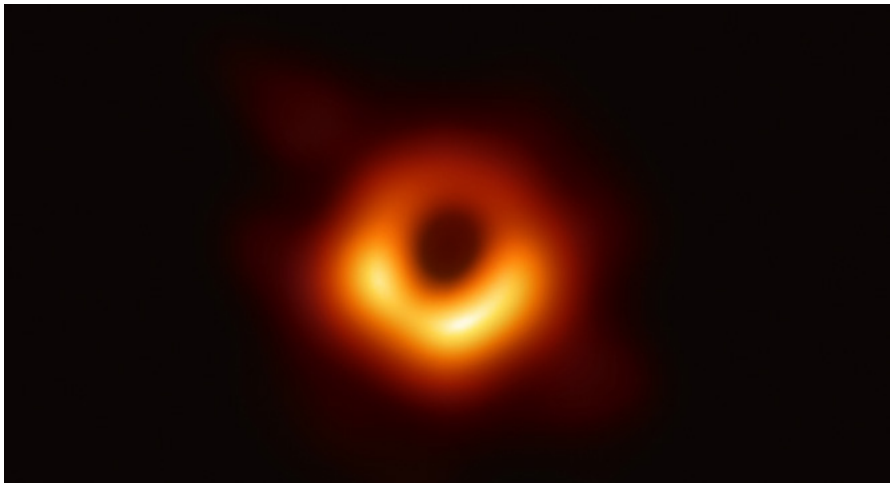
Even with these methods at hand, the detection of a black hole is not simple. For instance, confirming the Milky Way Galaxy's central black hole, Sagittarius A, took 20 years of observations. (Rest assured, Sagittarius A is quite distant: 26,000 light-years, or 246 quadrillion kilometres away. It does not pose a threat, and might, in fact, play an important role in keeping our galaxy together.)

Detecting is hard. But imaging a black hole? That should be impossible. Thus, heads turned on April 10, 2019 when the first image of a black hole was published. This was, in fact, an image of a black hole's shadow, because you can't take a photograph of something that does not emit light!

This feat was accomplished by the Event Horizon Telescope (EHT) collaboration, a global network of astronomers and astrophysicists coordinating eight telescopes around the world, from Hawaii to Spain to the South Pole. As a member of the EHT team, Dr. Broderick pointed out that the collaboration, "cut across many cultural divides, both societal but also professional." Yes, astronomers love black holes too!

In the now-famous image, the central black hole of the elliptical galaxy, M87, is shown in silhouette against the hot, glowing gas that envelops its event horizon. The gas gracefully traces the shape of the black hole and the information carried in the image is bountiful.

"Taking a picture is merely the beginning," explained Dr. Broderick, "I spend my time trying to figure out what this picture means." As a theoretical astrophysicist, Dr. Broderick uses the image to help generate simulations of black holes, essentially creating theoretical objects that look like this image. Astrophysicists used supercomputer simulations to predict this black hole's mass. The answer is the staggering number of approximately 6.5 billion suns.



The historic image captured, for the first time, of a black hole (Messier 87) and its shadow by the Event Horizon Telescope (EHT). (Photo: European Southern Observatory)

This groundbreaking photo may work to change public perception of black holes. There has already been some progress on the silver screen. Dr. Smith notes that some films now show black holes as 3-dimensional spheres, rather than flat black spots with discs of material slowly spinning into them.

This was particularly well done in the film *Interstellar*, released in 2014. And no wonder, as theoretical physicist, Kip Thorne, consulted on the film. Under Thorne's guidance, they produced simulations of what a black hole would look like from different perspectives, whether moving towards or away from it. Viewers can see distortions and bending that give the black hole, known as *Gargantua*, a surrounding halo, as well as its accretion disk. As digital effects evolve, it will be interesting to see if and how scientific knowledge is reflected in the public perception of these incredible objects.

After decades of groundwork, discoveries in the realm of black hole detection and imaging are advancing more rapidly than ever before. From the confines of our planet however, not to mention biological limitations on space travel and, well, event horizons, we are unable to take the final leap and learn first-hand what lies within a black hole. Dr. Broderick has certainly considered this, noting that "the only way to find out is [for] you to go. Then you don't get to tell us though. There's a price for knowledge."

Then again, where would we not venture? ●

Click here to watch "Black Holes: From Speculative to Spectacular" in full on RCIScience's YouTube channel now.

In 1970, with a newly-minted PhD, C. Thomas Bolton arrived at the University of Toronto to do post-doctoral work. At this time, X-ray astronomy was in its infancy. Only a handful of X-ray sources were known and Bolton was interested in studying one of them, Cygnus X-1. He wondered if it was a neutron star, which physics said should emit X-rays.

Bolton used the David Dunlap Observatory's 74-inch telescope to comb the space near Cygnus X-1 and employed spectroscopy to confirm a nearby star's mass and the tell-tale doppler shift in the star's spectral lines that happen when a star moves towards and away from the observer. With the star's mass and its motion in hand, Bolton used simple physics to infer the mass and physical size of its unseen companion. It was not a neutron star. The only thing Cygnus X-1 could be was a black hole.

Bolton is usually co-credited for this discovery with two researchers at the Greenwich Observatory, but all of us at the University of Toronto know that he did it first! - Kirsten Vanstone, BSc Astronomy & Physics 9T4.

YORK UNIVERSITY DISCOVERY PROJECT

An Evening with **RCIScience** and the **Universe Discovery Project** at York University

by JACOB FINE

RCIScience was delighted to work with some talented undergraduate students this year. The undergraduate student group, York University Discovery Project presented an evening exploring *How Did We Get Here? The Cosmos, Humanity and the Unknown*.

Our Waterloo program saw the start of a new Science Communication micro certification administered by the University of Waterloo, in which undergraduate students attended programs and wrote short pieces based on them for RCIScience's blog and magazine.

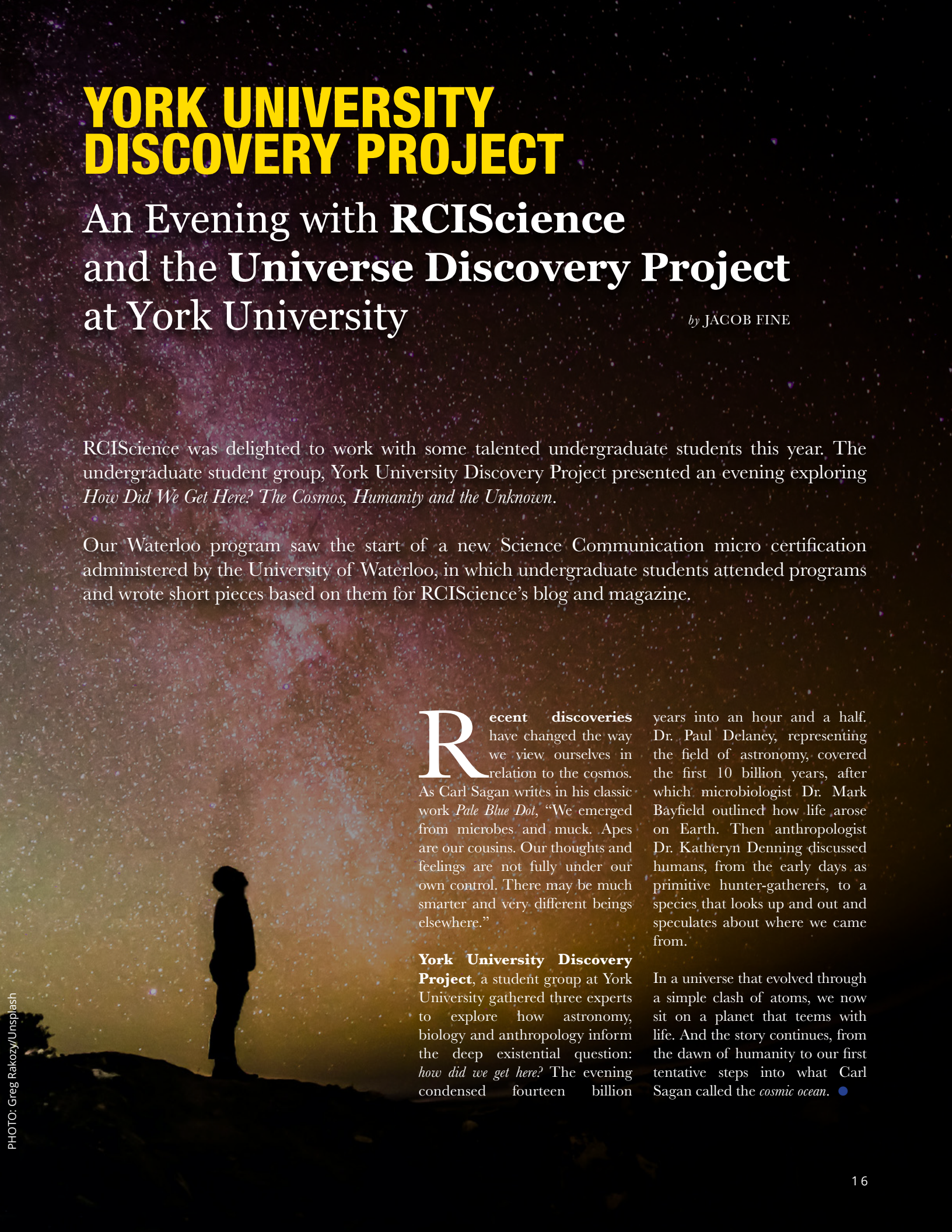


PHOTO: Greg Rakozy/Unsplash

Recent discoveries have changed the way we view ourselves in relation to the cosmos. As Carl Sagan writes in his classic work *Pale Blue Dot*, "We emerged from microbes and muck. Apes are our cousins. Our thoughts and feelings are not fully under our own control. There may be much smarter and very different beings elsewhere."

York University Discovery Project, a student group at York University gathered three experts to explore how astronomy, biology and anthropology inform the deep existential question: *how did we get here?* The evening condensed fourteen billion years into an hour and a half. Dr. Paul Delaney, representing the field of astronomy, covered the first 10 billion years, after which microbiologist Dr. Mark Bayfield outlined how life arose on Earth. Then anthropologist Dr. Katheryn Denning discussed humans, from the early days as primitive hunter-gatherers, to a species that looks up and out and speculates about where we came from.

In a universe that evolved through a simple clash of atoms, we now sit on a planet that teems with life. And the story continues, from the dawn of humanity to our first tentative steps into what Carl Sagan called the *cosmic ocean*.

The OCEAN MICROBIOME

a world in a drop of water

by ALYNE TEIXERA

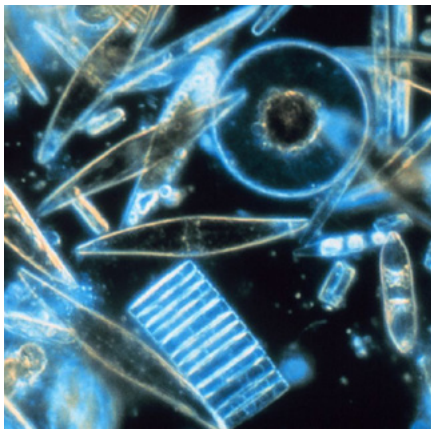
PHOTO: Cristian Palmer/UNSPLASH

Microbes are microscopic organisms (microorganisms) that exist as single cells or in colonies of cells. They can be found everywhere on Earth, from soil to water and even in and on our bodies. Some microbes have evolved to exist in very harsh environments that do not easily support other forms of life, such as our planet's polar regions, arid deserts and volcanoes. The marine environment presents some of the world's most inhospitable conditions, and yet hosts a diverse ecosystem of microbes.

The ocean is teeming with life.

DR. JULIE LAROCHE

Marine microbes come in many different types and forms. *Diatoms*, a type of single celled algae, for example, exhibit a great diversity of sizes, shapes, and colours that are beautiful under the microscope. The genes found in single-cell marine microorganisms vary widely, reflecting the many specific functions these tiny organisms need to survive in the ocean. The most common marine microbes are bacteria which, unlike diatoms, do not present features that are easily recognizable under a microscope. To characterize them, scientists use DNA sequencing. Dr. Julie LaRoche, a Professor in the Department of Biology at Dalhousie University, compares this process to barcoding different products at a grocery store: each barcode has a unique pattern that can identify a specific product. Similarly, microbes are "barcoded" by specific sequences of genes, enabling their identification and classification.



Assorted *diatoms* found in the sea water from Antarctica, seen through a microscope. (Photo: Gordon T. Taylor, Stony Brook University)

One of the most abundant organisms on the planet is a tiny bacterium called *Pelagibacter*. Found in salt water, *Pelagibacter* is rod or crescent-shaped with a diameter of only 0.12–0.2 micrometres—1,000 times smaller than that of a human hair! Like many bacteria, *Peligibacter* uses oxygen for energy and releases carbon dioxide. These bacteria have an interesting relationship with another marine microbe called *Prochlorococcus*. *Prochlorococcus* is a cyanobacteria, which means it obtains energy through photosynthesis, using carbon dioxide and sunlight to produce oxygen and carbon-rich biomass. Together, *Pelagibacter* and *Prochlorococcus* exist in a symbiotic relationship—a close and long-term interaction between the two organisms, which in this case is mutually beneficial, that is crucial for maintaining the balance of nutrients in the oceans.

Relationships are complex—even for single-celled life!

DR. ERIN BERTRAND

Dr. Erin Bertrand, Associate Professor in the Department of Biology at Dalhousie University, explains that life as a single-celled organism is not without its complications. Her lab examines coping strategies that diatoms employ to manage stress. She uses a technique called mass spectrometry for proteomics. Proteomics is the large-scale study of proteins. In ocean water, proteomics can uncover plankton stress and microbial drama!

Much like a cake recipe, diatoms require certain ingredients to thrive. These include nitrogen, iron and vitamins,

A single drop of ocean water can contain over 100,000 *Prochlorococcus* bacteria, and the entire mass of *Prochlorococcus* in the world's ocean would be equal to 220 million Volkswagen Beetles. Despite being microscopic, marine cyanobacteria *Prochlorococcus* contains four times the number of genes as humans!

Pelagibacter ubique, ocean microbes that are the most abundant organisms in the ocean, and quite possibly the most abundant bacteria in the entire world. (Photo: NOAA)

all in the correct ratios. If a particular ingredient is missing or lacking, it becomes a limiting nutrient and a source of stress on the diatom population.

Normally, diatoms have a symbiotic relationship with ocean bacteria. Diatoms are a type of phytoplankton—a diverse collection of organisms that drift in ocean currents. Diatoms produce carbon that ocean bacteria metabolize. In return, these bacteria release vitamins, such as B_{12}, that help diatoms grow. These organisms normally support each other, but problems can arise when both microbes are competing for the same nutrient.

The Southern Ocean around Antarctica, for example, is rich in nitrogen but lacking in iron, forcing diatoms to compete with bacteria and other phytoplankton for this limiting nutrient. In a starved state, diatoms can produce particular proteins to help them cope with starvation. They grow for a time, though slowly, and ultimately, they cannot survive. Nutrient starvation is a major factor governing whether diatoms flourish or fade in our oceans. One of the consequences of rising atmospheric and surface temperatures in our oceans is that there is less mixing and fewer nutrients available for plankton, leading to increased stress. In a sense, plankton, including diatoms, are bellwethers for the health of our oceans.

A group of scientists tested nutrient stress in the Southern Ocean around Antarctica by adding iron to the water to investigate how diatoms would respond. The added iron relieved the nutrient stress and competition, and the diatoms flourished. Similarly, Dr. Bertrand's group collected water samples from the Southern Ocean and supplemented them with iron and vitamin B_{12}. Sure enough, they found that diatoms and other plankton grew much better in these conditions, suggesting a possible strategy to help improve the health of these organisms in the ocean.

Dr. Bertrand cautions that adding nutrients to our oceans is a delicate business. Get it wrong, and diatoms grow too quickly, forming dense blooms. When these blooms exhaust the available nutrient supply, they sink, transferring large amounts of carbon from the surface deep into the ocean. This process plays an important role in determining how much heat-trapping carbon dioxide the ocean can absorb from the atmosphere. With humans continuing to alter ocean chemistry through coastal pollution and burning fossil fuels, the balance has never been harder to get right. ●

LEFT TO RIGHT: Dr. Erin Bertrand, Dr. Julie LaRoche, and RCIScience Halifax Coordinator Alyne Teixeira

VOLUNTEERSPOTLIGHT

ALEXA FITZPATRICK

Alexa Fitzpatrick is a third year PhD student in the Department of Biochemistry at the University of Toronto. As a microbiologist, Alexa researches bacteriophage—a type of virus that infects bacteria.

She hopes to become a well-rounded science communicator, believing an essential part of scientific research is making your work accessible to the general public. For this reason, she got involved with RCIScience, where she helps with events and hopes to soon try her hand at science writing.

Her most memorable moment with RCIScience so far has been helping out at *Science is a Drag*—a night of fashion, dance, music, science and art in Toronto's historic Gladstone Hotel. She found it inspiring to see and support diversity within the scientific community.

For anyone considering volunteering with RCIScience, she advises: "the role is very accommodating to volunteers with busy schedules and is an amazing and supportive team to be a part of!"

SciCommTO2020 Conference

In February, RCIScience had the great pleasure of partnering with Ryerson University's SciXchange to host the inaugural ***SciCommTO Conference***. This two day conference brought together over 120 journalists, practitioners, academics, influencers, researchers and students from Toronto and beyond to tackle the biggest issues facing science communication.

Our hope is to foster a skilled network of professionals and organizations, who can work together to move the sector forward, shaping an engaged Canadian science communication community.

QUANTUM AND POP CULTURE

by SAMEER JAFAR

WHAT IS QUANTUM PHYSICS?

Quantum physics is a way of modelling light and particles as discrete packets of energy called quanta (plural of quantum). Quantum physics was born when experiments with light produced results that could not be modelled with classical physics. A new form of mathematics was developed that allowed physicists to model light, and eventually particles like electrons, as discrete packets of energy.

What's the difference between a new laptop and the Quantum Computer X Forever Plus laptop?

Probably not much. And nothing to do with quantum physics. Distorting science for dramatic effect is a common marketing tool that also seeps into popular entertainment. Quantum physics is a rich source of dramatically-altered science. And at least one scientist thinks that examining quantum in pop culture is a great way to help people better understand the quantum world.

Quantum physics is a rich source of dramatically-altered science.

Dr. John Donohue is the Scientific Outreach Manager at the University of Waterloo's Institute for Quantum Computing. He describes quantum physics as a rule book for sub-microscopic activity. Donohue believes that the mathematics, abstract thinking and intangibility of quantum physics contribute to the subject's reputation as being complex and difficult to understand. When it was first described about a century ago, quantum physics dealt with a world that was almost entirely unmeasurable and was often described as being, "born on the blackboard." Pop culture has exploited this intangible nature to skew public perception of quantum physics away from breakthrough science towards the mystical.

Despite this, Dr. Donohue believes that quantum physics is a very teachable idea that most of us are perfectly capable of understanding. Even without accessing 100% of our brains as the protagonist in the movie, *Lucy*, did before she learned the science "overnight." Donohue's job takes him away from the lab and into educational settings where he often finds he is debunking the mysteries of quantum physics through student workshops, technical lectures and talks to the general public.

Growing up an aspiring film critic, Donohue employs compelling film and television references to illustrate ideas in quantum physics. For example, there are many instances in which quantum phenomena are used, vaguely or incorrectly, to explain complex things. The parody newspaper, *The Onion*, captured this perfectly with an article about a science fiction writer who attributed all complicated plot points to "quantum flux."

Television's *MacGyver* falls prey to another common usage, what Donohue calls "quantum-sploitation." In one episode, our hero is tasked with stealing a quantum computer chip from a biohazard lab. Combining the words quantum and biohazard implies high-stakes danger. To save the world, MacGyver breaks into the lab, steals the chip and carefully stows it in a small cooler. While it is true that quantum circuits need to be stored and operated at very low temperatures, those temperatures are near absolute zero, -273° Celsius or 0 Kelvin. Not the -1 or -2° Celsius achieved in a lunchbox with some ice.

Other quantum properties that pop culture exploits, often to dubious effect, are superposition and entanglement. Superposition is the idea that a particle can be in multiple states at the same time. These states collapse into one when some aspect of the particle is measured. Entanglement is a strange quantum property in which particles that interact, even for a short time, will forever share a connection even at great distance. Even more spookily, measuring one particle can affect the state of a particle that is entangled with it, even if that second particle is not being measured.

The popular sci-fi video game, *Mass Effect*, features a clever piece of technology called the "quantum entangled communicator." This device allows our protagonist, Commander Shepard, to access information on a computer from anywhere in space without worrying about that pesky universal speed limit—*c*—the speed of light! Unfortunately, this is another case of quantum fantasy. And let's not even get started on the popular trope of using quantum entanglement to explain romantic love...

Dr. John Donohue shares his favourite quantum pop culture references with the RCIScience audience.

Fortunately, it is possible to find accurate references to quantum physics in pop culture. An episode of the cartoon *Futurama* pokes fun at the thought experiment known as *Schrödinger's Cat*, often used to illustrate quantum superposition. This is usually described as a cat sitting in a sealed box which also contains a lethal substance that could escape into the box at any moment and kill the cat. To an observer outside of the box, the cat is both dead and alive and you cannot know which until you open the box and check.

To exist in more than one state at the same time—in this case both dead and alive—is superposition. Once someone observes the state of the cat, the multitude of possible states of the cat collapse into a single state—alive OR dead. In the episode, Fry and his sidekick Bender approach Dr. Schrödinger and demand to see the

From those blackboard beginnings, we now understand the universe more clearly, which is the goal of all science.

contents of his box. Fry and Bender open the box, upon which the cat collapses into a very much alive state, pounces on them with a vicious meow, and runs off.

Beyond movies, TV and video games, the world of marketing is littered with examples of using the term "quantum" to suggest superiority. You can find "quantum batteries," "quantum hair conditioner" and even "quantum RV sleepers" that have nothing to do with quantum technology. These advertising ploys mask the true purpose of, for example, quantum computing, which may eventually lead to everyday applications. Just not likely applications in the field of hair care or recreational vehicles.

Quantum physics has, in fact, produced many real things. Ground-breaking devices that are by-products of quantum research are already in everyday use. Magnetic resonance imaging (MRI) machines, for example, capture physiological snapshots of patients for clinical analysis. On a smaller scale, transistors work on quantum principles. This once novel technology is now so common that you're probably carrying several in your pocket buried in your cell phone.

Quantum is a hot topic throughout the business world. Over the past decade, there has been a global rise in quantum technology investments, to the tune of billions of dollars. Canada is among the world's leading contributors, particularly in the area of quantum computing, one of the next big things on the horizon. In *MacGyver*, these were portrayed as futuristic and somewhat sinister. In reality, quantum computers make use of both superposition and entanglement to allow quantum circuits to perform calculations much faster than traditional computers. The danger is that a quantum computer will be able to crack the encryption algorithms currently used to safeguard information. So, like before Y2K, those encryption algorithms will have to be upgraded when quantum computers become a reality.

Beyond computers, quantum research is also producing better lasers, new materials and sensors that will provide faster, more accurate and more precise results. But, as Dr. Donohue reminds us, it is easy to get wrapped up in quantum's potential for money-making products, but we should not forget that it was basic research and musing about the nature of light and particles that brought quantum physics

Dr. John Donohue is the Scientific Outreach Manager at the University of Waterloo's Institute for Quantum Computing. (Photo: John Donohue)

into existence a little more than a century ago. From those blackboard beginnings, we now understand the universe more clearly, which is the goal of all science. That said, the next time your favourite TV character uses a quantum computer to "hack the mainframe," please take it with a grain of salt. ●

Click here to watch "QUANTUM + Pop Culture" in full on RCIScience's YouTube channel now.

VOLUNTEERSPOTLIGHT

AREN MNATZAKANIAN

Aren Mnatzakanian has been volunteering with RCIScience for the past two years. After attending an RCIScience event about the science of human movement as an undergraduate student, he became hooked on the field of science communication. Since then, he has attended as many events as his schedule permits, helping with registration, interviewing speakers and contributing to RCIScience publications.

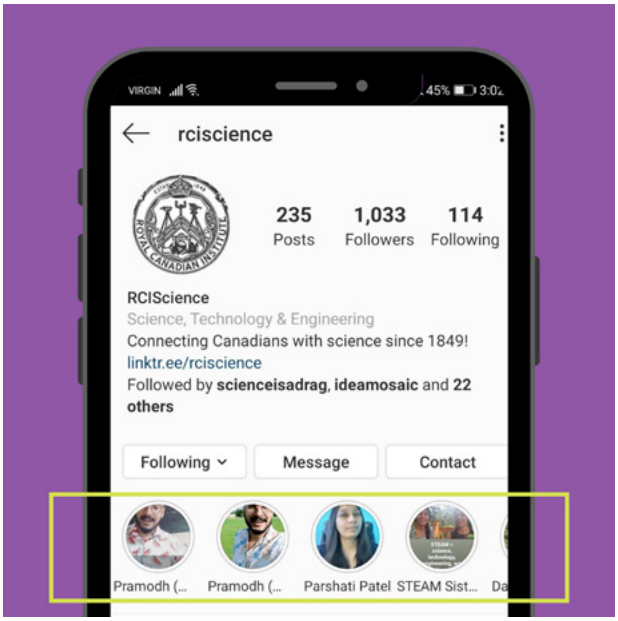
Aren decided to volunteer with RCIScience to gain experience in science communication and network with the community. Growing up, Aren loved reading popular science books and hopes one day to become an author himself. He values the platform and guidance that RCIScience provides for him to hone his amateur science writing skills.

Aren encourages all individuals with a passion for science to consider volunteering with RCIScience. Whether you are a seasoned science communicator, an up-and-coming researcher, or just a student of curiosity, RCIScience has something worthwhile to offer.

Aren's next challenge awaits him in medical school, where he's excited to develop his science communication skills further for the benefit of his patients.

INSTAGRAM TAKEOVERS

This Spring, we opened up our Instagram account for a series of 'takeovers', connecting you with science and scientists from across Canada. Researchers take control of our account for anything between one to five days, finding innovative ways to share their work and interests with our followers. So far we've covered everything from astronomy to chemistry and neuroscience to quantum physics, profiling some fantastic science communicators and organizations along the way. Don't miss out—follow us **@RCIScience** and check out our past takeovers saved in the Highlights!

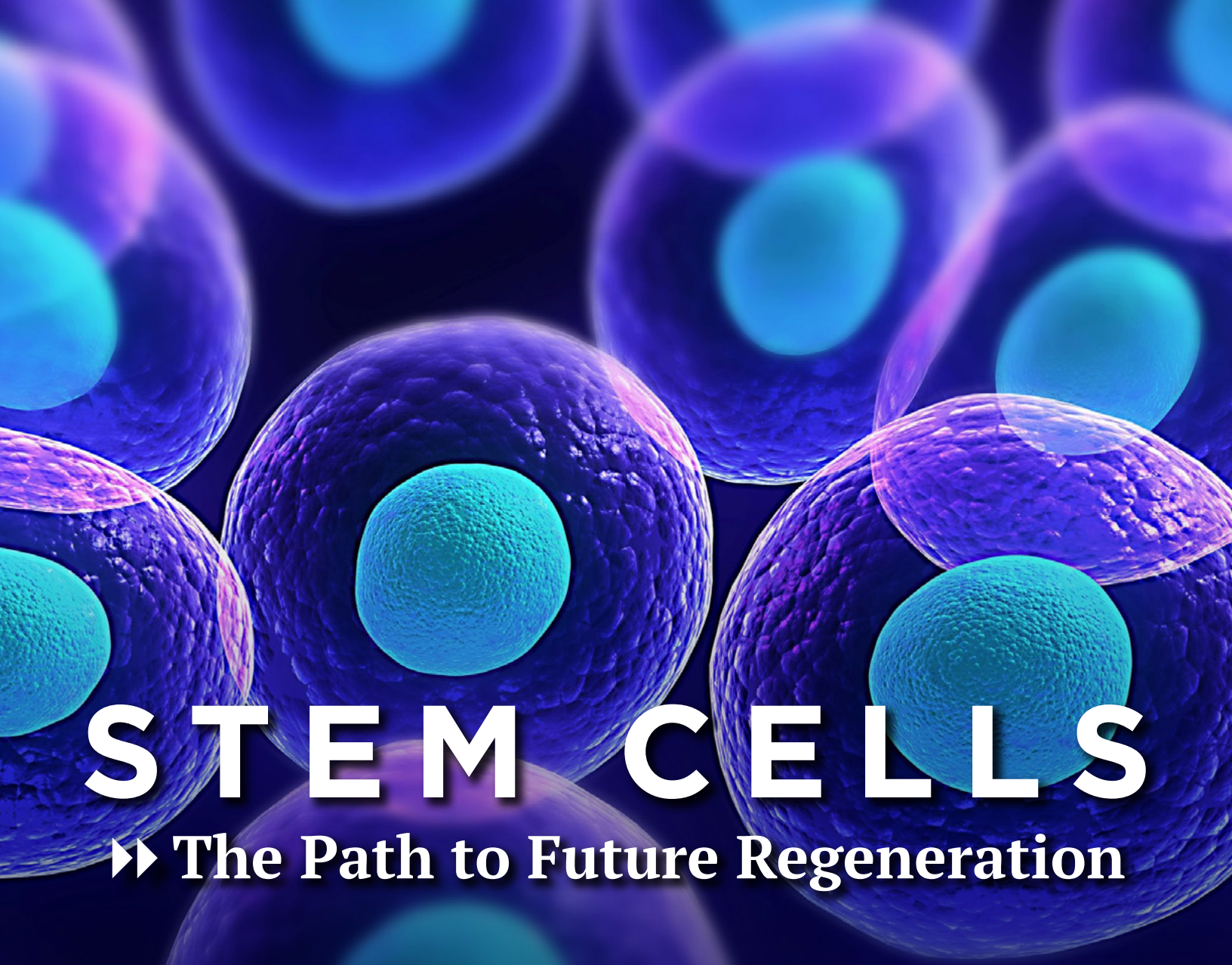


MEMBERSPOTLIGHT

GEORG KRALIK

Georg Kralik has been a member of RCIScience since 1992, attracted to the Institute by its engineering heritage through founder, Sir Sandford Fleming, and by its mandate to encourage people to embrace Science, Technology, Engineering and Mathematics (STEM). Engineering is Georg's profession and passion. He worked as a Structural Engineer with Ontario Power Generation for many years, but he also volunteers with the Professional Engineers of Ontario (PEO), acting as a mentor to new engineers and working to increase interest in the profession among K-12 students. Georg acted as Engineer-in-Residence to grade 8 students and as a judge in the hugely popular First Robotics Competition. For these and other contributions encouraging diversity in Engineering, Georg was inducted into the PEO Order of Honour in 2018.

Through the pandemic shutdown, Georg has continued to pass along his love of engineering through weekly emails and addressing some specific engineering questions on the part of RIScience staff. We remain grateful for Georg's willingness to share his experience and knowledge, and also for his editing ability, particularly with respect to our walk-in powerpoints. Many thanks for sticking with us, Georg, and we look forward to seeing you again in person soon!



STEM CELLS

The Path to Future Regeneration

by NICHOLAS DEMERS

With what sounds like science fiction rapidly becoming scientific fact, the future of stem cell research is bright.

Our bodies are remarkable machines. We are made up of trillions of cells, the building blocks that allow us to breathe, eat, see, and move. But these cells are not all the same. In fact, we are composed of approximately 200 different types of cells, all with different roles. Some are responsible for contracting our muscles, some are involved in fighting off infections, others in extracting oxygen from the air, and so on. But an overarching question persists: how are we able to make so many different kinds of cells? The simple answer: stem cells.

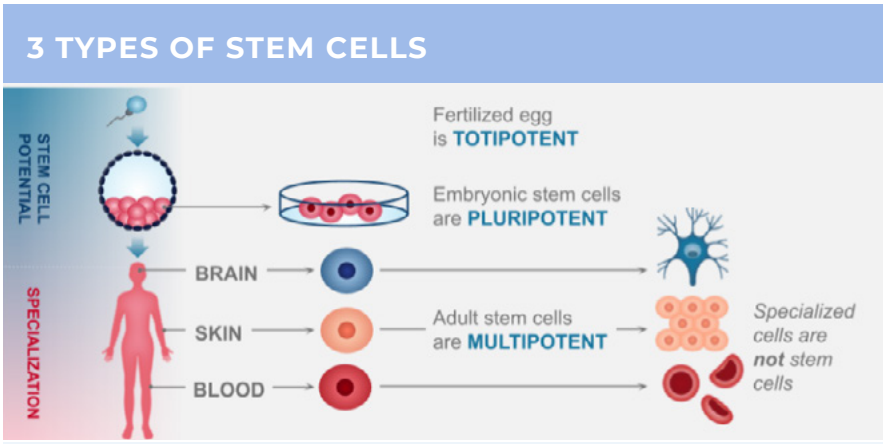


FIGURE A. Full of Potential. A fertilized egg (or zygote), is the very first cell in the development of a human being. It is **totipotent**, meaning it has total potential to differentiate into all the cell types found in our bodies. As the egg develops, stem cells start to commit to certain fates, becoming **pluripotent**, with the potential to differentiate into *many* cell types in our bodies, but not *all* cell types. Further down the line, **multipotent** stem cells arise. These cells can still differentiate into varying cell types, but their differentiation is restricted to the organ in which they reside. For example, cells in the brain will develop into different types of neural cells but not renal (kidney) cells. Once committed to a single fate, cells become **unipotent** - they can only differentiate into one particular cell type. (Illustration: Medicine By Design)

STEM CELLS 101

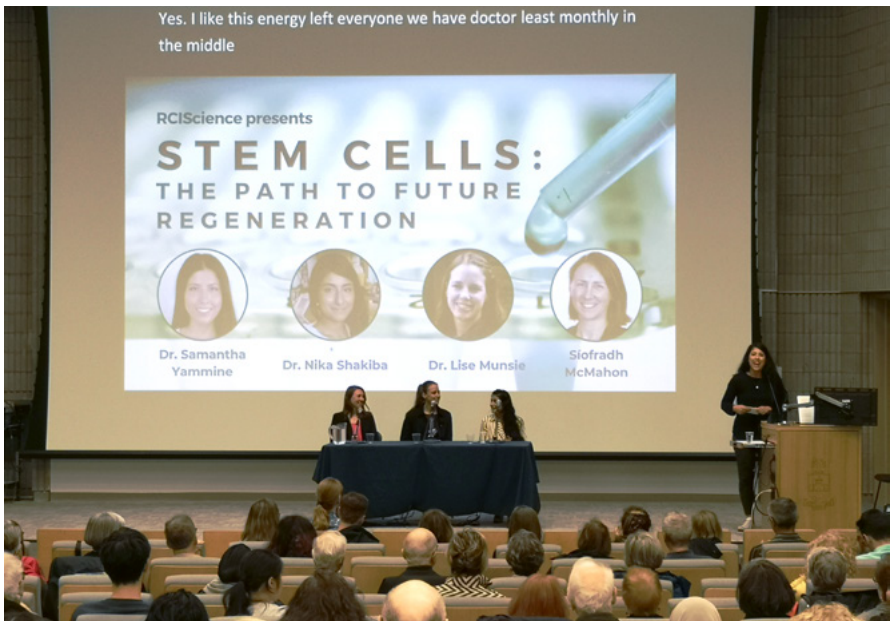
Dr. Nika Shakiba, a postdoctoral fellow in the Department of Biological Engineering at MIT, defines stem cells as, "the building blocks of tissues and organs." They have two main properties: the first is that they can self-renew, that is, they can make copies of themselves. The second is that they can differentiate, meaning they can become specialized cell types that perform specific functions – for example, immune cells that fight bacteria. There are different levels to how specialized a stem cell can become (see Figure A). Dr. Shakiba finds stem cells fascinating. "I'm really interested in understanding how this one cell goes on to form a magnificent body."

She also explained some new discoveries in stem cells. "For many years, scientists thought that differentiation was a unidirectional trajectory. That once a stem cell has differentiated and made itself into, say, a skin cell, it's stuck there. It's not going to change back." However, in 2006, Dr. Shinya Yamanaka showed that it was possible to "reprogram" cells, where highly differentiated cells (specialized cells) could be induced to turn back into pluripotent stem cells by treatment with specific conditions. These cells are called induced pluripotent stem cells or iPS cells. This work earned Dr. Yamanaka the 2012 Nobel Prize in Physiology or Medicine, and has huge potential for disease treatment.

REGENERATIVE MEDICINE

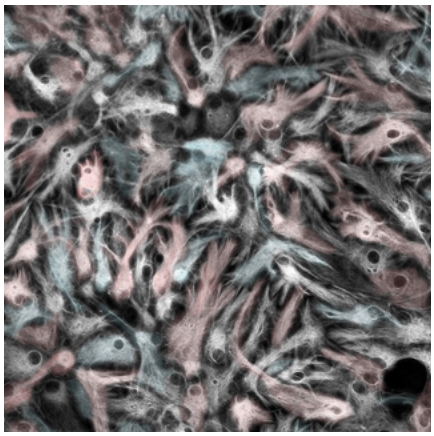
Stem cells, whether naturally occurring or produced *in vitro* (in a dish), are the cornerstone of regenerative medicine – a branch of medicine that develops methods to regrow, repair or replace damaged cells, tissues or organs. In helping us understand the basic biology of tissue development and disease, stem cells open up multiple avenues for potential disease treatments. Strategies are being developed to grow tissues or organs from stem cells *in vitro* to replace damaged systems in the body and to stimulate the body's own stem cells to regenerate and repair damaged tissue.

Perhaps the most famous use of stem cells to treat diseases is in bone marrow transplants. Bone marrow contains hematopoietic stem cells, or multipotent blood stem cells, which were the first stem cells ever to be discovered. This breakthrough has its roots in Canada and was accomplished by University of Toronto researchers Drs. James Till and Ernest McCulloch at the Princess Margaret Hospital in Toronto. Hematopoietic stem cells can be extracted from a healthy donor and injected into a patient to replenish the entire blood cell system. Bone marrow transplants are commonly used to treat blood cancers such as leukemias and lymphomas, as well as immune deficiencies.



LEFT TO RIGHT: Panellists Síofradh McMahon (CCRM), Dr. Lise Munsie (CCRM) and Dr. Nika Shakiba (MIT) on stage with Dr. Samantha Yammine moderating a lively Q&A.

Stem cells have traditionally been studied on a two-dimensional plate but this is not how cells grow or react in our bodies. To get around this, scientists have developed three-dimensional cultures of cells called organoids—simplified, miniature versions of particular organs that can be made *in vitro*. Using organoids is a powerful method to study how iPS cells might behave *in situ*, that is, within the body.



Icy astrocytes: Stem cells have the ability to become other types of cells, something that can be performed in the dish in the laboratory. Here, neural stem cells isolated from mice are differentiated into astrocytes, characteristically star-shaped cells found in the brain and spinal cord. (Photo: Dr. Samantha Yammine)

THE FUTURE IS NOW

There are many exciting developments at the Centre for Commercialization of Regenerative Medicine (CCRM), where the mandate is to facilitate the most promising regenerative medicine therapies from the lab bench to the clinic. In outlining some of the stem cell therapies that are currently being developed in research labs around Toronto and the world, Dr. Lise Munsie, a Senior Development Manager and Project Leader at CCRM, sounds like she's describing science fiction. Sheets of skin grown from stem cells to aid in wound healing, for example, or thin layers of retinal pigment epithelium cells for implantation into a degenerating eye to treat sight loss, as labs in Japan are attempting.

Dr. Yamanaka's iPS cells are key innovative players in the regenerative medicine boom. The ability to "reprogram" cells means that you can turn any cell (such as a skin cell, which is easily harvested) back into a stem cell, and then redirect it again to make a different cell of the body. Although scientists cannot make entire organs just yet, skin cells in a dish can be turned into cardiac cells that twitch. While far from a full beating heart, the hope is that one day these cells can be used to repair damage in the organ and ultimately save lives.

In the field of personalized medicine, stem cells have massive potential to create patient-specific drugs or organs for transplant, negating the risk of an immune response to foreign tissue, and ultimately rejection of a particular treatment.

AUTOLOGOUS VS ALLOGENEIC

With so much potential, why are these disease therapies not reaching the clinic? The sad reality is time and money. The current methodology to convert a blood sample into iPS cells of a clinical standard takes about 6 months. The technology required to scale up the volume of these cells into the billions required for therapeutic intervention, something that happens at CCRM, did not exist until recently. Differentiating vats of iPS cells into the cell type that you want adds another 1-8 weeks, sometimes longer. All totalled, the process can take up to a year, costing somewhere between $1-2 million for one autologous therapy (where cells from one individual are used to treat that same person).

Using one cell line to produce many cell types and treat many people would cut the cost significantly. This type of allogeneic therapy is the goal, but faces potential rejection by the patient's immune system which identifies the transplanted cells as foreign. A solution may lie in the art of deception...

CLOAKING

Part of what makes cells unique to an individual are distinct proteins found on the surface of the cell membrane. A healthy immune system recognizes these proteins as the body's own and ignores them. Foreign cells, such as those from a transplant, have their own distinct protein coat. The immune system sees these cells as strangers and attacks, leading to cell death, rejection of the transplant, and ultimately treatment failure.

Scientists have identified specific parts of the genetic code that define these surface proteins. Using genetic scissors, they can extract this portion of the code and remove the proteins from the cell surface. The iPS cells are now invisible or 'cloaked' from the immune system. This active area of research is not currently available in the clinic as scientists work to understand the repercussions and ethics surrounding gene editing.

With the seemingly endless potential of stem cells, it can be easy to believe that they are a miracle cure. Unfortunately, that's not the case - at least not yet. Many purported treatments remain largely unproven and unauthorized in Canada. But with media hype and celebrity endorsement rife (comedian Joe Rogan, soccer player Christiano Ronaldo and Canadian hockey legend, the late Gordie Howe, have all endorsed stem cell treatments), the need for strict regulation is crucial.

REGULATORY CHALLENGES

Síofradh McMahon, Senior Manager of Clinical Translation and Regulatory Affairs at CCRM, explains that in many countries, including Canada, stem cell therapies are treated like new drugs. This means that they must undergo rigorous, phased clinical trials to test for safety, efficacy and adverse reactions in multiple groups of patients, including healthy control groups. Manufacturing and distribution controls are essential, with exceptionally high minimum quality standards established to ensure cell cultures are not contaminated or active in ways they should not be.

Imagine what would happen if a stem cell intended to differentiate into a neuron actually differentiated into bone within the body? Furthermore, once a therapy has been approved to go to market, it can only be used to treat the specific disease for which it was developed. For example, if a stem cell therapy was developed to treat Alzheimer's disease, it can only be used to treat Alzheimer's. It cannot be used to treat, say, Parkinson's disease until there is sufficient evidence that the stem cell therapy is also safe and effective for that condition. As Ms. McMahon explains, "This is a really important concept to understand because, at every single stage of development, every stage of research, we're controlling risk. We're trying to reduce the level of risk that people are ultimately exposed to."

Unfortunately, the development of stem cell therapies is not regulated as stringently everywhere. With development and administration occuring in legal grey areas, horror stories about cancer-causing DNA being found in stem cells used in patients, or women in the US contracting HIV from 'vampire facials' administered by untrained staff are all too true. Worse, this Wild West of unregulated therapies preys on the desperation of the most vulnerable patient groups. With the recent development of the 'Right to Try' movement, Ms. McMahon urges caution: "We need to be careful not to accidentally dismantle a process that exists specifically to protect us." She highlights a need to understand the true meaning of the underlying deregulation demanded by this movement and the potential influence of non-medical agendas before proceeding. "We need to work with the system to bring these types of things to patients [...] Regulations are in place in order to protect public health and in order to structure and define what companies must do to show us that these products are safe, of high quality and are going to be effective."

So where do we go from here? Well, with what sounds like science fiction rapidly becoming science fact, the future of stem cell research is bright. But with just three stem cell therapies currently approved by Health Canada, in addition to bone marrow transplants, it seems we will have quite a (justified) wait on our hands before we can expect to see much of this work safely translated to the clinic. ●

LEFT TO RIGHT: Moderator Dr. Samantha Yammine with panellists Síofradh McMahon (CCRM), Dr. Lise Munsie (CCRM) and Dr. Nika Shakiba (MIT) discuss innovations and controversies in stem cell research with the RCIScience audience.

HOT TIPS

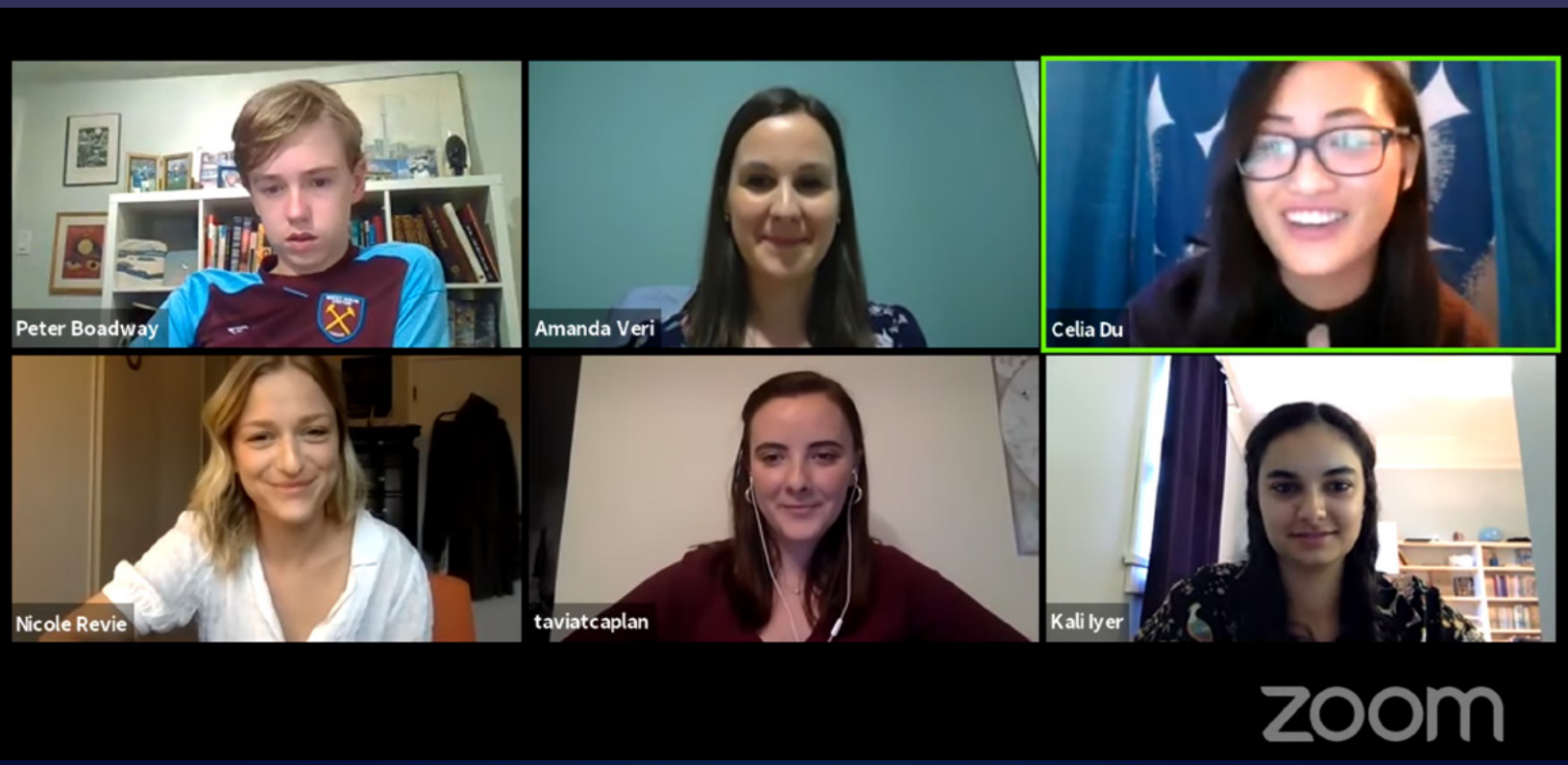
HOW TO SPOT RED FLAGS WHEN RESEARCHING STEM CELL THERAPIES

- If you are being asked to **pay out of pocket**, it is probably not a safe, effective stem cell therapy. Right now, stem cells are almost only being administered at hospitals and are therefore covered by the public healthcare budget.
- A **lack of published data** on the product or the therapy is a good indicator that the treatment has not been through clinical trial. The data has to be from human patients - studies in mice do not indicate human safety or effectiveness.
- You could be **one of the first** few to be administered the treatment in a clinical trial, but this is usually surrounded by publicity, particularly from trusted journals and research institutions. A lack thereof is a red flag!
- **One therapy to rule them all.** The same injection to treat everything does not exist. A drug can only be used to treat the disease that it has been approved for and should not be used to treat anything else.

Click here to watch "Stem Cells: The Path to Future Regeneration" in full on RCIScience's YouTube channel now.

Social distancing. Flattening the curve. Zoom.

These words, for better or for worse, have made their way into our daily vernacular in 2020.



DON'T PAN(DEM)IC!

The Science Behind the Board Game

by MICHAEL ZARA

Along with these new terms, the first half of 2020 has brought with it many adjustments to our daily lives. We've grown accustomed to staying at least two metres apart from others when we leave the house; we wear masks to the grocery store; wash our hands while humming "Happy Birthday"; and conduct work and school meetings online, from the comfort of our homes. The novel coronavirus SARS-CoV-2 is responsible for a global pandemic that changed the world in a matter of weeks. As we adjust to a "new normal," we get used to stay-at-home orders to contain the spread of infection, protect the vulnerable, and avoid overburdening the healthcare system.

While the COVID-19 pandemic will have lasting repercussions, both socially and economically, this is not the first time humans have encountered widespread infections that changed the way we live our lives. The last decade alone has seen epidemics of Zika virus in Central and South America, Ebola virus in West Africa, and the 2009 pandemic H1N1 influenza (swine flu) virus that spread globally. HIV/AIDS has ravaged communities around the world since the 1980s, and the notorious 1918 Flu Pandemic claimed an estimated 500 million lives globally.

Viruses and other disease-causing microscopic organisms, or microbes, are all around us. To help us understand these "germs," why they spread disease and how to stop them, four scientists working in infectious disease and public health gathered virtually over an online version of the popular board game *Pandemic*.

INFECTION AND OUTBREAK

An infection happens when microbes enter our body and cause harm. Kali Iyer, a PhD candidate researching emerging infectious diseases at the University of Toronto, emphasizes that, while the thought of these germs entering our body sends shivers down the spine, it's important to keep in mind that the majority of them are harmless. In fact, some are even helpful. Our bodies need bacteria to help digest food. Other bacteria are responsible for the tangy taste of cheese and yogurt. Fungi are instrumental to making bread and beer. Microbes play an important role in our day-to-day lives.

Some microbes do, however, cause disease. Tavia Caplan, a recent MSc graduate from the department of Molecular Genetics at the University of Toronto, explains how spreading disease-causing microbes from person-to-person can occur very easily. In the context of respiratory infections, such as the common cold and the flu, viruses can be transmitted through respiratory droplets, which are expelled by coughing, sneezing or, as one Prime Minister put it, "speaking moistly." If the germs in these respiratory droplets make their way into someone else's eyes, nose or mouth, the individual may become infected as the virus makes its way into the airways and attacks and kills respiratory cells. Fortunately, most of these droplets are heavy and do not remain airborne long enough to travel more than about 2 meters before falling. This is why physical distancing measures and mask-wearing are important strategies to reduce the spread of infection. On top of this, washing your hands thoroughly with soap and water kills many germs and prevents them from entering your eyes, nose or mouth when you unconsciously touch your face.

Once an infection spreads, the medical community can start classifying the disease as an "outbreak," "epidemic," or "pandemic." Dr. Amanda Veri, a microbiologist and Research Associate at the University of Toronto, acknowledges that the distinction between these terms can be confusing and understandably so. She describes an ***outbreak*** as a sudden increase in the number of cases of a disease over a short period of time in a localized space, region or community. An ***epidemic*** occurs when an outbreak becomes uncontrolled and we see a sudden increase in the number of infections over a short period of time in a larger space, region or community. Examples include the 2016–2017 Zika virus and 2014–2016 Ebola virus epidemics, which largely affected a handful of countries clustered close together geographically. Finally, a ***pandemic*** happens when an infection spreads worldwide, leading to several epidemics in many different continents. At the time COVID-19 was declared a pandemic by the World Health Organization (WHO), it had already spread to 114 countries, eventually hitting all continents except Antarctica. Knowing the difference between these classifications can clarify why public health officials suggest specific strategies and responses, especially as global travel facilitates rapid disease spread around the world.

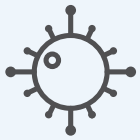
"...this is not the first time humans have encountered widespread infections that changed the way we live our lives."

ILLUSTRATION: Designed by starline/Freepik

MICROORGANISMS THAT CAN CAUSE DISEASE IN HUMANS

4 BROAD CATEGORIES

BACTERIA
Prokaryotes, or single-celled organisms, that come in all shapes and sizes. Some of them, like streptococcus or salmonella, can make us sick. Others, like lactobacillus, help us digest food.



VIRUSES
Non-living agents consisting of viral genetic material wrapped in a protein coat. Viruses need to infect other living cells in order to reproduce. Common examples include the influenza virus (which causes the flu), Ebola virus, and HIV.

FUNGI
A family of eukaryotes, or multi-celled organisms, that includes yeasts, molds, and mushrooms. While fungi can cause diseases like ringworm or athlete's foot, they are also essential in bread-making and beer-brewing.

PARASITES
Organisms that live in or on a host and cause harm. Diseases like malaria and sleeping sickness are caused by parasitic protozoans that get transmitted to humans through vectors like mosquitoes.

(Graphics: vecteezy.com)

PREVENTION AND CONTAINMENT

The most important question during an outbreak is: *how it can be controlled?* Nicole Revie, a PhD candidate studying microbiology and infectious diseases at the University of Toronto, explains that one of the best ways to control infections is by developing and administering an effective vaccine, conferring immunity so that people do not get sick and spread the disease further.

A vaccine consists of small components of the disease-causing microbe or the microbe in an inactivated form, along with immune-stimulating factors. Administering the vaccine, which does not cause infection, but does stimulate the body's immune system to develop a response, creates a sort of blueprint for your body, so that if it is ever confronted with the real microbe, it can respond more quickly and effectively.

The development of an effective vaccine is not an easy task and usually takes about 10 years to move one from lab to clinic. Many fail and trials are completely stopped if the vaccine does not offer strong enough protection or elicits adverse effects to patients. In the context of an emergency pandemic, that timeframe can be condensed, but the safety and efficacy of the vaccine must still be demonstrated before it can be used. An effective immune response needs to be both protective and long-lived. Protective immunity can wane over time which is why certain vaccines, such as the one for tetanus, require repeated "booster" vaccinations.

Successfully controlling an infection through vaccination relies on herd immunity. Herd immunity refers to the need for most of the population to develop immunity in order to contain an infectious disease. It ensures that vaccinated people will not get sick and, importantly, not transmit the illness to others. Herd immunity can be achieved when the right vaccine is made widely available to the public. It is especially important in protecting people in our society who cannot be vaccinated due to age or health-related conditions.

On the *Pandemic* game world map, our team of scientists showed some creative strategizing as they treated infections and developed cures to fictitious diseases. Unfortunately, they fell one move short of winning the entire game. While they may not have won this round, their journey around the *Pandemic* world map closely parallels what is going on in the real-world. The fight to prevent and contain the global spread of infectious diseases, as displayed during the COVID-19 pandemic, highlights the importance of international cooperation and global collaborative efforts amongst scientific experts, policymakers, healthcare officials and the public. ●

Click here to watch "Don't Pan(dem)ic! The Science Behind the Board Game" in full on RCIScience's YouTube channel now.

TRIBUTE **BOARD MEMBER**

DR. RONALD PEARLMAN

Professor Ronald Pearlman leaves the RCIScience Advisory Board in 2020, after 6 years of service as Past President. Ron was President of the RCI Council from 2012-2014 and was involved with the council prior to this.

In addition to bringing an academic rigour and incredibly wide network of scientists, Ron is deeply committed to increasing scientific literacy. This is evident from the fact that RCIScience is only one of many organizations in which he has been active, including the Gairdner Canada Foundation, where he not only acted as Associate Scientific Director, he also organized opportunities for university and high school students to engage with Gairdner Laureates. He was involved with the Sanofi BioGenius program and Science Rendezvous, as well as helping a group of enthusiastic York University undergraduates form a club to host popular science lectures, with RCIScience's help. And he did all of this while running a very active lab at York University, in which research into genomics and proteomics addresses questions about genetic organization and expression.

Ron is concerned that science is, too often, seen as a body of knowledge rather than a process. He believes that conveying this difference is key to fighting against the notion that science often contradicts itself. That contradiction, he argues, is not a bad thing. It is, in fact, exactly what science should do. That is, scientific models evolve as new data is collected and incorporated into them. We are seeing this in fast forward mode during the COVID-19 pandemic.

My very first meeting as RCI's new Executive Director was in Ron's lab at York University. I remember lab benches full of equipment and an office packed with books, and Ron just rattling some ideas apparently off the top of his head. These included all of the interesting things RCI was doing. What it did in the past, and what it could be doing. Along with names and contact information for people in his network who he thought I should get to know. This was incredibly useful.

Since then, I have enjoyed many conversations and collaborations with Ron about how to weave the idea of science as a process into our science communication activities. I would like to take this opportunity to thank Ron for his official service with RCIScience. For being my first "boss" in the organization. I hope that he will remain an active contributor though his official obligations are now over.

Kirsten Vanstone
Executive Director

Dr. Pearlman with fellow longtime members of the RCIScience Council.

From RAIN GARDENS *to* PERMEABLE PAVING

SAVING OUR HOMES FROM FLOODS

by JOHNSON DUONG

Are you equipped to survive a flood? In 2019, the town of Bracebridge, Ontario learned the answer to this question the hard way when they declared a State of Emergency following a severe rainstorm. The resulting flood displaced numerous families from their homes and devastated the town.

You may be surprised to hear that, according to estimates by the Insurance Bureau of Canada, over 1.7 million Canadian homes are at risk of flooding. Urban areas like Waterloo are especially vulnerable. Like most cities, it is not prepared to handle the evolving consequences of climate change.

HOW TO START A FLOOD PROOFING PROJECT

There are many ways to prepare a house to handle a flood. Here are some steps to get started:

BLUE SKY. Look to your neighbours or online for gardens you like then research whether those plants and materials will help you enact a flood prevention strategy.

LEARN MORE ABOUT THE ECOLOGICAL CONDITIONS OF YOUR PROPERTY. Does the soil absorb water or does it run across the top of the soil? Are there areas in your garden where water flows or pools when it rains?

CONTACT A PROFESSIONAL. For bigger jobs, a contractor or landscaper can help you design a detailed plan and offer advice, as well as assist in applying for any required permits.

CALL BEFORE YOU DIG! Call your local municipality to have them locate buried utilities like electric lines and pipes.

APPLY TO ASSISTANCE PROGRAMS. Check your municipality's website for incentive programs to help offset the cost of your flood prevention actions.

PHOTO: Immanuel Giel

Rain garden (Photo: Wikimedia Commons)

As cities continue to expand and develop land, impervious surfaces such as pavements, sidewalks, parking lots and driveways limit the ground's ability to soak up rainwater. In fact, during a 5-year storm, that is, a storm large enough to occur about once every five years, a typical detached home sheds approximately 1400 litres of runoff water. That is the equivalent of 700 large pop bottles of water running off one house during one storm. Now imagine the amount of water running off all of the homes in a city! It can rapidly become more than the city's storm sewers can handle, causing water to flood through streets and even contaminate local water sources.

It is clear that homeowners should be taking preventative measures against floods. Some municipalities offer incentive programs to entice homeowners to implement storm water control measures. The City of Waterloo, for example, offers a discount to the storm water fee on residential utility bills for people who take steps to reduce runoff. Click here.

There are many ways to retrofit a home to mitigate the devastating effects of a flood. Reep Green Solutions, an environmental charity that focuses on sustainable home development, has collected a comprehensive list of different features that can not only help protect dwellings but also support local wildlife and plants, all while helping improve water quality–it's a win-win situation.

RAIN GARDENS

Rain gardens are shallow, sunken gardens designed to collect and filter rainwater. These gardens feature loose, deep soil that can easily absorb rainwater, and can have a considerable impact on preventing floods. Many plants are well suited to the growing conditions of a rain garden. These plants can help to remove contaminants in storm water. Rain gardens are a unique way to enhance biodiversity and improve the aesthetic appeal of any home.

NATURALIZED LANDSCAPING

Like a rain garden, naturalized landscaping replaces a traditional grass lawn with a wide variety of plants. These plants absorb more water than grass, improve air quality and create a habitat for bees, birds and butterflies, all while requiring little to no irrigation.

INFILTRATION GALLERIES OR SOAKWAYS

Infiltration galleries or *soakways* are a great alternative for spaces too small for rain gardens, or which require low maintenance. These underground reservoirs are filled with clean gravel that allows collected rainwater to gradually soak back into the ground.

PERMEABLE PAVING

Permeable paving is a very effective solution as it allows large quantities of runoff to absorb through the pavement and back into the ground. One disadvantage is that dirt can build up in the cracks between paving stones, making a home for weeds. Filling the spaces with sand can help prevent this.

Runoff (Photo: TRCA)

Rain barrel (Photo: Harry Cunningham)

RAINWATER HARVESTING

Rainwater harvesting is familiar to many with outdoor gardens. This method captures and stores rainwater in a barrel, which can be connected to a hose or irrigation system and used to water plants. Although this is not very effective against flooding because a barrel can only hold so much water, it is a great way to reduce your water bill.

People have a dangerous tendency to be reactive rather than proactive when it comes to flood proofing their homes. By taking precautions to protect homes from potential floods, homeowners can prevent a significant deal of pain and inconvenience, not only for themselves, but for their neighbourhoods. ●

ARE WE STRESSING OUT THE ARCTIC?

by SAMEER JAFAR

PHOTO: Annie Spratt/Unsplash

Since the industrial revolution, climate change has accelerated. It is, "running faster than we are," according to UN Secretary-General António Guterres. To ensure a sustainable and liveable planet for future generations, the many facets of climate change must be approached collectively and with appropriate legislation, resource management and innovation. We need such solutions worldwide, but particularly in the northern Arctic communities of Canada, where both livelihoods and wildlife are threatened.

The Arctic is a polar region encompassing the northernmost third of the Earth. It consists of the Arctic Ocean, adjacent seas and the bordering lands in Alaska, Finland, Greenland, Iceland, Norway, Russia, Sweden, and of course, Canada. About 40% of it, in fact. These northern lands have a deep-seated effect on the rest of the world.

Black smoke from an oil spill (Photo: SINTEF)

MELTED PASSAGES

The Arctic existed almost exclusively as a solid ice sheet until mere decades ago. When the ice began to melt, open water routes allowed freighters to navigate even the famously impassable Northwest Passage between the Atlantic and Pacific Oceans. Dr. Jackie Dawson, the Canadian Research Chair in Environment, Society and Policy, explains that shipping accounts for 90% of the global trade of goods. Countries like Russia and China quickly started to use these newly-opened arctic shipping routes, joined by other Pacific ports.

This increased shipping contributes to pollution in the region. In addition to shipping, the Arctic is a massive reservoir of natural resources, particularly oil and fish, which are now more accessible due to the great thaw. There are concerns that these once pristine and fragile areas are now vulnerable to such things as oil spills and overfishing. Not to mention potential conflict as countries vie for access to this wealth. Fortunately, Canada has jurisdiction over its inland routes, but fine-tuning regulations on these is tricky and often met with international debate.

ECOSYSTEMS AT RISK

Arctic melting creates a positive feedback loop or "snowball effect" in which a melting trigger can be compounded by

Science and evidence-based research can inform how we create Arctic infrastructure while maintaining air quality, protecting wildlife and supporting communities.

things that occur because of the melting. Melting allows for increased shipping and industry. Soot from this industrial activity falls on the snowy ground, which reduces its reflectivity, also known as *albedo*. A lowered albedo means the ground absorbs more light energy from the Sun, which converts to heat, accelerating the melting.

Water trickling down from melting snowpack can pool, allowing organisms such as algae to grow. Algae are typically darker in colour and absorb more light than snow, creating more areas with low albedo and encouraging further melting.

Peary caribou. (Wikimedia Commons)

Algae and other plants can help the situation a bit by sequestering carbon. But the amount taken in by living organisms is negligible compared to that released as the ground thaws. This is particularly dire in the case of permafrost, the arctic soil that remains frozen year-round. Permafrost, it happens, is a tremendous reservoir for the greenhouse gases carbon dioxide and methane. As permafrost thaws, the outgassing of these greenhouse gases simply adds to the positive feedback loop.

Dr. John Smol, the Canadian Research Chair in Environmental Change, emphasized that, as permafrost melts, the release of carbon and methane affects the temperature as well as the wildlife within the area. Caribou, for example, use densely packed snow to escape from predators like wolves. If the snow melts, the caribou's natural camouflage is no longer useful, leaving them exposed and over-hunted. Further, this changing landscape paves the way for new fauna which may introduce new diseases to the area.

Even Arctic air quality is at risk. Dr. Jennifer Murphy, an analytical chemist at the University of Toronto, studies atmospheric particles in vulnerable climates. She has found that white smoke from industrial activity and other organic particles reduce visibility. These particles get caught in water droplets and form low level clouds. The clouds scatter light, creating a hazy atmosphere and poor breathing conditions.

Arctic Settlement (Photo: Damon On Road/Unsplash)

LIVING IN THE ARCTIC

Inuit communities face changing conditions every day. Tim Argetsinger, the political advisor to Inuit Tapiriit Kanatami, a non-profit that represents over 60,000 Inuit in Canada, outlines the weak legislation put in place to counteract the Arctic's problems. Much of Canada's Arctic infrastructure has been neglected, leaving dwellers dealing with housing, water and other problems. Developers and investors need incentives to fund the Northern regions of Canada. Currently, financing models favour Southern Canada's urban lifestyle. Consequently, 70% of the population in the North face, for example, food insecurity. Even with established trade routes, 90% of Inuit communities are only re-supplied once or twice a year, with the price of goods skyrocketing. A watermelon, for example, was recently reported for sale at $78 in the North during the summer.

Melting in the Arctic has created some unexpected opportunities, however. For example, tourism to the area has increased. Since the 2000s, the area saw a 400% increase in private yachts. While this serves as a short-term stimulus to the local economy, yachts must be cautious to navigate icebergs and collapsing ice sheets carefully.

Polar bears in a melting Arctic tundra. (Photo: Annie Spratt/Unsplash)

IS THERE A FUTURE IN THE ARCTIC?

Despite the stressors, the Arctic remains a vibrant though relatively underdeveloped place. Canadians have an opportunity to shape the Arctic into an innovative and sustainable place. But, as Jackie Dawson pointed out, "the risk in the Arctic is enormous." Change there may present great opportunities, but only if that change comes with policies to mitigate risk. Policies that provide opportunities to benefit those who live in the region and not just for the countries that can afford to access it.

Science and evidence-based research can inform how we create Arctic infrastructure while maintaining air quality, protecting wildlife and supporting communities. With suitable government action and proper funding designed to promote sustainable living, the world can try to slow the effects of climate change and preserve the Arctic for generations to come. ●

RCIScience event in partnership with the Institute for Science, Society and Policy (ISSP), in Ottawa, Ontario. (Photo: Tonu Tosine)

NEW YEAR, NEW YOU

Healthy Eating

by MIRAN TSAY

What is my ideal weight? Is there a fad diet out there that actually works? Should I count calories? What is a carb? Does the method of cooking an egg improve it's nutritional content? Is it really possible for yogurt to have zero calories?! Consumers are faced with confusing advice on what constitutes a healthy diet and a puzzling array of choices at the grocery store. And sometimes, the line between healthy and unhealthy eating seems thin.

We live in an age where our understanding of nutrition and health problems are constantly evolving and being conflated. Trying to be healthy is challenging, from understanding the food environment, to how concerned you should be about your weight, and if you should go on a diet. Incessant marketing and mixed messages don't help either.

PHOTO: Brooke Lark

Dr. Amy Botta highlights the extent of fad diets over the years.

DIETS

According to Dr. Amy Botta, a researcher at York University, fad diets today include the ketogenic (keto) diet, vegan diet and intermittent fasting. While there have been numerous studies on the effectiveness of these diets on weight loss, it is very difficult for people to maintain these diets over 6 months. As such, long-term results are lacking. Each of them sport variations of fat, protein and carbohydrate (carb) levels. Keto is a high fat, low carb diet that recently gained popularity. Research suggests it is generally successful at achieving short-term weight loss so may have a place in dieting, but it is not always successful in the long run.

The vegan diet, by contrast, excludes all animal products and byproducts, including meat, poultry, chicken, fish, cheese and eggs. It is generally lower in fat. Often considered healthy, Dr. Botta notes that one recent study indicates that, while a vegan diet can reduce the risk of having cardiovascular problems, it may increase the chance of strokes by 20%. This, however, is a very new area and more research is needed to better understand these results. Humans require amino acids - vital building blocks of protein in our bodies. Amino acids sourced from plants have a different profile compared to those sourced from meat, and are often incomplete. As a result, Dr. Botta explains that someone following a vegan diet has to be careful to consume enough protein in order to have a more complete complement of amino acids needed for the body to function.

> **“Listen to your body.”**
>
> DR. JESSICA MUDRY


Dr. Lindsay Bodell explains how weight suppression can lead to eating disorders.

Intermittent fasting is a diet that restricts, not calories, but the time of food intake. Types of intermittent fasting include: complete fasting, modified fasting and time-restricted fasting, and each can produce benefits for people with specific conditions. However, these fasting diets and their collateral effects have not been studied over long periods. The main takeaway, according to Dr. Botta, is that a diet can be helpful when trying to lose weight or become healthier, but it is not the only factor in determining our food intake.

FOOD ENVIRONMENTS

Our food environment is a crucial and influential part of our plate. The food environment encompasses everything from the farms where our food is grown, to the grocery stores where we shop, and even back to our homes. Laura Vergeer, a PhD candidate at the University of Toronto, studies how food policy can help make the healthier choice the easier choice. She highlights the influences of our food environment on diet, including policies surrounding food and food marketing. A country’s food environment policy can be shaped by social norms, beliefs, food-availability, food-origin, nutrition, labelling and many other factors. Together, these determine how we make food-related decisions.

Food marketing strategies include ads targeting specific demographic groups, such as children. Think of a sugary cereal with cartoon characters on the label. Online ads that reach children through games and websites, and include rewards linked to buying their product. Marketing practices aimed at adults often include “zero calorie” foods, energy boosters and items guaranteed to “help” weight loss or ease time constraints. Even when shoppers try to read food labels to better understand what they might be consuming, the sometimes wordy explanations make products confusing. Ms. Vergeer noted that addressing these types of questions will help better understand a country’s food environment and its effects on the individual consumer.

EATING DISORDERS

When does "healthy eating" become unhealthy? A danger in modern society is constant media pressure to look skinny and therefore be "attractive." Diets that begin as a way to lose weight can lead to eating disorders - problematic eating or eating-related thoughts and behaviours that can produce serious psychological and physiological effects.

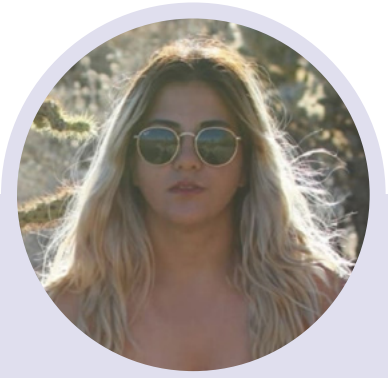
Dr. Lindsay Bodell from Western University researches how diets can evolve from a health-driven act to an eating disorder. Her work includes investigating how dieting can be driven by body image insecurity and a desperate desire to lose weight. Eating disorders affect millions. Thirteen per cent of all Canadian youth (under 20 years old) suffer from some form of eating disorder. In anorexia nervosa, food intake is limited, while bulimia includes binge-eating, followed by a counter-acting behaviour, such as induced vomiting. This is distinct from binge eating disorder, in which the person restricts intake then overeats. There are many others.

Recently, a new eating disorder has surfaced: avoidant restrictive food intake disorder, or ARFID, in which individuals avoid specific foods. Their reasoning is due to trauma related to the food, or abdominal pain linked to eating. ARFID can result in dramatic weight loss, nutritional deficiencies and a lack of energy.

Dr. Bodell confirmed that dieting is a strong risk factor leading to eating disorders. Weight suppression, the difference between one's heaviest weight and current weight, is a big player in eating disorders. Higher weight suppression is associated with fearful mental states, low self-esteem, obsession and responses to poor treatment. Eating disorder cycles usually begin with an individual wanting to lose weight due to weight suppression. When it works, they experience satisfaction...for a moment. Subsequent weight gain results in renewed dieting, falling prey to the desire of being skinny once again. They try to achieve greater weight suppression, and the cycle continues. Once this solidifies as a habit, it is very difficult to break and can become extremely dangerous. It is important to note that people with eating disorders are often at a healthy weight. Eating disorders do not discriminate. There is no single cause and no single solution.

If you're wondering about your diet, these researchers recommend going back to basics. Consume a diverse array of fresh products, and consider around 80% healthy foods and 20% "cheats." That said, a "one-size-fits-all" diet does not exist. Dr. Jessica Mudry, author of *Measured Meals: Nutrition in America* and Assistant Professor in Professional Communication at Ryerson University highlights, "We are not objects. We are subjects." We need to consider our overall health, psychology, food preferences and availability. "Listen to your body." We have to take care of our own bodies, mental health, and diets, which fuel our lives and our happiness. ●

Click here to watch "New Year, New You: The Science of Healthy Eating" in full on RCIScience's YouTube channel now.



VOLUNTEERSPOTLIGHT

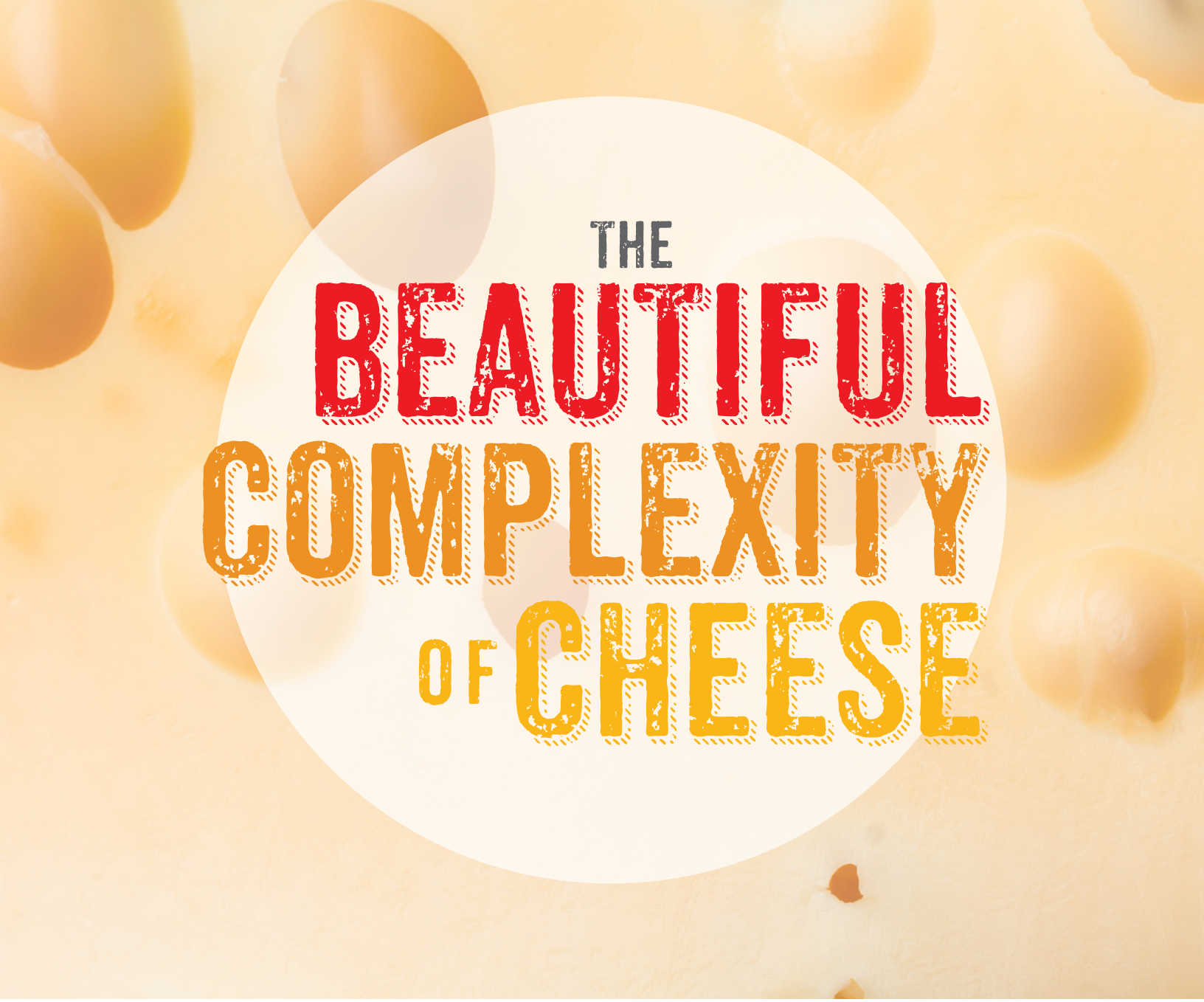
NARGOL GHAZIAN

You may have seen her at our Toronto events, registering attendees, helping with refreshments, or having a post-talk discussion with the RCIScience community. Nargol Ghazian is a soon-to-be PhD Candidate at York University, specializing in Ecology and Evolutionary Biology. Her interest in climate change research has taken her all the way to the deserts of the American Southwest.

Intrigued by the impacts of anthropogenic stressors on ecosystem wellbeing, Nargol spends spring and summer in the Californian drylands observing how fluctuations in sunlight and temperature are impacting the regional flora and fauna. She has developed artificial shelters that mimic the natural canopy, a stepping-stone for conservation and restoration practices.

Nargol is a big advocate for open science, most recently collaborating with Microsoft on their AI initiative for environmental innovation. She is also passionate about science communication, "I think us scientists spend a lot of time in bubbles where, more often than not, we're the only ones understanding the jargon. That's why it's important to be able to communicate front-line research to a more general audience. Science should be accessible to everyone and dismantling complex ideas into simpler terms is a challenge I enjoy very much."

She loves volunteering with RCIScience because it's an opportunity to learn from great science communicators. Her favourite moment is seeing members coming back event after event—"It shows that the organization is doing it right!" You can follow Nargol on Twitter @NargolG.



THE BEAUTIFUL COMPLEXITY OF CHEESE

by JON FARROW

There is a lot of biology, chemistry and physics involved in making good cheese, but there is also an art.

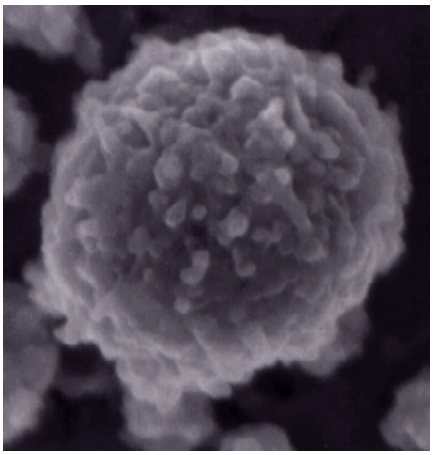
PHOTO: Designed by Freepik

You can love it or hate it, but there's no denying that cheese is probably the most interesting thing in your fridge right now. With everything that could go wrong, it is a modern miracle that we regularly, safely and eagerly eat what is essentially milk that has gone bad under careful supervision.

Guests at the RCIScience's Art & Science of Cheese event were introduced to the secrets of this miraculous food with talks from two of Ontario's best cheese ambassadors: Dr. Mary Ann Ferrer and Shep Ysselstein.

Mary Ann Ferrer, a food consultant who received her PhD in food science from the University of Guelph, is a passionate cheese scientist and frequent judge at cheese competitions. She develops solutions for cheesemakers trying to improve their processes and teaches on the University of Guelph's Cheese Making Technology course.

She introduced the cheesemaking process as a series of choices. "At every step you have to consider many factors," she says. A prospective cheesemaker must think about not just the physical characteristics of the mixture in front of them (e.g. temperature, pH, salt and mineral concentrations), but also the strains of bacteria present (those introduced and those already present in the environment). What makes it all the more difficult is that the timing of operations like cutting the curds or adding an enzyme called rennet can radically change the end result. She emphasized that there are only a few differences in process between a hard, crumbly feta and a soft, gooey camembert. They both use the same ingredients.



Electron microscopy image of a casein micelle, a molecule present in all milk products, including cheese. (Photo: Prof. H. Douglas Goff, University of Guelph)

The key to cheese, she explained, is the casein micelle, a "hairy" clump of molecules that is present in all milk. "When you see white milk," she says, "it's because of these dudes." The hairs on casein micelles keep them apart, but if you add an enzyme like rennet to cut those hairs, the micelles start to clump. After the milk coagulates, the cheesemaker must cut, cook, drain, press, brine and age the result until the perfect cheese emerges.

Shep Ysselstein, the owner and operator of Gunn's Hill Artisan Cheese, is too modest to say he has made the perfect cheese. But by the looks on the faces in the room as his samples were devoured, it's clear Shep has come pretty close.

After an introduction to his family-run business, a cheese education pursued in the Swiss Alps, and how the cheesemaking process unfolds at

FUN FACT!

2019 was the 150th anniversary of Dmitri Mendeleev's organization of the elements into the familiar periodic table. Mendeleev was an advocate for agricultural reform and, as he assembled his ideas on the periodic table in 1869, was visiting cheese dairies.

Dr. Mary Ann Ferrer, food scientist, University of Guelph

Shep Ysselstein preparing cheese samples

Gunn's Hill, Shep led a tasting of five of his establishment's best cheeses. All are made using milk from a dairy farm next door, owned by his father and brother.

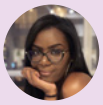
Among the samples were "Dark side of the Moo", a beer-soaked cheese modeled on a Swiss style called *Mutchli*, a preservative-free and creamy brie dubbed "Brigid's Brie" for Shep's late mother-in-law, and probably his best known product, "Five Brothers." This last cheese borrows traits from Gouda and Appenzeller styles, and vaulted Gunn's Hill and Shep to Canadian cheese fame after it won at the Canadian Cheese Grand Prix.

RCIScience members sampled various cheese varieties

There is a lot of biology, chemistry and physics involved in making good cheese, but there is also an art. With so many variables, the experience and intuition of makers like Shep goes hand-in-hand with the technical expertise of scientists and judges like Mary Ann to make sure that cheese stays interesting. ●

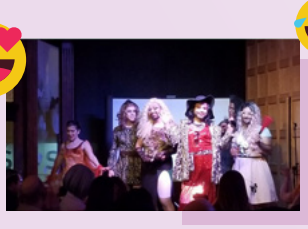
Gunn's Hill Artisan Cheese located in Woodstock, Ontario, is owned and operated by Shep Ysselstein

seen & heard



Kayonne Christy @KSChristy1 · Jul 8, 2019
Just coming home from #scienceisadrag and...WOW! Such a fantastic event!!! Fabulous queens, fabulous research, fabulous KT...just wow!

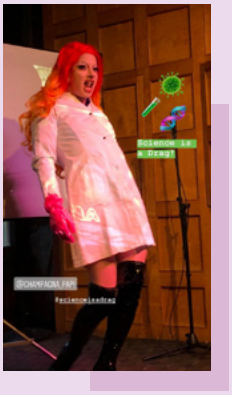
Amanda Veri (she/her) @AmandaOVeri · Mar 10
I learn new science every single day and it is never as beautiful, engaging, celebratory, inclusive and patriarchy smashing as SCIENCE IS A DRAG! Thanks to all the Queens and King, @heysciencesam and team, and @RCIScience for the BEST night ever!



Elizabeth Neswald @eneswald1 · Jul 8, 2019
Just back from #ScienceIsADrag
Some very impressive grad students presentations.

Jessie MacAlpine @jessiemacalpine · Jul 8, 2019
So stoked for #SCIENCEISADRAG happening tonight! Thanks to @heysciencesam and @RCIScience for organizing this amazing event at the Gladstone Hotel!! And most of the @CowenLab is here to cheer on the queens!!!

Hannah May Charnock @HMCharnock · Mar 9
#ScienceIsADrag is serving some #SciComm realness tonight at the @GladstoneHotel @heysciencesam @RCIScience @GeithMB @_Champagna_



Rob Ulrich (he/they) @robertnulrich · Jul 9
One of the best #LGBTQSTEMDay events yet???!

RCIScience is proud to support: ***Science is a Drag*** —the world's first fully science-themed drag show!

Originally conceived by friends Dr. Samantha Yammine and PhD candidates Shawn Hercules and Geith Maal-Bared, *Science is a Drag* was created to challenge cis-heternormative stereotypes of scientists and archaic notions of professionalism, and to provide a safe and empowering platform for queer scientists to feel creative and unrestricted in their efforts to communicate science.

Presentations have included stand-up, lip sync medleys, dance, live DNA extractions and even using RuPaul's Drag Race clips to expertly explain antibiotic resistance! Our performers have showcased some of the most creative examples of science communication that RCIScience has seen in its 170+ year history.

Of the two events we've currently hosted at the Gladstone Hotel in downtown Toronto, both sold out within 24 hours, with a significant portion of the audience stating they would not have attended were it not a drag event, that they'd never attended a science-themed event in the past and that they would *all* come back to a future show!

The team was working on its international roll out when the global pandemic hit, but we're certain this is one night audiences can't wait to see safely return.

Follow all the ***Science is a Drag*** action on Instagram! @scienceisadrag

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**he intersection of science and performance art,
Dark is a variety show like no other! A unique
of comedy, song, dance, spoken word, gameshows
owcases science in a new light for a fun night out.**

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“I LOVED THE EASY-TO-UNDERSTAND SCIENCE INTRO AND THE ACCOMPANYING TASTING EVENT. THE Q&A WITH THE TWO GUESTS WAS A GREAT OPPORTUNITY TO UNDERSTAND DIFFERENT SIDES OF THE INDUSTRY.”

“LIVELY PRESENTATION WITH A STORYTELLING FORMAT.”

“I LIKE THE GREAT SPEAKERS YOU FIND & THE TOPICS ARE VERY 2020.”

“THANKS FOR MAKING COMPLEX TOPICS ACCESSIBLE :)”

“SHORT AND INFORMATIVE, ENGAGING, FUNNY AND NOT RIGID NOR LONG AND BORING.”

“CASUAL, TASTY AND INFORMATIVE.”

“THE WHOLE VIBE AND ENERGY OF THE EVENT WAS SO DIFFERENT (IN A GOOD WAY) FROM TYPICAL STEM PANELS.”

“EXCELLENT LECTURE! I LOVED IT.”

“THE SPEAKERS WERE VERY KNOWLEDGABLE AND AMAZING COMMUNICATORS.”

“THE SPEAKER WAS VERY ENTHUSIASTIC AND ENGAGING.”

RCIScience
Royal Canadian Institute for Science