



CIFAR REACH

2023

THE FUTURE OF RESEARCH TODAY

Science is taking us to places we never imagined — and it's happening sooner than you think

AI IN 2063

Interpreters, regulation and automation. In 40 years, what could AI look like?

THINK SMALL

Quantum might well change the world, one tiny, subatomic particle at a time

EARTH, SPACE AND THE UNKNOWN

Can the search for what lies beyond be answered here on Earth?

GLOBAL CALL FOR IDEAS

Three new programs seek to unlock insights into the future of being human

CIFAR

What is the future of...

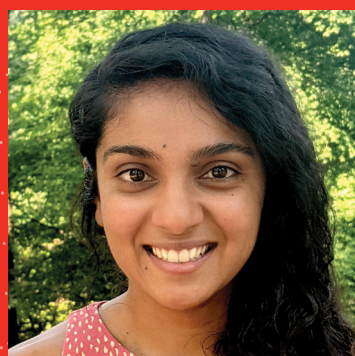
***fairness
in AI?***

***mars
exploration?***

***human gut
health?***

***human
consciousness?***

***treating
infectious
fungal
diseases?***



In celebration of CIFAR's 40th anniversary, we're highlighting researchers whose big ideas aim to make the impossible, possible.

Check out the "Believe the Impossible: The Future of..." series on cifar.ca/news

REACH 2023

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AI IN 2063

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Contributors
Liz Beddall, Ty Burke,
Ania Czupajlo, Ekua Quansah,
Kathleen Sandusky, Elissa Strome,
JP Udo

DESIGN

Creative Director
Emma Tarswell

Cover Illustration
Ariel Davis

Photography
Kate Astaire, Liz Beddall,
Dominic Blewett, Josh Fee,
Korina Joseph, Kryani Kanavaros,
Cheriss May, Mel Musto,
Ben Nelms, Winni Wintermeyer

Illustration
Ariel Davies, Christopher
Dupon-Martinez, Raz Latif,
Joel Kimmel

CIFAR
REACH Magazine
MaRS Centre, West Tower, 661
University Avenue, Suite 505
Toronto, ON M5G 1M1

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CIFAR is a global research organization that convenes extraordinary people to address the most important questions facing science and humanity. We are supported by the governments of Canada, Alberta and Quebec, as well as foundations, individuals, corporations and Canadian and international partner organizations.

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This issue of REACH is a
testament to how CIFAR's
global community of
researchers is transforming
the world around us.

When I joined CIFAR as President & CEO in November 2022, I was already familiar with much of the great work this organization has accomplished in the past. Having served on the Board and as a member of the Research Council, I had a line of sight into both how CIFAR operated, and the breadth and depth of the research it supported. Joining in my new capacity as its leader, however, gave me unparalleled insight into just why CIFAR has succeeded for 40 years (a milestone that we celebrated recently). I have witnessed first-hand the foresight and the capacity to dream big that makes our organization great, and positions it squarely as a leader in the global research community. Our ability to build long-term, interdisciplinary, global networks of collaboration that are characterized by trust, openness, and the free exchange of ideas across both disciplinary and national borders, has never been more important. At this moment in history, we are grappling with significant issues that threaten the well-being of people and the planet — strong political division, war, class divides, food and water inse-



curity, global pandemics and, of course, climate change. Looking ahead, I truly believe that cutting-edge research, through the lens of global collaboration and ethical application, has a unique power to make our world better. This issue of REACH is a testament to how CIFAR's global community of researchers is transforming the world around us. Our feature article propels you into 2063 for a glimpse of how AI will be seamlessly integrated into your life. In "Earth, Space and the Unknown", we learn how CIFAR researchers are seeking to understand the origins of Earth to discover more about alien life beyond our planet. We also take you inside the complex world of quantum to better understand how materials like graphene or silicon might surface in usable applications. And, we share the exciting outcome of our third Global Call for Ideas, which yielded three bold, new research programs pursuing lines of inquiry into the future of being human. I hope that our newly redesigned and revamped REACH inspires you, providing insight into the future of CIFAR. I look forward to reshaping CIFAR's Strategy

to capitalize on our many strengths. We will continue to do what we do best: convene extraordinary people to address the boldest, most important questions facing science and humanity. And we look forward to addressing key issues, like climate change, in our activities both internally as an organization, and more broadly with a wider public. Now is the time for action and our momentum is a testament to the strength of our CIFAR community — the researchers, supporters, donors, and, of course, staff who make our work possible. Thank you for looking to the future with us.

STEPHEN TOOPE
OC, LLD, FRSC
President & CEO, CIFAR

CIFAR IN THE NEWS

From climate change to the human microbiome, top news outlets from around the world turn to CIFAR’s community of scientific leaders for expert commentary. Here are just a few of the statements made by CIFAR researchers in international media during 2022-2023. Read more at: cifar.ca/news

“People most often think about fungi as foot infections, or something kind of trivial, as opposed to a deadly disease. But what we have seen is — now that people are actually paying attention — fungi are killing more than 1.5 million people every year.”

LEAH COWEN
Program Co-Director, Fungal Kingdom: Threats & Opportunities,
in *CBC*, February 2023



“Antibiotics were a great miracle when they were introduced in the 1940s, and we’ve been digging a hole of resistance for the last 75 years... Vaccines are an important part of getting us out of that hole.”

MARTIN BLASER
Advisor, Humans & the Microbiome,
in *Financial Times*, May 2022

“We live in a ‘controlled hallucination’ that remains tied to reality by a dance of prediction and correction, but which is never identical to that reality.”

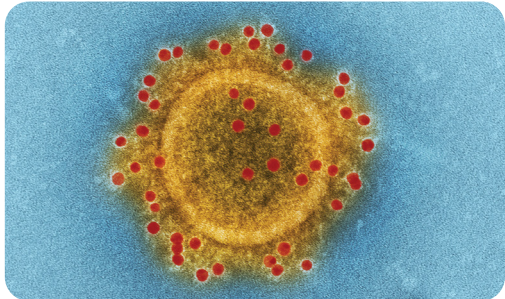
ANIL SETH
Program Co-Director, Brain, Mind & Consciousness,
on embracing the diversity of our experiences, in *The Guardian*, October 2022



Photos: Leah Cowen (courtesy of the researcher); woman getting vaccine (CDC via Unsplash); Anil Seth (Neil Ta)

“Since we expect to see many more climate-change-related disasters in the coming century, quantifying the health costs of exposures will allow us to better estimate the toll these disasters take on our societies and perhaps to proactively intervene.”

JENNY TUNG
Fellow, Child & Brain Development, in *Scientific American*, March 2022



“Understanding the dynamics that have shaped the human immune system is key to understanding how past pandemics, like the plague, contribute to our susceptibility to disease in modern times.”

HENDRIK POINAR
Fellow, Humans & the Microbiome,
in *The Independent*, October 2022

“When companies come up with a new medicine, they cannot just put it in the market. They have to meet standards, and they have to be accountable. We should have that in AI as well.”

GOLNOOSH FARNADI
Canada CIFAR AI Chair at Mila, in “Can we make artificial intelligence less racist?” *Toronto Star*, June 2022



“In a few years, I fully expect our understanding of stars and galaxies and the evolution of the Universe will be completely and irrevocably changed.”

KATIE MACK
CIFAR Azrieli Global Scholar, Gravity & the Extreme Universe, in *BBC’s Science Focus*, July 2022

Photos: Jenny Tung (courtesy of the researcher); Germ (CDC via Unsplash); Golnoosh Farnadi (courtesy of the researcher); Galaxy (Bryan Goff via Unsplash)

“Open research is the only way of addressing the intricate challenges of society-scale algorithms in a democratically legitimate way.”

GILLIAN HADFIELD
Canada CIFAR AI Chair at the Vector Institute, in *WIRED*, February 2023



“Good Lord, it was hydrogen, these rocks were full of hydrogen.”

BARBARA SHERWOOD LOLLAR
Program Director, Earth 4D: Subsurface Science & Exploration discussing a discovery she made when surveying sites for gases, in *WIRED*, February 2023

“What we see next is the commercialization of quantum, and so we’ll start to see little glimmers and then all of a sudden it’s going to change everything we do.”

STEPHANIE SIMMONS,
Fellow, Quantum Information Science, in *CBC*, August 2022



“What Canadians should fear is not automation, but the lack of automation. If we don’t engage with new technologies, the result is lower wages and much more boring jobs.”

DAN BREZNITZ
Program Director, Innovation, Equity & The Future of Prosperity, in *The Globe and Mail*, April 2022

Photos: Gillian Hadfield (courtesy of the researcher); Barbara Sherwood-Lollar (courtesy of the researcher); Stephanie Simmons (courtesy of the researcher); Robotic arms (Simon Kadula via Unsplash)

THE FUTURE OF BEING HUMAN

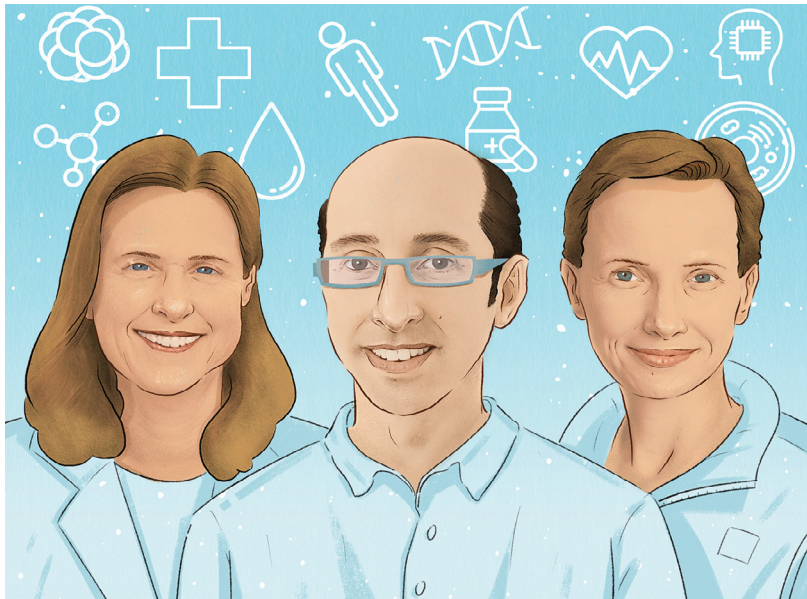
By Justine Brooks
Illustrations by Raz Latif

CIFAR’S NEW PROGRAMS AT A GLANCE

In April 2023, CIFAR unveiled three new programs that were selected from the Global Call for Ideas. These programs embody high-risk, high-reward research challenges — and the future of being human.

The world is at an inflection point. Rapid changes in the environment, technology and threats to human health are exacerbating inequalities and revealing the need to rethink our position as human beings and global citizens.

Three new CIFAR research programs, and their new program directors, are poised to answer big, bold questions on the future of being human. By exploring environmental, sociological and philosophical factors, among others, these researchers are seeking solutions to the world’s emerging challenges.



“The fundamental knowledge we discover about the human body, coupled with our new experimental and computational methods for multiscale analysis, promises to spur a revolution in medicine.”

THE MULTISCALE HUMAN

RESEARCH CO-DIRECTORS:

GARY BADER
University of Toronto, Canada

KATY BÖRNER
Indiana University, United States

SARAH TEICHMANN
Wellcome Sanger Institute
& Cambridge University,
United Kingdom

Imagine a “Google Maps” for the human body. From mapping individual molecules to an entire person, across populations and time, researchers from CIFAR’s new Multiscale Human program seek to create a universal encyclopedia of the human body, which would transform biomedical research and practice.

“The fundamental knowledge we discover about the human body, coupled with our new experimental and computational methods for multiscale analysis, promises to spur a revolution in medicine,” says Sarah Teichmann. Despite knowing that a mutation at the DNA level can affect all levels of the body’s systems, we have little understanding of these effects and how they relate to each other.

“Learning how this works would enable us to predict the effects of genetic and environmental perturbations and how to control them,” explains Gary Bader.

Such an ambitious project faces many challenges — how does one combine data across modalities, spatial and temporal scales and accurately represent the diversity of the human population? An interdisciplinary approach is key. The team also sees opportunities in machine learning.

“Mapping the human body at multiple scales is a marvelous challenge that will require both human and machine intelligence,” says Katy Börner.

The interdisciplinarity and extended time period is one of the major draws for these researchers. “The opportunity to work face-to-face over an extended time period is fantastic, and one you simply wouldn’t get with other sources of funding,” says Teichmann when reflecting on being chosen as part of the CIFAR Global Call for Ideas.

What could a definitive tool like this mean for the future of being human? Börner imagines a future with a “Digital Twin” program that is initiated at birth, and used to predict ideal fitness, nutrition and medical treatments for the real-life human.

“Working towards this self-understanding will help us solve some of the most pressing challenges we face in improving our health and reducing human suffering,” says Bader.

While the program has many goals and possibilities for discovery, Teichmann adds, “I think many of our biggest discoveries will be entirely unanticipated.”

GRAVITY & THE EXTREME UNIVERSE

RESEARCH CO-DIRECTORS

VICTORIA KASPI
McGill University, Canada

LUIS LEHNER
Perimeter Institute, Canada



In 1986, CIFAR launched its Gravity & the Extreme Universe program to uncover the mysteries of the cosmos. After more than 30 years, the program has been renewed for its final term.

One new exciting area of research for the team is time-domain astronomy, which studies highly variable sources on short time scales — things

that are there one moment, and gone the next.

Program co-directors Victoria Kaspi and Luis Lehner say the research promises to be highly fruitful, “particularly given upcoming groundbreaking instrumentation projects that will be coming online,” which will enable unparalleled insights into the cosmos.

These instruments include the upgraded Advanced LIGO/Virgo gravitational wave detectors, as well as the Canadian Hydrogen Intensity Mapping Experiment (CHIME) Fast Radio Burst (FRB) Outrigger telescopes. Both projects include many program members at the helm.

The CHIME/FRB project in particular has been one of the most exciting projects to come out of the program, says Kaspi. The team behind CHIME/FRB is sifting through the sounds of space, leading to unprecedented insights into astronomy’s greatest mysteries: understanding the origins of fast radio bursts. Kaspi hopes the next big discovery will be just as revolutionary — using the gravitational wave detector to constrain the equation of density of neutron-star matter.

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“Nothing about us, without us”

Essay by Ekua Quansah & Elissa Strome

Illustration by Christopher Dupon-Martinez

A journey of meaningful collaboration to increase Indigenous participation in AI

Advancements in artificial intelligence (AI) have the potential to change the world we live in, delivering social, economic and environmental benefits to Canada and around the world. They also carry potential for harm, if not created and implemented responsibly. As AI-based tools, products and services become increasingly sophisticated and ubiquitous, it is more crucial than ever that the humans behind AI technologies actually represent the diverse communities they serve.

Indigenous peoples have long been excluded and under-represented in science, technology, engineering and mathematics (STEM) education and training, despite their contributions to STEM knowledge. Unfortunately, to date, the field of AI has been no exception. As a leading international research organization and the leader of Canada’s national AI strategy, CIFAR is committed to being a leading actor in increasing equity, diversity and inclusion (EDI) in STEM. And, in our roles as CIFAR’s Head of EDI and Executive Director of the Pan-Canadian AI Strategy respectively, this is of foremost concern to us.

With the calls to action from Canada’s Truth and Reconciliation Commission in mind, we set out to understand the barriers faced by Indigenous students to STEM education and training.

In exploring CIFAR’s opportunity to contribute to increasing Indigenous student participation in AI, our guiding principle was, “Nothing about us, without us” — a rallying cry long-used by marginalized groups worldwide. It reminds us that those who are most affected by societal inequities must lead and be at the centre of any actions to address those inequities. We met with Indigenous leaders in STEM and those already delivering STEM and AI programming to Indigenous and non-Indigenous students across the country to understand the challenges and where CIFAR might be able to make a difference.

In parallel, we participated in the Public Policy Forum’s Putting Reconciliation into Practice: Inclusion and Action Leadership program to deepen our understanding of best practices to advance reconciliation, both personally and professionally. We then completed the First Nations Information Governance Centre’s Fundamentals of Ownership, Control, Access and Possession (OCAP) course — to make sure that we had a foundational understanding of the principles that determine how First Nations’ data and information should be collected, protected, used or shared.

Through deepened knowledge and meaningful collaboration with partners, and in consultation with Indigenous and AI leaders, we developed a three-part plan to increase Indigenous student participation in AI and launched a pilot program in summer 2022. Our plan included: 1) providing

full funding of the direct and indirect costs for all Indigenous students accepted into any NextGen AI Training Program delivered by CIFAR and our partners across the country; 2) working with an Indigenous-led team to develop new curriculum to explore Indigenous perspectives on AI for inclusion in all of our NextGen AI Training Programs; and 3) working with partners to deliver AI training to Indigenous youth in their communities.

A key partner in our efforts to deliver AI training to Indigenous youth is Actua, one of Canada’s leading STEM outreach and engagement organizations. Actua’s National Indigenous Youth in STEM (InSTEM) program is Canada’s first national program designed to remove barriers to Inuit, Métis and First Nations youth engagement in STEM through land-based education.

“It is critical that Indigenous voices are included in all aspects of the AI space,” shared Doug Dokis, Director of the National InSTEM program and member of the Dokis Anishinabek Nation in northern Ontario. “While there are incredible opportunities for the inclusion of AI in Indigenous practice as it relates to land management as cultural practice, there are things to consider around potential impacts on Indigenous Knowledge and culture that must also be considered when introducing AI in this space.”

With CIFAR’s partnership, Actua integrated AI curriculum into their existing land-based, for-credit summer camp for high school students, at the Thompson Island Cultural Camp in Akwesasne First Nation. Further, during the 2022-23 school year, the CIFAR team had the opportunity to meet with Indigenous student leaders in Actua’s InSTEM Youth Delegation to explore opportunities and challenges in the field of AI with them.

In tandem with our work to advance participation and inclusion of Indigenous students in AI we continue to develop programming, supports and resources for other underrepresented groups in AI, including Black students. To this end, we have recently launched the CIFAR Inclusive AI Scholarship for Black and Indigenous students and a new partnership with the Vector Institute to support internships for Black and Indigenous students.

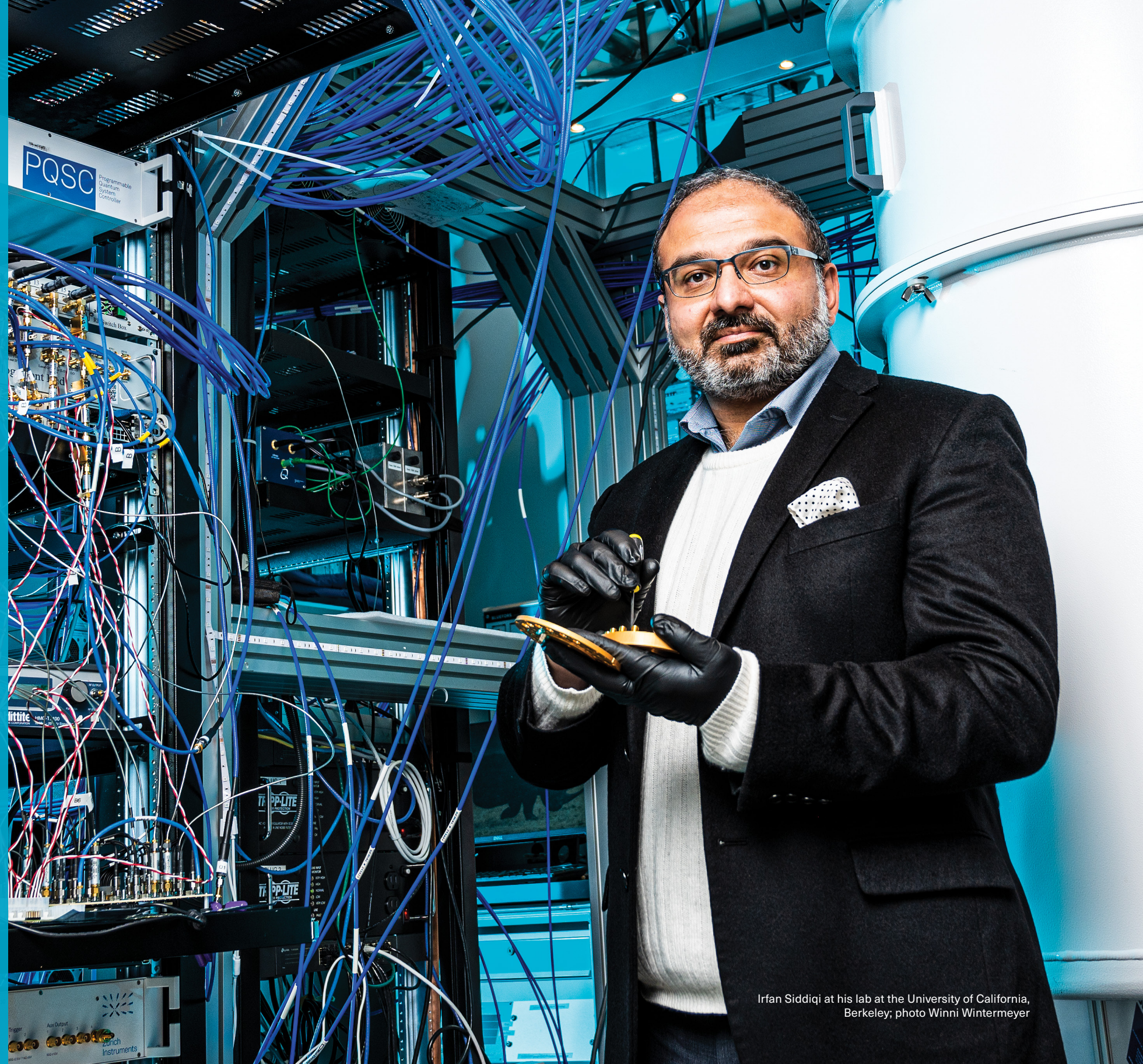
As we continue building initiatives that address underrepresentation in STEM, we are grateful for the rich learning opportunities it has provided along the way. Our progress so far is a direct result of our partnerships and collaborations, taking leadership from communities and individuals, and integrating their insights and perspectives in our work. Our commitment to a “Nothing about us, without us” approach has been the key to breaking down barriers. And the power of that simple philosophy has been the most valuable lesson of all. •

THINK SMALL

HOW QUANTUM WILL CHANGE THE WORLD

By Ty Burke

CIFAR researchers in the Quantum
Materials and Quantum Information
Science programs are doing big things
with tiny particles



Irfan Siddiqi at his lab at the University of California, Berkeley; photo Winni Wintermeyer

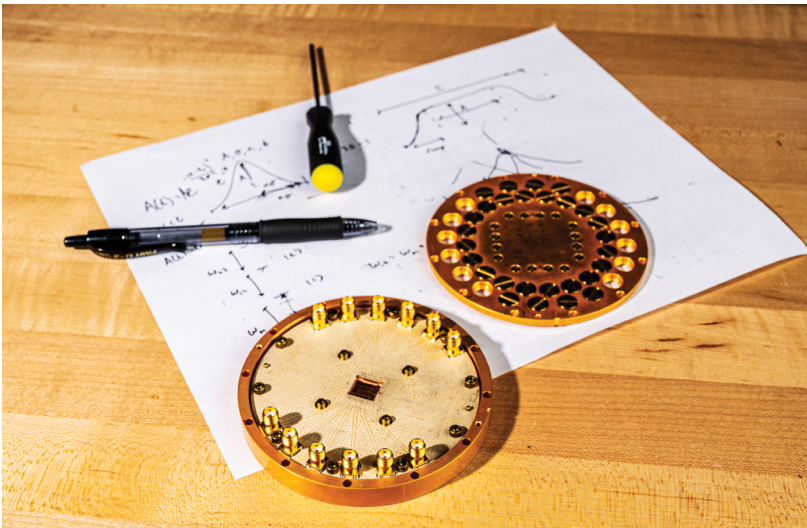
We are on the cusp of another technological revolution.

To the ancient Greeks, the word ‘atomos’ means uncuttable, and the philosopher Democritus applied this idea to the smallest possible unit of matter. If you cut a material into ever-smaller pieces, until you can cut no more, then you have an atom.

The modern idea of the atom borrows this word, but we now know that there are particles far smaller than the atom itself. These subatomic particles defy explanation by classical physics, and new theory was needed to explain their bizarre properties. It’s called the theory of quantum mechanics, and in the early 20th century, it began to transform how we understood the workings of the universe, on the tiniest scale.

It has already enabled powerful technologies like computer chips and MRI machines. And now, quantum mechanics is being applied to the next generation of transformational tech.

Researchers in CIFAR’s Quantum Materials and Quantum Information Science programs are advancing quantum technologies that will revolutionize computing, electrical grids, transportation networks, and more.



A quantum chip, a specialized processor that uses quantum effects. Photo: Winni Wintermeyer

IRFAN SIDDIQI

When an electron leaps between orbits around an atom’s nucleus, a tiny particle of light is emitted. It is so faint that it’s barely perceptible, but this particle, called a photon, is predicted by quantum mechanics. It’s called a “quantum jump,” and when it occurs, the photon and atom can be linked by a phenomenon called quantum entanglement. Their physical properties are interdependent, even if the particles are far apart.

The concept is, well, kind of spooky. That’s how Albert Einstein described it. He argued that quantum entanglement was impossible because it allowed for the interdependence of particles, even if the distance between them is so great that light itself could not travel quickly enough to bridge it. Einstein called it “spooky action.” It seems to defy his theory of special relativity, which posits that nothing travels faster than light.

But the signatures of quantum entanglement can be observed, and it can even be created on demand. And it is central to unlocking the potential of quantum computing. Classical computing devices like laptops conduct operations using bits — made with transistors on a computer chip. Each bit can have a value of zero or one. It can be in either of these, but not both.

But a quantum computer makes computations with qubits — short for quantum bits. There are different approaches to physically creating these, but all use quantum mechanical phenomena to allow the qubit to be in a state of superposition. That means that it can be both a zero and a one at the same time.

And when multiple qubits are linked together through quantum entanglement, they can be operated on simultaneously. This increases computational power exponentially, and allows certain types of operations to be performed much more quickly.

“In a classical computing device like a laptop, each transistor is independent — none interferes with the others,” says Irfan Siddiqi, a fellow in the Quantum Information Science program and a professor of Physics at the University of California Berkeley in the U.S.

“But qubits are entangled with each other. This could allow them to process information more effectively. It is the promise of quantum mechanics, but we need to create entanglement on a large scale. We can do a hundred qubits, but we need to entangle a hundred thousand, even a million. And we don’t know how to create and control qubits at that scale.”

Creating entanglement requires a highly controlled setting. Quantum computers are especially vulnerable to interference that researchers call “noise,” which causes errors and disrupts quantum entanglement. Error-causing “noise” can be anything from light to radiation from nearby wi-fi networks.

“Quantum information lasts a very short time, but there are ways to extend its lifetime. You can make the materials and everything else perfect, so that there are no errors and no noise. We have been trying that for more than 20 years, and it’s pretty hard. You need to get all of the pieces right. Otherwise, it doesn’t work,” says Siddiqi.

Siddiqi uses magnetism to control quantum information, and this can help reduce errors. It helps prevent certain types of noise because magnetism couples more weakly than electric charges.

BEN LANYON

The trapped ion chamber of Ben Lanyon’s quantum computer is made of titanium, plated in gold, and bonded by sapphire. It uses electric fields to suspend electrically charged calcium atoms called ions, and manipulates their quantum state with lasers.

Trapped ion systems are among the most promising approaches to quantum computing.

“One reason is their level of proven quantum control,” says Lanyon, a fellow in the Quantum Information Science program and an assistant professor at the University of Innsbruck in Austria.

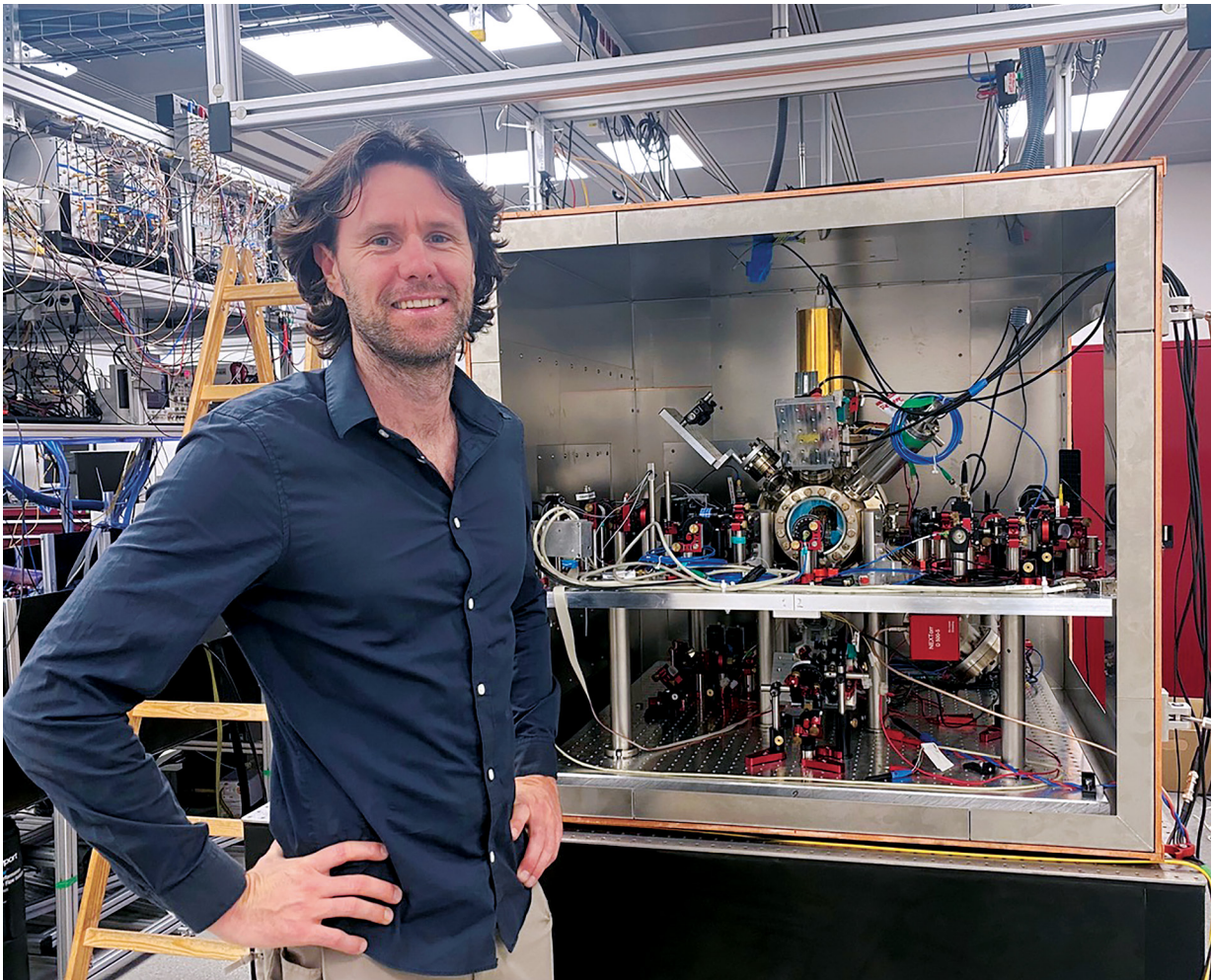
“We can precisely manipulate ions, and get them to evolve into very interesting quantum states that we do not properly understand yet. But you do not get anything for free, and trapped ion quantum computers are not as easily scalable as some approaches to quantum computing could be.”

Researchers have scaled this system to trap tens of ions, and harness their quantum states to use as qubits. But there is no path to directly scale up

“We should design quantum information systems so only certain types of errors occur, then pair them with practical error correction methods,” says Siddiqi.

“This makes error correction easier. You might only have to correct for one type of error. Whereas correcting for arbitrary types of error is hard. There are many ways something can go wrong. All it takes is a photon or even a cosmic ray.”

“We can precisely manipulate ions, and get them to evolve into very interesting quantum states that we do not properly understand yet.” — Ben Lanyon



Fellow in CIFAR’s Quantum Information Science program, Ben Lanyon, at his University of Innsbruck lab. Photo courtesy of researcher.

this type of system to the thousands or millions of qubits needed to perform some applications.

So instead of making trapped ion quantum computers larger, Lanyon is linking them together.

This is a step toward distributed quantum networks, which have near-term applications in computation, communications security and atomic clocks.

The building blocks of quantum networks are already emerging, and, in collaboration with colleague Tracy Northrup at University of Innsbruck, Lanyon is using light to create links between ions that are hundreds of metres apart.

A recent experiment linked two University of Innsbruck ion trap quantum computers with fibre optic cable — the same commercial glass cable used in existing communications networks. And inside each computer's 2-centimetre-long cavity, a single calcium ion was suspended in an electric field. These were surrounded by small mirrors, and lasers induced each ion to emit a photon — a single particle of light.

The photons bounced around inside each chamber tens of thousands of times before emerging through a mirror and into the cable. One mirror was slightly weaker than the other, and that mirror connected to the cable. Once the photons passed through their respective mirrors, they hurtled toward each other at the speed of light, meeting in the middle. That's where quantum theory kicks in.

"When the calcium ion produces the photon, the two are entangled. And when it leaks out the side of the chamber, they remain entangled. When the two photons met in the cable, they were still entangled with the ions that produced them," says Lanyon.

"We can detect these particles with a photon detector — and if you do that just right, it will destroy them. And when these photons are destroyed together, the entanglement gets swapped from the ion-photon pairs to the two remote ions."

Though the remote ions in the trapped ion chambers were hundreds of metres

"New technologies go from being magic to boring, and that's the vision for quantum. We want to make it routine."

— Stephanie Simmons

apart, they maintained an entangled state — a step toward building quantum networks that link together quantum computers that stretch across cities, countries and even continents.

"Entangling atoms over a distance of 100 kilometres would be meaningful. That is only six steps to Vienna, or a further 10 to Paris," says Lanyon.

"The real question is how to practically and reliably do this. Then we could distribute and store entanglement across Europe — a new resource for science and technology."

STEPHANIE SIMMONS

Silicon has been the backbone of the information revolution. Many billion silicon computer chips are manufactured each year, and they power everything from mobile phones to laptop computers to smart refrigerators. Silicon chips are everywhere — a single automobile can have as many as 3,000 of them.

But Stephanie Simmons, a fellow in the Quantum Information Science program, believes that silicon computer chips can do much more than they are today. She is using silicon to power quantum computing.

Silicon's advantage is its ubiquity. We already know how to work with it, and Simmons is using its known properties to create qubits. To do this, Simmons uses natural defects in silicon called colour centres. Using these defects, it is possible to make computations with a type of qubit called a spin qubit. Its spin is controlled with magnetism, and the spin qubits can absorb or emit photons, which allows them to communicate with each other. This is not possible with traditional computing chips, on which each bit functions independently.

"I thought we would be looking for the right kind of colour centres for decades," says Simmons, a Professor of Physics at Simon Fraser University (SFU) in Canada.

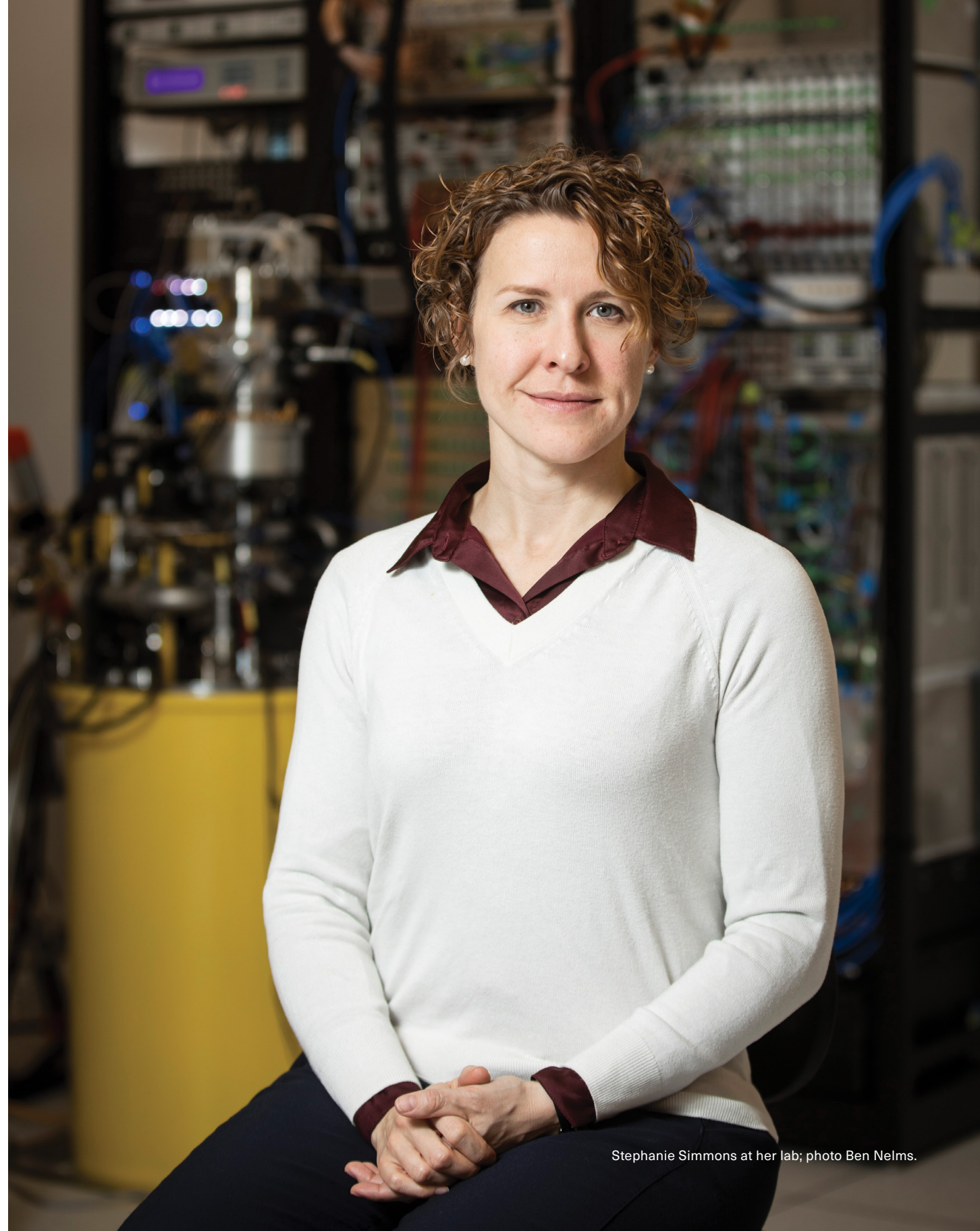
"It had to be something that formed naturally. You take what nature gives you, because otherwise it will be difficult to produce qubits with enough uniformity, quality and scale. I won't necessarily be able to engineer an entirely new defect, but many form naturally. And when you use these as the quantum backbone, you can basically print them at scale, right into silicon chips. There has been decades of development in silicon, and that matters for scalability."

Quantum computing was first proposed by the American physicist Richard Feynman in the 1980s. Quantum mechanics is too complicated to be computed on classical computers because of the large number of dynamic interactions at the atomic and subatomic level. Even with today's powerful computing technology, researchers use approximations to conduct these calculations.

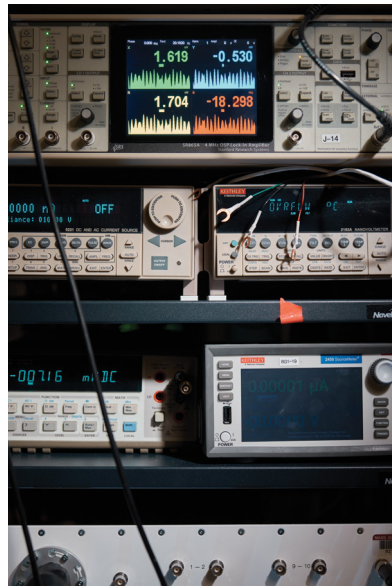
Feynman argued that a quantum mechanical machine might overcome this, but building one hasn't been easy. No dominant design has emerged, but Simmons believes silicon has what it takes. In 2016, she co-founded Photonic Inc. with SFU Professor Emeritus Mike Thewalt, and the Vancouver-based company is developing quantum computing and networking technology to deploy at scale.

"We think of bits as abstract, but they are actually physically in silicon, moving and changing state. Ultimately, information is a physical thing," says Simmons.

"There has been a worldwide race to harness and commercialize quantum



Stephanie Simmons at her lab; photo Ben Nelms.



Left image: Part of a dilution fridge used to keep components of a quantum computer at a temperature where quantum effects can occur; photo Ben Nelms. Centre image: Electronic measurement instruments (voltage sources, lock-in amplifiers, etc.) used to measure the electronic properties of Pablo Jarillo-Herrero's twistrionic devices; photo Mel Musto. Right image: Magnifying glasses used to handle small pieces of electronics and samples; photo Mel Musto.

physics. And historically, every time we have seen something like this, it has been transformational and unpredictable. Two centuries ago, people filled auditoriums to see magnets. Now, we don't think twice about electromagnetism, even though we use it every time we plug in our devices. New technologies go from being magic to boring, and that's the vision for quantum. We want to make it routine."

PABLO JARILLO-HERRERO

Graphene is the strongest material known to exist. It is a layer of graphite just a single atom thick — so thin it's called a two-dimensional material. Graphene is also extremely flexible, and already used in electronics like bendable mobile phones.

One day, graphene might allow you to wrap a tablet around your wrist like a smart watch — then easily return it to its original shape. But graphene could have even more intriguing applications than that, and Pablo Jarillo-Herrero is probing the material's quantum properties to better understand what those could be.

"Graphene comes from graphite, which is three-dimensional. But it is

like a deck of cards. It consists of many two-dimensional pieces," says Jarillo-Herrero, a fellow in the Quantum Materials program and a professor at the Massachusetts Institute of Technology in the U.S.

"Graphite is the material in a pencil, and when you write, it is almost like taking the deck, and spreading out the cards. A layer of graphene is like a single card, and at just one atom thick, it is the thinnest material."

Graphite is a form of carbon, and before 2018, superconductivity had never been observed in carbon. But by aligning two graphene layers at a 1.1-degree angle, Jarillo-Herrero achieved it. It's called magic angle graphene.

"Graphene is not a magnet, superconductor or insulator. But with different twist angles, we can make it have these properties," says Jarillo-Herrero.

"Using graphene, and a material called hexagonal boron nitride, we have realized most quantum phases of matter. This is unique. No other material can realize all of these. Usually, you have to change the chemistry, or the material. But by twisting graphene, we can do it all in one."

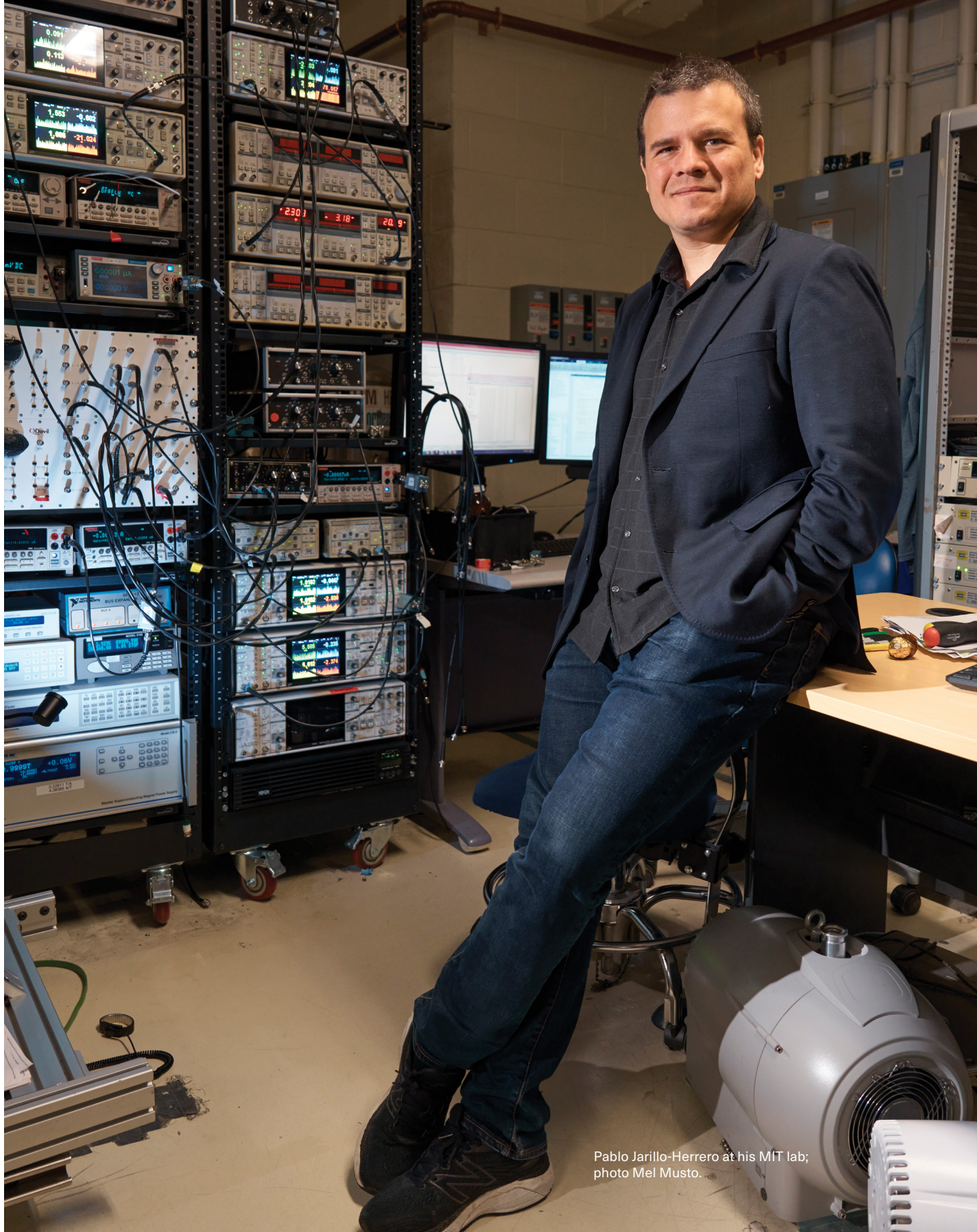
"Graphene comes from graphite, which is three-dimensional. But it is like a deck of cards."

— Pablo Jarillo-Herrero

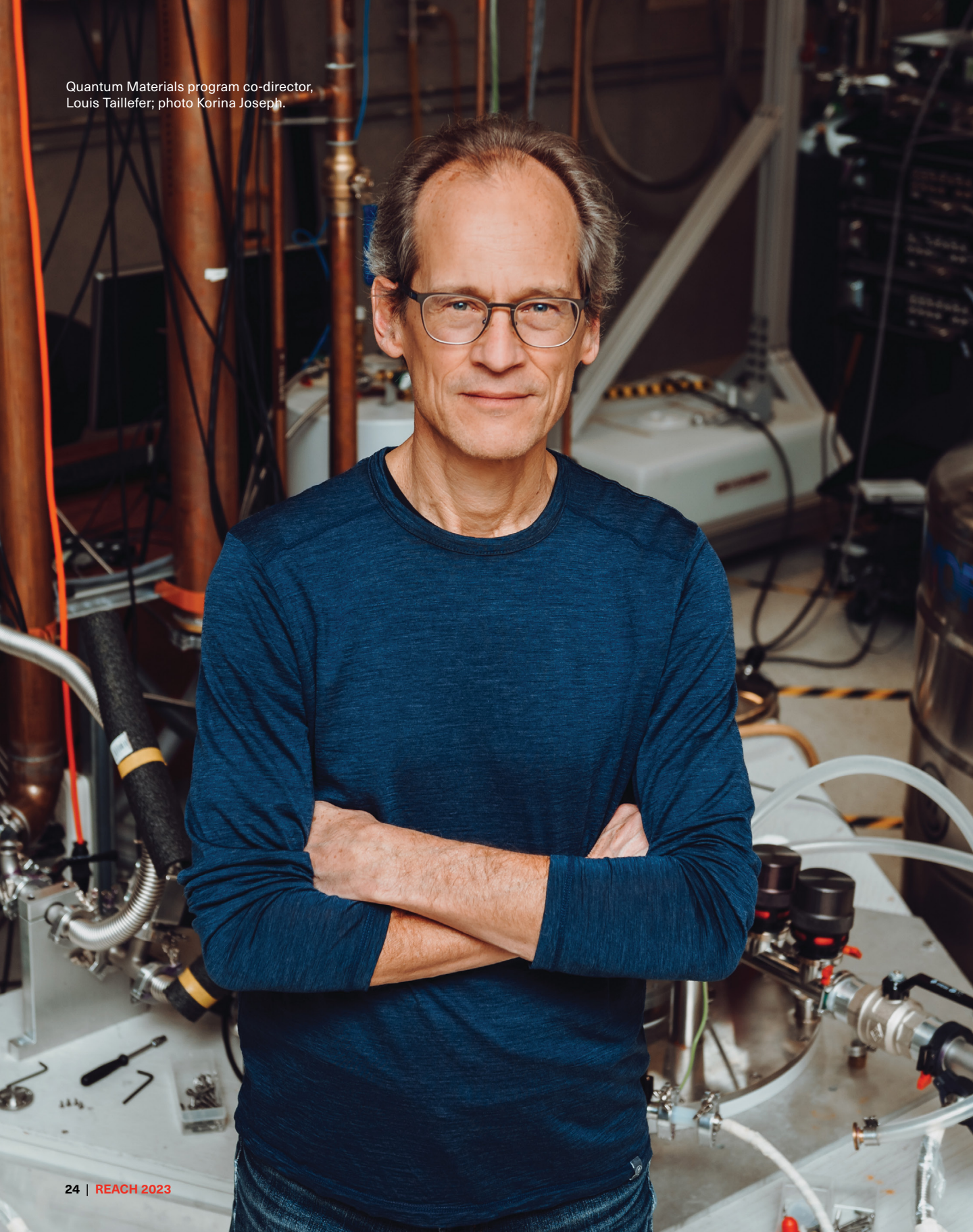
Research into two-dimensional twisted materials is still in its infancy. Jarillo-Herrero compares it to transistors in the 1940s. There is great potential, but we have only scratched its surface.

"There are many challenges. We want to fabricate devices with different twist angles, and always hit the same angle. These systems are sensitive to tiny variations. An angle of 1.13 or 1.14 degrees is not the same, and we don't have the technology to always make identical devices," Jarillo-Herrero says.

Currently, these devices are made by graduate students, who Jarillo-Herrero compares to medieval monks who labour meticulously at their craft. He envisions a machine that automates and



Pablo Jarillo-Herrero at his MIT lab; photo Mel Musto.



standardizes the fabrication process. He compares this to a Gutenberg press for quantum technologies. And just as the invention of an automated printing press ushered in an era of intellectual flourishing by greatly increasing the dissemination of the written word, Jarillo-Herrero views automation as critical to a fuller understanding of the potential of two-dimensional materials.

"A quantum press would automate stacking, and allow you to make materials in any combination, and at any angle. This would allow you to systematically test electronic, optical and mechanical properties. It takes my students several weeks to make each device, so it will take decades to explore this area. A quantum press would allow us to do this with the press of a button."

LOUIS TAILLEFER

In our existing electrical grid, a significant amount of electricity is lost during the transmission process because of the electrical resistance of the materials used in transmission wires. In practice, that means we generate a lot of electricity we don't actually use.

Enter superconductors. A superconductor is a material that is able to conduct electricity with zero resistance. They could help solve this waste problem by eliminating the resistance, but there's a problem in putting them to use. Superconductors only exhibit property below a critical temperature threshold, and for all known superconducting materials, that temperature is downright frigid.

Superconductivity was first observed all the way back in 1911, when Dutch physicist Heike Kamerlingh Onnes observed that mercury had no electrical resistance at the temperature of -269° Celsius. But that is roughly the same temperature as deep space, and led only to a few specialized applications, such as in magnets in MRI machines.

But in the 1980s, researchers identified a promising new type of superconducting material: copper oxides, also known as cuprates. These exhibited superconductivity at much higher temperatures — a still-very-brisk temperature of -140° C.

A superconductor that functions without complicated cooling equipment wouldn't only transform power grids, it would enable applications we haven't even imagined. But to achieve this, we need a better understanding of cuprates' quantum properties.

But it is possible to reach these temperatures with widely available coolants like liquid air, and this has enabled new applications. Cuprates are helping enable a clean energy revolution by making it possible to build wind turbines at sea.

"Nobody likes turbines in their backyard, and many are being built at sea. There is a lot of wind, and it's out of the way, but also more delicate," says Louis Taillefer, co-director of the Quantum Materials program and a professor at Université de Sherbrooke in Québec, Canada.

"You want to minimize a turbine's weight. A superconductor can do this, while maintaining efficiency. It can reduce weight by a factor of five, but needs to be cooled with liquid nitrogen."

The goal is to move beyond niche applications. A superconductor that functions without complicated cooling equipment wouldn't only transform power grids, it would enable applications we haven't even imagined. But to achieve this, we need a better understanding of cuprates' quantum properties.

Cuprates are what is known as a strange metal — a type of material that defies the conventions of electrical conductivity. "Strange metals behave in baffling ways. They do not conform to our standard theory of electrons," says Taillefer.

"There are many collisions between electrons, which seem to reach a maximum. When we try to measure the time between collisions, we find it given by Planck's constant."

Planck's constant is fundamental to quantum mechanics. It was introduced in 1900 by the Nobel Prize-winning physicist Max Planck, who is considered the father of quantum theory. Planck theorized that light was constituted of indi-

vidual particles that he called quanta of light. Today, physicists call these particles photons, and Planck's constant is a calculation of the relationship between a photon's energy and its frequency.

"The fact that Planck's constant emerges as the shortest time electrons can have for collisions is leading us toward a new fundamental law of physics that we don't yet understand. Strange metals behave in new ways. And we don't know whether this could be harnessed for technology," says Taillefer.

Superconductors have the potential for diverse applications because they behave as macroscopic quantum objects, meaning they have a single coherent quantum wave function.

"Think of it like a laser. What is the difference between a light bulb and a laser?" Taillefer asks.

"Both emit light, but a bulb does this in an incoherent way. Each photon is separate, and there are many different wavelengths and phases. But in a laser, every photon is in the same state — same frequency, same phase. We call this coherence. Superconductors are the electrical equivalent. All electrons are in a coherent quantum state. This is what makes them so powerful."

Applications like power grids are obvious, but room temperature superconductors would open the door to entirely novel applications.

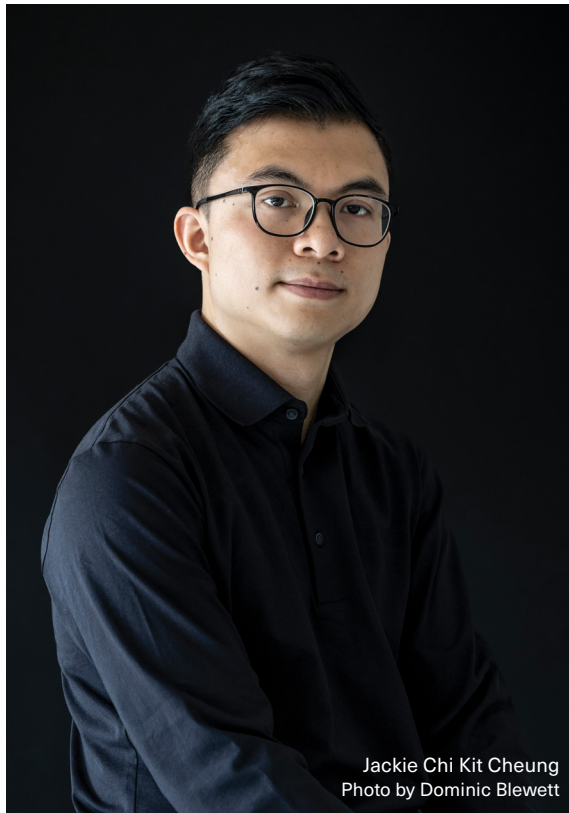
"When lasers were invented, nobody knew what to do with them. Now, they're everywhere," says Taillefer.

"This would happen with superconductors. When you need a specialized lab, few people can play with them. But once any kid can use their imagination with a superconducting object, the possibilities will multiply. It would be a technological revolution." •

AI in 2063

By Kathleen Sandusky
Illustrations by Ariel Davis





Jackie Chi Kit Cheung
Photo by Dominic Blewett



Nidhi Hegde
Photo by Katie Astaire

ChatGPT introduction

ChatGPT prompt:

Write an introduction to a series of interviews with three people who hold the position of Canada CIFAR AI Chair. The interviews are about their predictions for the future of artificial intelligence in 40 years.

ChatGPT output:

Welcome to our series of interviews with three Canada CIFAR AI Chairs, where we ask them about their vision for the future of artificial intelligence. These experts have dedicated their careers to advancing the field of AI, and have a unique perspective on where the technology is headed. Over the course of these interviews, we will delve into their thoughts on the potential impacts of AI on various industries, as well as the ethical considerations that will need to be addressed as the technology continues to evolve. Join us as we explore the exciting and potentially transformative possibilities of AI, 40 years into the future.

It's 2063. How do we use AI in our daily lives?

AI is already part of our daily lives, in ways previous generations couldn't have imagined. As CIFAR wraps up our 40th anniversary, we asked three Canada CIFAR AI Chairs about where they believe AI will lead us in the next four decades.

JACKIE CHI KIT CHEUNG

Canada CIFAR AI Chair, Mila;
Associate Professor, McGill University

It's 2063. Will we be moving through a borderless world, communicating across languages with universal translators attached to our ears?

Language is a very complex phenomenon. It's not just understanding that

a string of words is put together in a sentence — there's a lot more contextual processing required. Even from a young age, humans are amazingly skilled at taking that string of words and extracting a huge amount of information, like the people and objects being described, their backgrounds, relationships, and goals, and even the speaker's attitudes and emotions. Our brains are capable of detecting all of these really abstract things at once. But these more subtle contexts aren't easy for machines to extract using current techniques. When you consider the differences across languages, that's even more challenging. There are considerations like the way different languages are structured or what they require to be explicit — for example, the

Even the best systems will always be at risk of making mistakes, and sometimes those mistakes won't be obvious, especially as AI becomes more sophisticated

Jackie Chi
Kit Cheung

way some languages use or don't use pronouns. So these are really interesting challenges that we're looking at now with natural language processing.

In 40 years, I do think we'll be at the point where we have reasonable accuracy with instant translation, in terms of understanding the general intent. But even the best systems will always be at risk of making mistakes, and sometimes those mistakes won't be obvious, especially as AI becomes more sophisticated. Some of those mistakes may even seem convincing. They won't be the silly mistakes we laugh at with technologies like Alexa or Siri today — they'll be harder to notice.

So I can see us using AI in 40 years to rapidly translate regular everyday conversation, and even if a little bit of

the fidelity gets lost we'll understand the gist. But if it's for something really high stakes, like peace negotiations at the UN, then we'll always need human oversight and scrutiny to avoid potentially disastrous outcomes.

What I'm really hoping for in 40 years is a much more widespread adoption of natural language processing technologies in our daily lives. They'll be so widespread that we won't even notice them.

There are lots of small, administrative and mundane tasks that we do every day that cost us a lot, like all of the emails we send or notes that we take to remember things — I'd like to see AI assistants that let us skip over those tasks so that we can focus on more interesting and useful work, like advancing human achievement in science and art.

NIDHI HEGDE

Canada CIFAR AI Chair, Amii; Associate Professor, University of Alberta

It's 2063. Will we live in a more just and fair society, supported by AI? And will we finally understand the privacy agreements we sign for new technologies?

It's hard to imagine a future where we're all going to be very AI fluent and know exactly what's going on when we sign up for services, because these technologies are really complex and keep moving. I don't see that changing. We have these long unreadable agreements now because it's easy, but it's not fair or reasonable.

Sci-Fi that gets it right

The Expanse by James S. A. Corey

(Novel series; later adapted into a TV series)

"They did a great job of thinking through the implications of how certain technologies can influence societal structures and dynamics, languages and class systems and so forth."

— Jackie Chi Kit Cheung

Black Mirror (TV series)

"Some of the episodes can be pretty scary, so I don't know if they get it right in the sense that I hope they're not getting it right—but they open our eyes to potential outcomes of technology that we're not paying attention to, when we should be." — Nidhi Hegde

Diamond Age by Neal Stephenson (Novel)

"A really interesting take on what could happen when you have an individual AI tutor for the masses, a personalized educator that can optimally teach anyone, regardless of historical barriers of access." — Jeff Clune

Ultimately, privacy and fairness should be seen as part of product development, recognizing that they do not stifle innovation: they add to innovation

Nidhi Hegde

But the challenge is that we need to get the distribution of these technologies — and by extension, wealth — correct, so that it's not concentrated in the hands of a few

Jeff Clune



Jeff Clune
Photo by Kryani Kanavaros

I'd like to see these responsibilities pushed back to the developers. They should have to ask: is every piece of this data really necessary for what I need to do? Am I making sure that the output of this model is still private? Some people argue this will stifle innovation, that we should just let AI develop in the best way that it can, but you have to ask — in the best way that it can for whom?

That's what fairness in AI boils down to: what is the real outcome of a machine learning or AI system, and do all groups benefit equally?

Maybe there's a job you apply for, or an admissions process in a university or a mortgage risk assessment that has rejected you, and you don't know why. This invisible force is preventing you from attaining your potential, and you don't even know how. That's unfair. There are so many examples of these significant harms, such as predictive policing using biased algorithms or

criminal risk tools that keep certain groups of people in jail longer. These effects compound over time, creating generations of harm.

Ultimately, privacy and fairness should be seen as part of product development, recognizing that they do not stifle innovation: they add to innovation. I want to see the AI community take it up as a challenge to make sure that you can get the optimal outputs that you're hoping for from AI, but still keep the data and outputs private. And I would like to see AI products regulated. We've done this in the past with consumer protection agencies that review drugs and toys and other products before they go out into the market, and we see that as necessary to prevent harm. We need to recognize that bias and lack of fairness in AI also cause real harm.

I'd like to see AI tools in the future that improve the fairness of AI itself.

We already have GANs, or generative adversarial networks, that challenge their own data points to continually refine and improve, and they're getting better all the time. So we can imagine an adversarial system for fairness, with an AI algorithm that checks and challenges bias. That would be an AI solution to an AI problem.

In 40 years, I hope we're building fairness into new AI as a matter of course.

JEFF CLUNE

Canada CIFAR AI Chair, Vector Institute; Associate Professor, University of British Columbia

It's 2063. Will human workers be replaced by robots with artificial general intelligence? Will artists be replaced by technologies like DALL-E? Writers by GPT? Will even AI researchers be made redundant?

We know from history that as technology gets better, some jobs disappear. But they are usually jobs that are low-paying, less interesting or dangerous. And we adapt, because new jobs are also created. Nobody today complains that there aren't jobs for professional blacksmiths, or drivers and street-sweepers for horse-driven carriages. Today we have jobs like search engine optimization experts, machine learning scientists or GPU CUDA kernel programmers — jobs you could never have imagined at the time of blacksmiths. So as some jobs go away, others emerge. That does not diminish the real pain that can be caused by such transitions, but typically over time we adapt and thrive with technological progress.

There is reason to believe that this time might be very different, with AI having the potential to actually become as good as humans at many, if not most, economically valuable tasks. It is possi-

ble that this time far more jobs will disappear than will be created.

Across the board there are going to be major economic implications. What happens when we achieve artificial general intelligence, meaning AI that can do almost everything as well as humans? Could we get to a point where we have, effectively, infinite wealth and GDP with all the hard work being done by AI? What does that look like? Maybe we'll have more time for leisure and pursuing our interests. I like rock climbing, maybe I'll get to do more of that while AI does my work for me.

But the challenge is that we need to get the distribution of these technologies — and by extension, wealth — correct, so that it's not concentrated in the hands of a few. We can hope that everything will become cheaper and we will have a more plentiful world. This is, of course, putting aside the many

important existential risks and downsides. But if we get it right, then we might all be much better off, with better health care, better education, cleaner water... the list goes on.

[OpenAI CEO] Sam Altman has written about a future when we'll have Moore's Law for everything, with technology cutting the cost of everything we need to live by half every couple of years. I think that that is an interesting way to think about it. As everything gets more affordable, maybe we'll all have more of what we want, as long as we share, as long as we get it right and ensure that powerful AI is safe and benefits everybody. That is a tall order for society, but with the potential for an immense payoff.

In short, the stakes are very high for society making sure that the development of artificial general intelligence goes well. •

Earth, Space and the Unknown

CIFAR researchers Katie Mack and Heather Graham are unlocking the mysteries of Earth and Space — from the end of the universe, to alien life

By Liz Do

The birth of the cosmos most likely began with a big bang 13.8 billion years ago. A hot, dense early universe rapidly expanded and inflated, creating the physical conditions for the evolution of the universe, and life on Earth.

That is how it all theoretically began — but what do researchers know of its future? Or what lives beyond Earth?

The work of CIFAR researchers in the Gravity & the Extreme Universe and Earth 4D programs, such as Katie Mack and Heather Graham, is unlocking the mysteries of Earth and Space.

The fate of the cosmos is one of humanity's biggest existential questions.

Mack spends her time studying the early universe. It may seem counterintuitive, but it is through learning how it was created that cosmologists can better understand the universe's final act.

"What happened at the beginning is very connected to our ultimate cosmic model, which is very connected to what will happen at the end," says Mack, a CIFAR Azrieli Global Scholar in the Gravity & the Extreme Universe program, and the Hawking

Chair in Cosmology and Science Communication at the Perimeter Institute.

Though the end is unknown, there are predominant scenarios, aided by physics concepts. Mack explores many of these theories in her book, *The End of Everything*.

One is vacuum decay, which theorizes that, due to the universe's metastability, there is the potential consequence of its sudden decay into something new. As Mack explains, in the very early universe, there was a process by which the laws of physics underwent a bit of a rewrite.

An energy field called the Higgs field, was "switched on" after the Big Bang, and its behaviour sets the scene for how fundamental particle physics works in the universe. Once that transition occurred, it created the conditions for everything in the universe, which is all made of atoms — stars, galaxies, planets, everything. None of that could have existed before that transition.

"The tricky thing is that, based on certain interpretations of the data, like the Higgs field, our universe right now is not entirely stable," explains

Katie Mack
Photo by Josh Fee



Mack. “And so it could transition again to something else. And if that happened, it would rewrite the laws of physics again in such a way that atoms and molecules would no longer be able to exist. And if that happened, that would be it.”

“You can’t predict it, you can’t see it coming — the only thing we can do is look at the data. And I can say that based on our current understanding, if it could happen at all, we’re looking at something that is very unlikely to occur for the next 10 to the power of 100 years or so,” added Mack.

The most widely accepted theory, however, is the heat death theory: the idea that the universe is currently expanding and will continue to expand forever. Whatever is making the universe expand faster, is called dark energy.

“But we don’t really know what dark energy is, we just know it’s something that makes the universe expand faster,” says Mack. “As long as it’s something that’s acting in that way, the universe will continue expanding forever, speeding up and speeding up.”

As it continues to speedily expand, it means that the universe gets colder and darker as all of the matter and energy is diffused over a larger and larger region.

“And that means that over time, the universe kind of fades away.”

Though theories such as these could elicit existential dread, Mack describes the work as fun, and a testament to the power of advancing the study of cosmology. “For example, with the vacuum decay theory: how do you quantify something that is a random event? What’s the probability like? How is that calculated? Well, we do it all the time in quantum physics.”

Mack also studies dark matter — the mysterious gravitational substance that makes up most of the matter in the universe — as well as black holes. On the latter, she hopes to work closely with her Gravity & the Extreme Universe program members to further investigate the topic — how they are formed, for example — which is just one of many mysteries to solve within space exploration.

While Mack explores the origins of the cosmos, Heather Graham is interested in the origins of life. In particular, she studies how to detect “weird life”: agnostic biosignatures on rocks and deep underground, that indicate life, but not life as we commonly know it.

“You and I are made of a selection of molecules that are diverse, and are intrinsically much more complex than the kind of molecules that get made abiotically — if we reach out into space and grab asteroids, which we’re doing with the OSIRIS-REx mission, or capture particles of the sun, or look at abiotic organic chemistry that happens deep in the Earth — we never see molecules above a certain kind of intrinsic complexity like we do in life,” explains Graham, a fellow in the Earth 4D program and a researcher at the NASA Goddard Space Flight Center.

That intrinsic complexity leads to different chemical reactions, including metabolism, representing the signature of evolution.

“What we’re looking at is chemistries that have been optimized through evolution and represent intrinsic complexity that isn’t observed and would be highly unlikely. We’re not saying it couldn’t happen. But it’s highly improbable to happen in kinetic systems where you’re just waiting for heat and pressure and time to make special molecules,” explains Graham.

Establishing tools and techniques to identify life not-of-this-Earth is becoming more important as space exploration accelerates. Graham’s research could help to truthfully determine alien life beyond Earth.

“I think something that’s become really evident as the pace of exploration has increased, is how much better we need to be thinking about what the expressions of life are, and how we constrain our observations,” says Graham.

Graham’s work also illuminates possible novel life deep in the Earth, where potential ecosystems have been out of communication with the surface for billions of years.

“I’m really interested in what is fundamentally different about life. How did it arise? Why is it an inevitable process? It’s pretty easy to start making things look like cells in the lab that start doing kind of basic metabolism. So is it an inevitable process?” says Graham.

“I think I’m really driven to understand the history of life. I came to astrobiology, not because of some innate curiosity about other planets, but because I’m very interested in the history of life on Earth,” she adds.

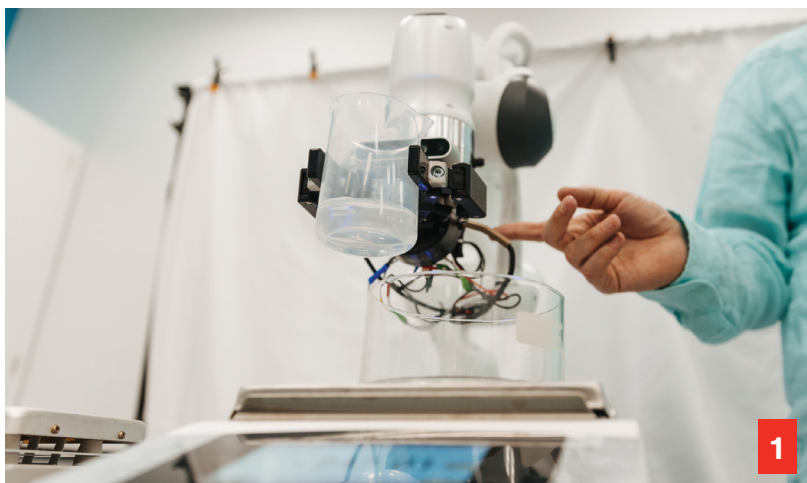
Graham’s work is highly collaborative, especially within the Earth 4D program, where members are particularly active and incredibly engaged with each other’s research. She is currently collaborating with program peer and CIFAR Azrieli Global Scholar, Jacqueline Goordial to examine microbial life within extreme subsurfaces, such as permafrost. As well, she is working with Barbara Sherwood Lollar, program co-director. “We use test materials that she brings to us from the deep mines of Ontario.”

Ultimately, Graham hopes to see “weird” life detection and experiments done on other planets as well.

“I want to see some real experiments happen. A lot of space exploration is going and observing, and seeing what’s out there. And all of that is great, but I would like us to try catalysis experiments on another planet to see if there’s evidence of energy transfer that we wouldn’t expect,” said Graham. “I think it would be fabulous to start interrogating some of the waters of the ocean worlds with these methods that we’re developing. I’m also really excited for the continued investment in bringing Extra Terrestrial materials back to Earth.” •

Heather Graham
Photo by Cheriss May





A DAY IN THE LAB WITH ALÁN ASPURU-GUZIK

By Liz Beddall

Alán Aspuru-Guzik is the Lebovic Fellow and Program Co-Director of the Bio-inspired Solar Energy program at CIFAR, and a Canada CIFAR AI Chair at the Vector Institute. His work is ambitious: he aims to accelerate the discovery of new chemicals and materials that are useful to society by means of new technologies such as quantum computing, machine learning and automation. His research group, the Matter Lab, blends the work of a "dry lab" (a laboratory for applied analysis and computation) at University of Toronto's Department of Computer Science, and a "wet lab" (a lab for more high-risk experiments like manipulating chemical and biological matter) housed in the university's Lash Miller Chemical Laboratories building. We followed Aspuru-Guzik for a day as he moved between the two research spaces.

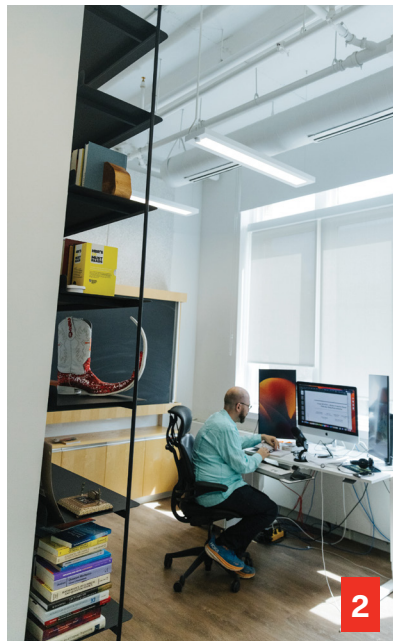
1. Alán starts his day at the 'dry lab'. "I live here," he jokes. He demonstrates the capabilities of one of his lab's robots. "The ability to see and recognize things is a much more complex process than you might imagine," he notes. "This robot is unique because it doesn't matter where the glass is, it knows how to pick it up and pour."

2. On a shelf in his office, Alán proudly displays brightly adorned red and white boots. "I grew up in Mexico," he says. "The day I got tenure at

Harvard, my Mexican grad students bought me these boots. They're called dragon boots and they're for dancing."

3. "CIFAR was very important for my recruitment to Canada as part of a network of researchers," shares Alán, when asked about his work. "Not long after I arrived, I became a Canada CIFAR AI Chair which has allowed me to have the resources to interact and work with many computer scientists."

4. En route from the dry lab to the wet lab, Alán muses more like a

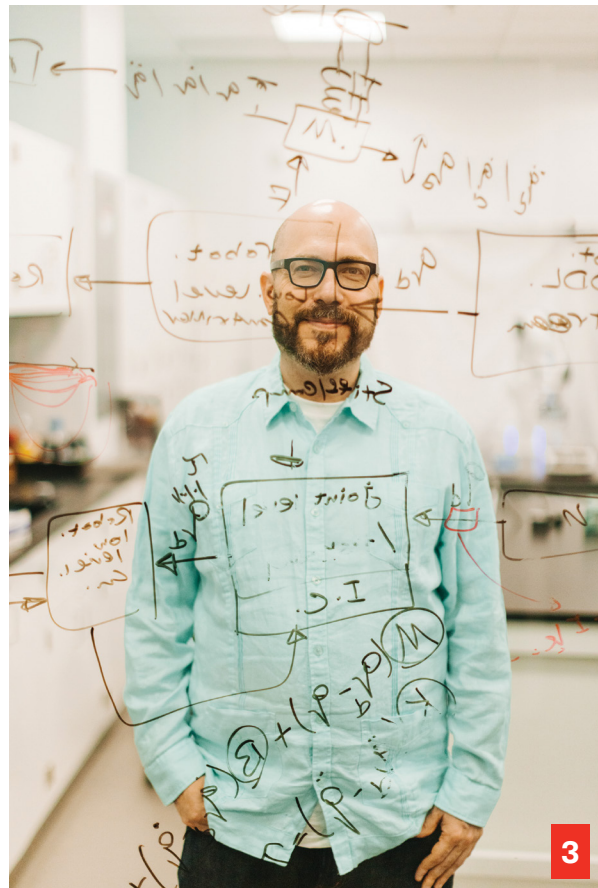


historian than a scientist. "It's exciting to think that when the idea behind neural networks was first being advanced by Geoff Hinton, it was here in these buildings around us now."

5. Over in the wet lab, Alán dons a white lab coat and safety gloves. "What you're looking at is a chemical reactor — a self-driving lab for chemistry," he explains. "We make several molecules at once. This lab does the real chemistry, while the other lab is thinking about the chemistry of the future."

6. Amid lowlight, Alán demonstrates a magnificent fluorescent reaction. "These are actual organic laser molecules, some of the brightest molecules that fluoresce in the world — we hold the record for making them."

7. As the tour ends, he shares some of the ambition of his work. "This is a station that is testing molecules for organic batteries," he notes. "We want to create the next generation of batteries to store the entirety of the world's energy."



A YEAR IN PHOTOS

After two years of virtual-only events, CIFAR and its community welcomed back in-person events in 2022.

In June, CIFAR kicked off its 40th anniversary year with a hybrid panel featuring five of our research program fellows. Moderated by Naomi Azrieli, chair and CEO of the Azrieli Foundation, CIFAR's researchers discussed their work and the importance of CIFAR in the research community.

In November, CIFAR held a gala dinner in honour of our outgoing President and CEO Alan Bernstein. Members of CIFAR's board of directors, donor community, and staff celebrated Bernstein's tenure and shared with him the announcement of the Alan Bernstein Fellow, an appointment established in his name to foster the next generation of early career researchers. The first fellow, Carolina Tropini, was appointed in March 2023.

The year also saw the return of in-person program meetings. Fellows, advisors, CCAI chairs, and Global Scholars were able to once again convene to exchange ideas and discuss bold new approaches to important research questions.

In November, the CIFAR Azrieli Global Scholars program held its first-ever all-cohort meeting in Montebello. Current scholars had the opportunity to learn from their predecessors, hear from CIFAR program fellows and even take to the curling rink.

Members of CIFAR's Brain, Mind & Consciousness program hosted a multi-day meeting, the Neuroscience of Consciousness Winter School, in Mexico. The Winter School gave the next generation of neuroscience leaders the opportunity to work closely with and learn from world-class researchers.

CIFAR 40th Anniversary event and Alan Bernstein Celebration dinner photography: Neil Ta
CIFAR Azrieli Global Scholars all-cohort meeting photography: Josh Fee
Neuroscience of Consciousness Winter School photography: Ivan Luckie Photography



1. From left to right: Advisor and Canada CIFAR AI Chair Joelle Pineau; CIFAR Azrieli Global Scholar Ameet Morjaria; and Fungal Kingdom program co-director, Leah Cowen at CIFAR's 40th event.

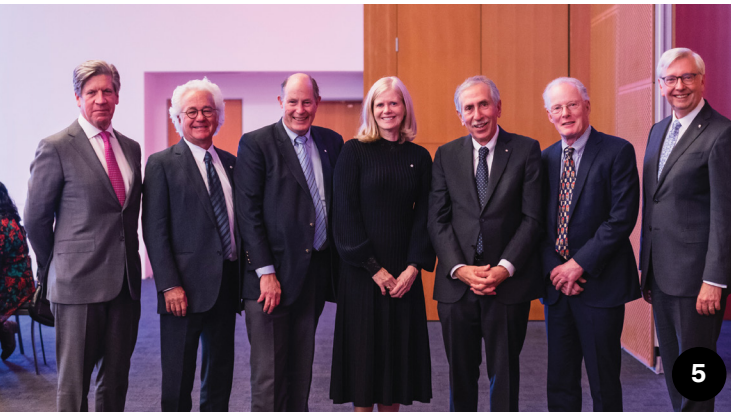


2. CIFAR Azrieli Global Scholars and organizers of the Neuroscience of Consciousness Winter School, Michael Cohen, Sahba Nomvula Besharati and Adeel Razi.

3. Participants of the Neuroscience of Consciousness Winter School.

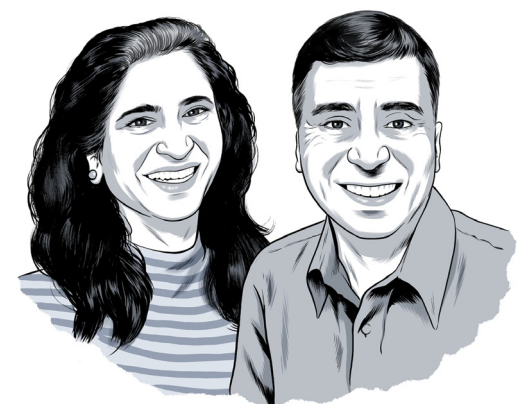


- 4. CIFAR President & CEO Stephen Toope and CIFAR President Emeritus Alan Bernstein with members of CIFAR's executive team, Pauline Yick, Elissa Strome, Leslie McCarley and Hannah Yakobi at Alan Bernstein's celebration dinner.
- 5. Members of CIFAR's current and past board of directors at Alan Bernstein's celebration dinner.
- 6. CIFAR Azrieli Global Scholar Shriharsh Tendulkar tries curling at the program's first all-cohort meeting.
- 7. CIFAR Azrieli Global Scholars Amanda Lea and Samuel Urlacher catch up with Alona Fyshe (centre), former Global Scholar and current fellow and Canada CIFAR AI Chair, during coffee at the all-cohort meeting.
- 8. Benjamin Rosman, member of the 2022/24 CIFAR Azrieli Global Scholars cohort, and Alannah Hallas, member of the 2020/22 cohort.



Why We Give

Philanthropy powers our work. We asked some of CIFAR’s donors what inspires them to give.



Over the last four decades, CIFAR has been the pride of Canada. They have contributed immensely towards furthering the state of the art and/or achieving breakthroughs in several domains in science, which consequently have led to the betterment of humanity. We are glad to be a small part of their journey.

ANANTH AND SUMITRA SESHAN
Donors since 2018

CIFAR is a champion of excellence and diversity within the scientific community. As a member of the board and long-time donor, I know that distinct voices and perspectives are being heard, valued and honoured at CIFAR. The result is strong research of importance to the world.

GILLES G. OUELLETTE
CIFAR Board member; Chairman,
BMO Global Asset Management;
Donor since 2004



My family’s foundation made its first gift to CIFAR in 1986 in support of the AI, Robotics and Society program, which was the foundation for CIFAR’s, and Canada’s, leadership in artificial intelligence. My family’s most recent commitment was to the Bio-inspired Solar Energy program. We believe that Canada is well positioned to demonstrate how a natural resource economy can transition to a sustainable, low-carbon economy, while continuing to be prosperous. CIFAR led the way once with artificial intelligence; it can do it again with sustainability.

RICHARD W. IVEY
Former CIFAR Board Chair and Board member (20 years);
Fraser Mustard Legacy Society member; donor since 1998



When I met Fraser Mustard, the Founder of the Canadian Institute for Advanced Research (CIFAR), he was in the early stages of realizing his vision of establishing Canada as a world-class player in basic research and knowledge creation. There were many years when the survival of CIFAR was uncertain, but with the hard work of Fraser and his supporters it did survive, and with an expanded team, it has grown magnificently. My admiration for all people past and present who make CIFAR what it is today — a research institute that benefits all of humankind — is unbounded. I am so pleased to have played a small part in CIFAR’s journey, and intend to continue to support this incredible organization.

BEVERLEY BRENNAN
CIFAR Director Emerita;
Donor since 1997

CIFAR is unique in its ability to bring leading researchers across disciplines and countries together to address some of the toughest questions facing humanity. As a global research organization based in Canada, donating to CIFAR is an investment in both a better Canada and a better world.



YASMEEN ABU-LABAN
CIFAR Fellow; Professor, University of Alberta;
Donor since 2022



Without CIFAR, the temptation to leave Canada would have been strong. Because of this incredible organization, I was able to stay in Canada to pursue my academic career — and launch many uniquely Canadian scholarly policies and initiatives. I give to CIFAR so that emerging great minds have access to transformative opportunities like I did.

DANIEL TREFLER
Former CIFAR Fellow;
Professor, Rotman School of
Management, University of Toronto;
Donor since 2001



WHY DO YOU GIVE?
I would love to hear what motivates you.
Contact me at giving@cifar.ca

LESLIE MCCARLEY
Vice-President, Advancement



LEAVE A LEGACY FOR FUTURE GENERATIONS

From the beginning, the idea of creating a “university without walls” has been compelling. And, it was this promise of collaboration across disciplines and geographies — an approach unheard of and unmatched within the academic community — that inspired a small group of academics, led by Fraser Mustard, to create CIFAR.

“My dad, Fraser Mustard, loved to engage in ‘blue sky’ thinking about the types of problems that got you hooked in your field,” says John (Jack) Mustard, co-director of the Earth 4D program. “Intriguing questions and unknowns were the most fun for him. I think that is part of his legacy at CIFAR and what makes CIFAR continue to be relevant 40 years later.”

With a remarkable capacity to rally leaders from different walks of life, interests and regions, CIFAR’s leadership grew from an idea shared by a few scientists, to a built-in-Canada network spanning countries and continents.

CIFAR’s foresight is fueled by the generosity of visionary donors. Just like Fraser, who became CIFAR’s founding president, they look beyond the horizon to the promise of a tomorrow that they may never see — and choose to leave the world in a better place by leaving a legacy gift to CIFAR in their Will.

In memory of CIFAR’s founding President, the Fraser Mustard Legacy Society honours the imagination and forethought of these donors, as they allow us to continue to address the most important questions facing science and humanity for years to come.

Your legacy can support the next generation of scientists, establish new research areas, and provide answers to global challenges. We would love to share more about how your gift will benefit future generations.



If you would like to leave a legacy gift, I am pleased to provide you with more information, including customized wording to include in your Will. Please contact me directly at 416-971-5409 or nic.miller@cifar.ca.

NIC MILLER, CFRE
Director, Development



MaRS Centre, West Tower
661 University Avenue, Suite 505
Toronto, ON M5G 1M1

cifar.ca

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