

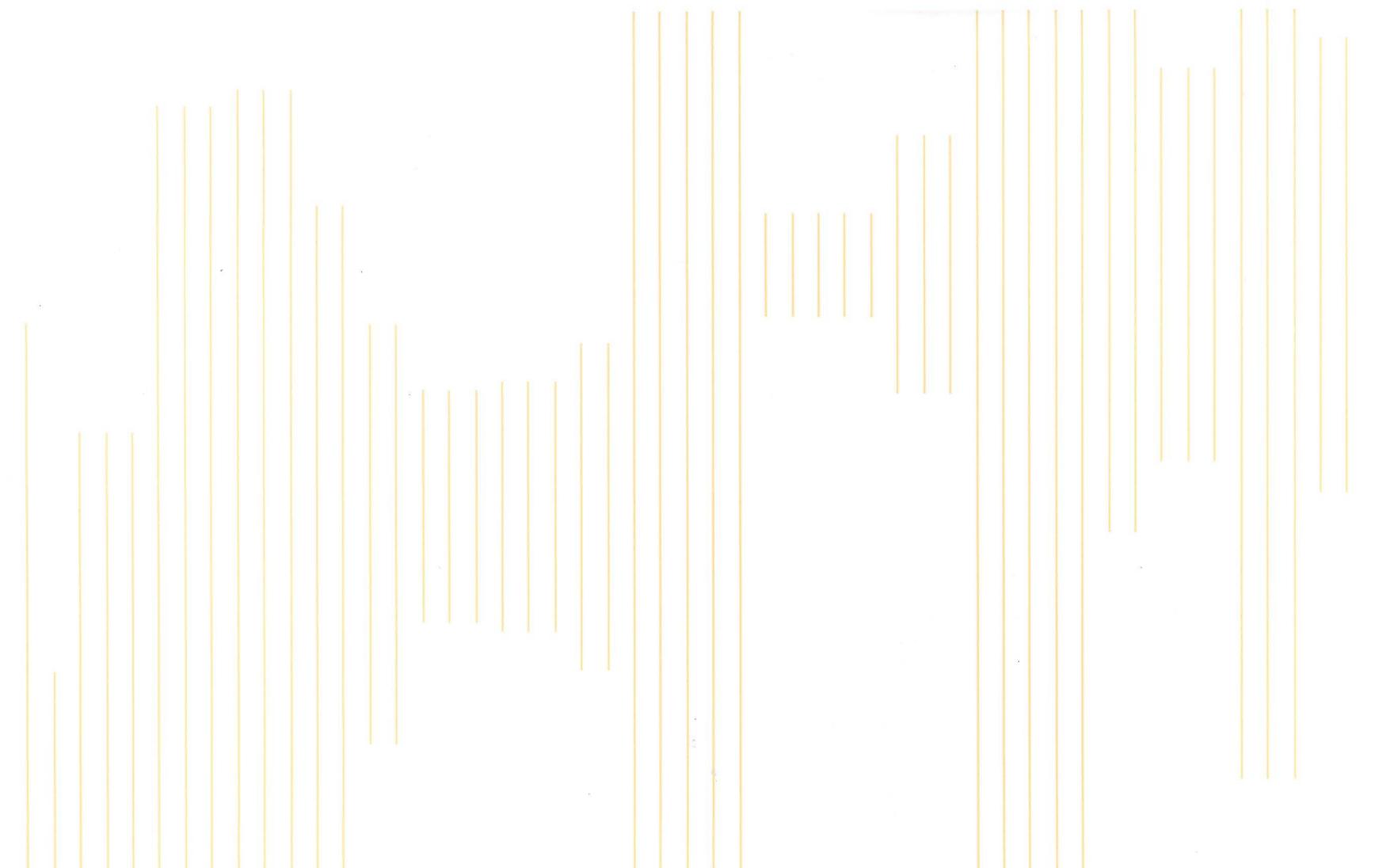
STATE OF THE UNIVERSITY

2018 - 2019

GLOBAL IMPACT

UNIVERSITY OF
WATERLOO





**WHAT ARE THE
REALLY IMPORTANT
PROBLEMS OF OUR DAY?
WHY ARE THEY IMPORTANT?**

“The lines on this page depict the sound waves created as I read aloud from *Toward a Shared Vision of Our Future*, a document that outlines key initiatives that will guide the future of the University of Waterloo. These lines are the shape of my vision, just one element of our collective future. The laws of physics tell us that the further you are from the source of a sound wave, the lower its intensity. So, we need people on every continent who have been touched by Waterloo to add their voices and amplify what they know of our unique culture. Together, we must raise our voices and apply our talents to the great challenges of the day so that people around the world can hear and benefit from the sound of innovation.”

Feridun Hamdullahpur
President and Vice-Chancellor

OPENING THE DOOR TO INNOVATION – AND BOLDLY WALKING THROUGH

The University of Waterloo is shaping the future by tackling global challenges that will impact our world for generations. We recognize the future holds tremendous challenges with far-reaching implications. This *Global Impact Report* demonstrates how our faculty, students, staff and alumni are having an impact on five such issues.

People want and deserve access to education and freedom from discrimination. They also want to participate in economic growth. In *Prosperity and Scarcity*, we examine how technology and policy play important roles in creating prosperity globally.

Next-Generation Computing is here at Waterloo – from quantum computing to nanotechnology and cybersecurity, Waterloo continues to be at the forefront of this sector.

As we enter a new age of machine intelligence, researchers are pushing the frontiers of *Human-Machine Interaction*. Waterloo researchers are developing technologies and systems that are making an impact on our lives today. We are asking the fundamental questions about how machines are affecting our health, well-being, economy and relationships.

In *Climate Resilience and Natural Wonders*, we are exploring the implications of living in the warmest period in the history of civilization. While we work to address the challenges of climate change, we are also unlocking the great mysteries of our universe.

In *Healthy Aging*, we focus on the fact that while the world's older population continues to grow at an unprecedented rate, Waterloo researchers are looking at technological, scientific and policy changes that will help us all age well.

This *Global Impact Report* captures a moment in time – and we are adding to this impact every day. With a culture of curiosity, exploration, risk-taking, entrepreneurship, global stewardship and leadership, the University of Waterloo has become the doorway through which the world finds solutions to the challenges that lie ahead.



A handwritten signature in black ink, appearing to read 'Feridun Hamdullahpur', written over a thin horizontal line.

FERIDUN HAMDULLAHPUR
PRESIDENT AND VICE-CHANCELLOR



PHILIP BEESLEY

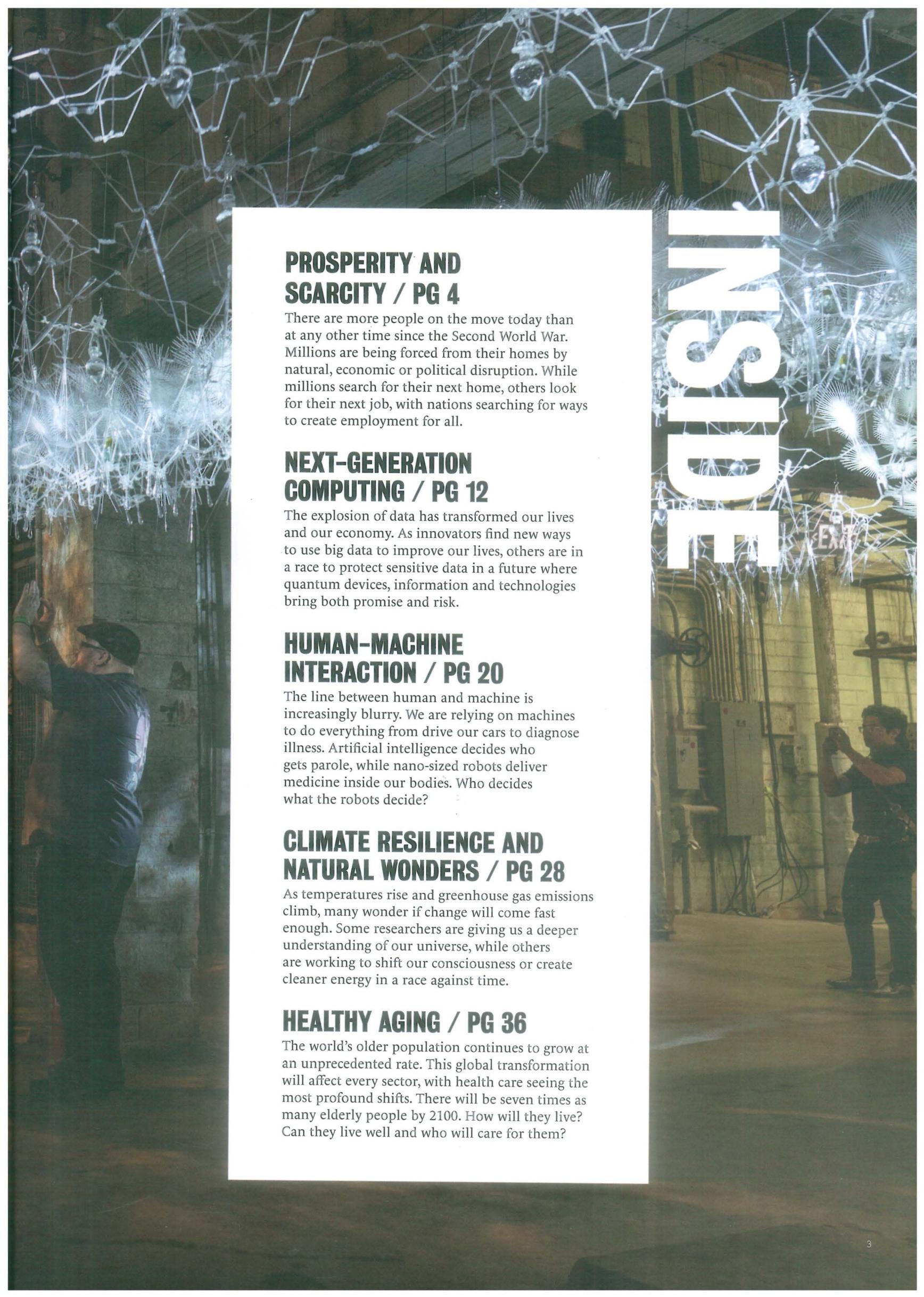
PROFESSOR, FACULTY OF ENGINEERING

- > SCHOOL OF ARCHITECTURE
- > LIVING ARCHITECTURE SYSTEMS GROUP
- > RIVERSIDE ARCHITECTURAL PRESS
- > WATERLOO INSTITUTE FOR SUSTAINABLE ENERGY (WISE)

Philip Beesley is a multidisciplinary artist, academic and architect leading Waterloo's Living Architecture Systems (LAS), an international group of pioneering researchers and industry partners developing far-reaching experimental architecture. His research explores bold questions such as, "Could future buildings think, and care?"

Images of these art installations are displayed here not only for their arresting beauty but because they are a testament to Waterloo's vision for the future. They provide a unique combination of expertise in architecture, environmental design, visual art, digital media, engineering, machine learning, cognitive psychology, synthetic biology and knowledge integration.

Society is facing challenges that will fundamentally change the way we all live and work. The University of Waterloo is committed to interdisciplinary solutions that are – like Beesley's work – empathic, adaptive, resilient and committed to a future that elevates the best parts of our shared humanity.



INSIDE

PROSPERITY AND SCARCITY / PG 4

There are more people on the move today than at any other time since the Second World War. Millions are being forced from their homes by natural, economic or political disruption. While millions search for their next home, others look for their next job, with nations searching for ways to create employment for all.

NEXT-GENERATION COMPUTING / PG 12

The explosion of data has transformed our lives and our economy. As innovators find new ways to use big data to improve our lives, others are in a race to protect sensitive data in a future where quantum devices, information and technologies bring both promise and risk.

HUMAN-MACHINE INTERACTION / PG 20

The line between human and machine is increasingly blurry. We are relying on machines to do everything from drive our cars to diagnose illness. Artificial intelligence decides who gets parole, while nano-sized robots deliver medicine inside our bodies. Who decides what the robots decide?

CLIMATE RESILIENCE AND NATURAL WONDERS / PG 28

As temperatures rise and greenhouse gas emissions climb, many wonder if change will come fast enough. Some researchers are giving us a deeper understanding of our universe, while others are working to shift our consciousness or create cleaner energy in a race against time.

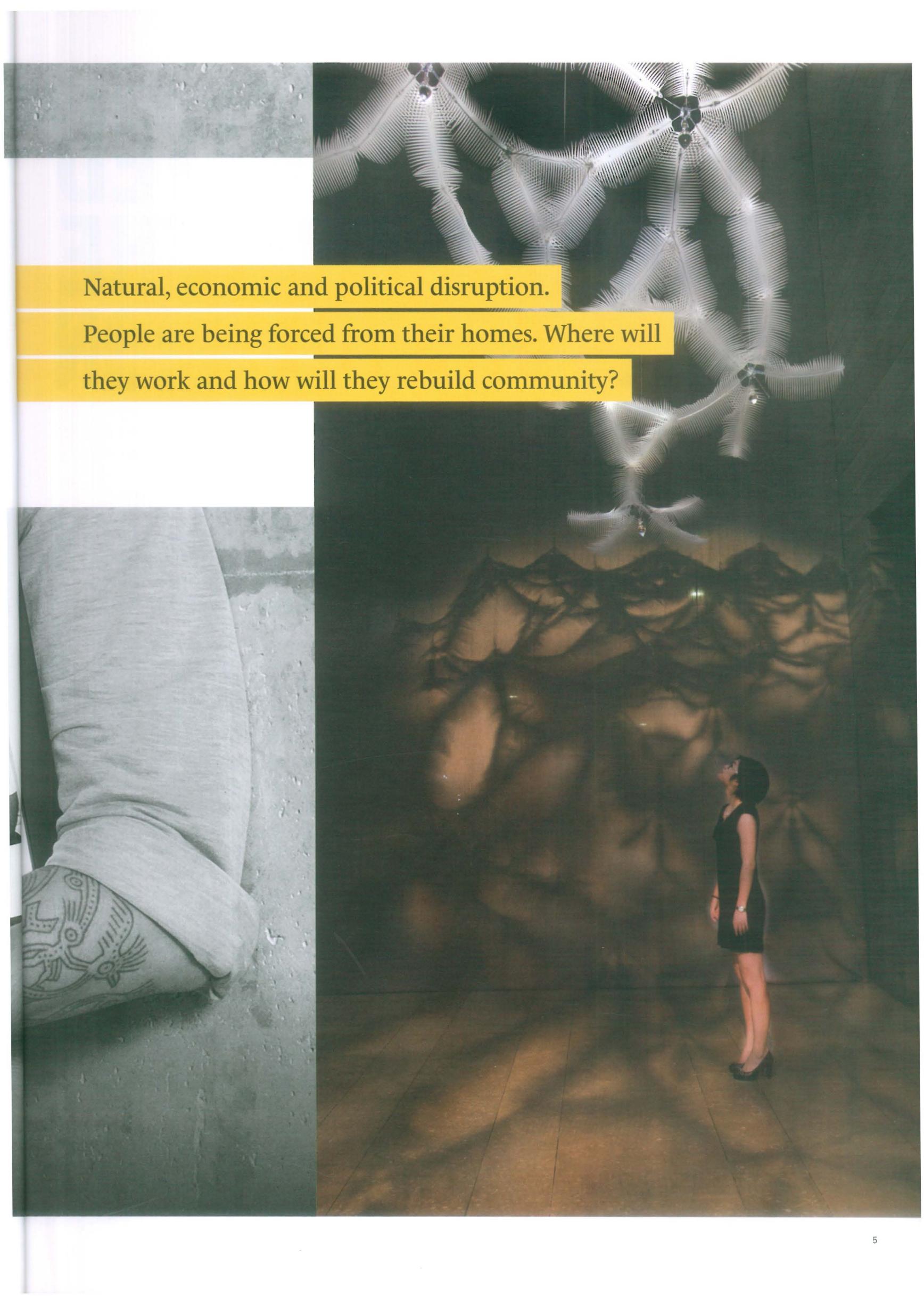
HEALTHY AGING / PG 36

The world's older population continues to grow at an unprecedented rate. This global transformation will affect every sector, with health care seeing the most profound shifts. There will be seven times as many elderly people by 2100. How will they live? Can they live well and who will care for them?

PROSPERITY AND SCARCITY



Vinh Nguyen, a professor in the Faculty of Arts, holds a framed photograph of his mother (far right) in a Thai refugee camp in 1988. Nguyen discovered the photo in a California archive while researching life stories of Southeast Asian refugees. (See story on page 8.)



Natural, economic and political disruption.

People are being forced from their homes. Where will they work and how will they rebuild community?

WORK-INTEGRATED LEARNING FOR THE SKILLS REVOLUTION

The world is at a historic crossroads with the largest generation of young people coming into the workforce at the same time as the fourth industrial revolution.



DAVE MCKAY (BMath '87)
PRESIDENT AND CEO, ROYAL BANK OF CANADA
ALUMNUS, FACULTY OF MATHEMATICS

Like many of the students who choose the University of Waterloo today, I was attracted by its co-op program. When I first enrolled as a computer science major in the 1980s, I certainly had no idea I'd end up in banking, let alone eventually lead Canada's largest financial institution. But Waterloo's pioneering co-op program changed that. An initial co-op term as a coder at Royal Bank of Canada opened my eyes to a whole world of strategy, customer service and finance. I returned for five more co-op terms at the bank and never looked back.

Those six terms were so instrumental in shaping my career that today I have become a passionate advocate for the power of experiential and work-integrated learning. It's why I helped launch a task force through the Business Council of Canada's Business/Higher Education Roundtable (BHER) to investigate its use; it's why experiential learning is at the core of RBC's largest-ever community commitment: RBC Future Launch.

I don't need to preach to the choir. Waterloo alumni know how co-op students who return from their placements are often more demanding and curious, pushing their peers and professors to look for more creative solutions. They have

witnessed how co-op jobs have become a critical bridge for employers to outstanding schools like Waterloo. They know how work-integrated learning can act as an important social leveler, removing the reliance on personal networks for that critical first job and improving access for minority groups.

As Waterloo has demonstrated over the past 60 years, the arguments for work-integrated learning have always been compelling. Today, in my mind, they have become irrefutable.

Canada is at a historic crossroads. We have the largest generation of young people coming fully into the workforce at exactly the same time as the fourth industrial revolution – the age of artificial intelligence and the Internet of Things – is beginning to affect every job in the country.

As new research from RBC Economics shows, our country is on the brink of a skills revolution. More than one-quarter of Canadian jobs will be heavily disrupted by technology in the decade ahead. And fully half will go through a skills overhaul.

We certainly don't see this as a cause for despair. Instead, we believe Canada is heading into an age of strong job growth, with new jobs demanding new skills; in particular, soft or foundational skills. Critical thinking and creativity, communication and collaboration – these will be the standout skills in the age of advanced technology.

Experiential learning will have a critical role to play.

In 2015, together with BHER, I issued a challenge that 100 per cent of Canadian undergrad students should be exposed to some form of meaningful experiential learning before graduation. Today, I remain more convinced of this need than ever. Certainly, we're heading in the right direction, and the University of Waterloo is leading the way. Since the turn of the century, we've seen a surge in experiential learning, but the focus has been

squarely on engineering, business and medical science; as a result, general arts students are being left behind.

As our research shows, business is already calling for more soft skills. That call is only going to get louder. A recent survey of Business Council of Canada members backed this up: it showed that 67 per cent of respondents identified collaboration and teamwork as a key skill for entry-level employees, with communication, problem-solving and people skills also in high demand.

If we're going to move from a jobs economy to a skills economy, we will all have to hire, train, retrain and promote differently to help our future workforce develop portfolios of skills as the landscape of jobs changes. We'll also need to start recognizing core skills and competencies rather than the job skills that will change faster than ever. Work-integrated learning will help us navigate through this transition.

RBC has clearly stated its intentions. Through RBC Future Launch, we are committing \$500 million over 10 years to empower young Canadians by tackling every part of the problem: work experience, skills development and networking. We have several work-integrated learning initiatives planned, and recently started a "no résumé required" paid internship program, with selection based on skills, not work experience. However, RBC can only be a part of the solution. That's why we're working closely with schools, colleges, universities and various levels of government – and calling on every industry to join us.

More than 60 years ago, the University of Waterloo helped start a movement of which I was just one of thousands of lucky beneficiaries. I will never truly be able to estimate the benefits I received from those six terms as a co-op student. As we move to a skills-based economy, my hope is that 100 per cent of Canadian students will soon be able to say the same thing.

PROSPERITY AND SCARCITY



Dispelling myths about refugees and their life experiences

VINH NGUYEN

PROFESSOR, FACULTY OF ARTS

- > DEPARTMENT OF ENGLISH LANGUAGE AND LITERATURE
- > RENISON UNIVERSITY COLLEGE, CULTURE AND LANGUAGE STUDIES,
CROSS-APPOINTED TO THE DEPARTMENT OF EAST ASIAN STUDIES

When the heartbreaking photo of Alan Kurdi, the drowned three-year-old Syrian boy, made global headlines in 2015, it galvanized many Canadians into action.

But for Vinh Nguyen, a professor in the Faculty of Arts, the moment signaled something else: a time for former Vietnamese refugees, like himself, to contemplate how their own memories of displacement and loss connect them to Syrians.

Now, with his prestigious 2017 Polanyi Prize in Literature win, Nguyen will be able to continue exploring the shared historical and political connections between “waves” of refugees. He’s collecting their stories and using that material to dispel myths that refugees are apolitical or passive.

“In the media there’s a sense that refugees are these people who are poor, helpless and at the edge of death,” he says. “That’s true, of course, but these people were also students, artists, writers, professors and waitresses. We need a more complex narrative.”

Canada
ranks

#2

in the world for economic
influence and quality of life

BEST COUNTRIES REPORT, U.S.
NEWS & WORLD REPORT, 2018



Building a generation of tech leaders in Africa

NADAYAR ENEGESI (BCS '13)

ALUMNUS, FACULTY OF MATHEMATICS

> CO-FOUNDER, ANDELA

With an acceptance rate of only 0.8 per cent, CNN has called African IT company Andela one of the most selective programs in the world and "... harder to get into than Harvard."

But extreme recruiting isn't about elitism, insists co-founder Nadayar Enegesi, a Waterloo computer science alumnus who co-founded Andela with two other alumni: Brice Nkengsa (BSE '12), from the Faculty of Engineering and Iyinoluwa Aboyeji (BA '12), of the Faculty of Arts. Andela is about breaking down barriers – and lifting up the hundreds of programmers it has trained since the company launched in 2014.

Africa is home to seven of the top 10 fastest-growing internet populations in the world so it's easy to see why corporations like IBM, Microsoft and Viacom are working with Andela programmers and why the company has been able to raise \$80 million in funding.

"You probably wouldn't have thought in the next million years that the tech leaders building your products will come from Africa," says Enegesi. "But now we're showing the world that that's possible."



Scaling up food security innovations to improve lives

HELENA SHILOMBOLENI (PhD '17)

PHD ALUMNUS, FACULTY OF ENVIRONMENT

> SCHOOL OF ENVIRONMENT, RESOURCES AND SUSTAINABILITY

Today's farmers grow enough food to end world hunger. Yet conflict, high food prices and climate change mean more than 800 million people in the world are undernourished.

Helena Shilomboleni, an alumnus of the Faculty of Environment, is doing her part by shedding light on food insecurity challenges in communities that rely on family farms. While her dissertation took her to Mozambique to study contributions from the African Green Revolution and the food sovereignty movement, she now works at the International Development Research Centre in Ottawa, Ontario.

Her team works on scaling up promising food security innovations to benefit rural communities in the global south. There are no fast fixes, Shilomboleni admits, but every new day brings hope.

"This kind of work really gives me a window into seeing that this is how change can happen," she says. "There's power in research and development."

PROSPERITY AND SCARCITY



From a remote Indian village to a PhD in engineering

PAMPA DEY (PhD '17)

ALUMNUS AND POST-DOCTORAL RESEARCHER,
FACULTY OF ENGINEERING

> DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

When Pampa Dey was a 10-year-old part-time cashier working in her father's sweet shop in a remote Indian village, she discovered a love of math. With no calculator to rely on, young Dey could add and subtract complicated sums in her head at lightning speed.

"I literally fell in love with mathematics there," says Dey.

Fast-forward a couple of decades. In October 2017, Dey received her doctorate in engineering at Waterloo and is now working toward her next goal: becoming a professor. Others describe her as a great role model for women aspiring to pursue STEM (science, technology, engineering and math) disciplines, especially those facing economic, social and cultural barriers.

Now, when Dey returns to India, she's passionate about helping girls discover STEM careers too. Her main advice? Don't be afraid to be independent – and study hard.

"I tell them to focus on science and engineering," says Dey. "That can change your life."



65.6M

displaced people
around the world

UNITED NATIONS HIGH
COMMISSIONER FOR REFUGEES

50%

of the world's household wealth
is owned by 1 per cent of adults

THE GLOBAL WEALTH REPORT, CREDIT SUISSE



Helping refugees and volunteers connect

JADE CHOY (BAFM '17)
ALUMNUS, FACULTY OF ARTS

- > CO-FOUNDER, EPOCH
- > VELOCITY GARAGE

Six minutes.

That's all the time Waterloo's EPOCH team had to pitch their idea at the recent \$1-million Hult Prize Challenge. EPOCH was one of only six team finalists at the prestigious international competition for social enterprise, dubbed, "the Nobel prize for students."

Jade Choy, who co-founded EPOCH with her brother and fellow alumnus Keith Choy (MAcc '16), admits their presentation at the UN Headquarters in New York went by in a blur.

EPOCH, an online platform, helps refugees trade skills for community services they need such as résumé assistance and English skills. Now the team – which works full time out of the University of Waterloo's Velocity Garage – is finding a way to broaden its scope by making corporate volunteer programs more engaging for the modern workforce.

"A lot of companies and community organizations are working in silos," says Choy. "We want to built stronger local communities by bringing them together."



Uncomfortable truths about why some immigrants prefer the U.S. to Canada

MIKAL SKUTERUD
PROFESSOR, FACULTY OF ARTS

- > DEPARTMENT OF ECONOMICS

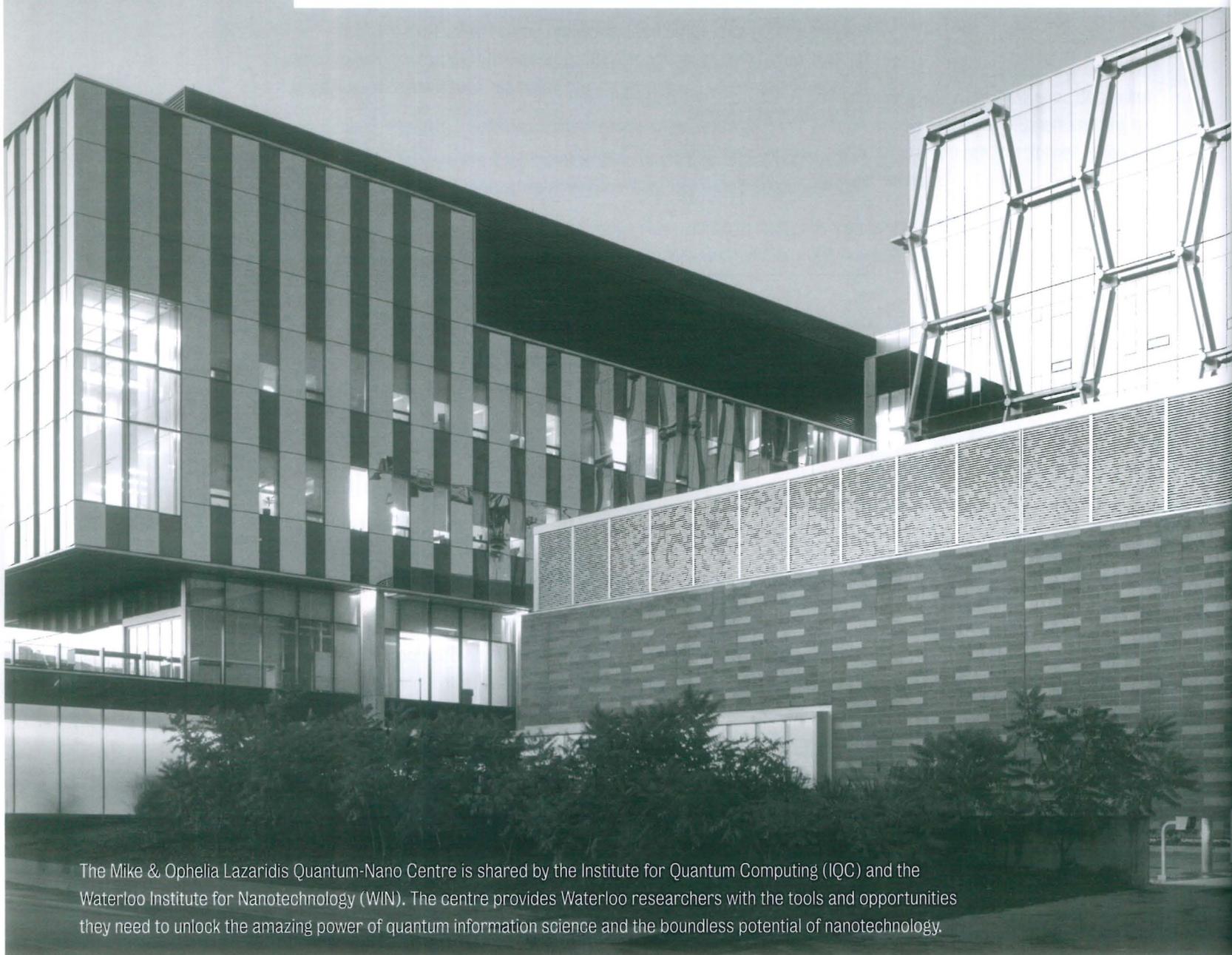
Mikal Skuterud is the first to admit his research results – although influential – might not win any popularity contests in Canada.

Focusing on the field of labour, economics and immigration policy, Skuterud, a Faculty of Arts professor, has uncovered a difficult truth: university-educated immigrants who come to Canada don't earn as much as those who move to the U.S.

But why? Skuterud has found that the way countries select immigrants has an impact but it's also decisions made by the immigrants themselves. Industry stars, whether they're IT experts, engineers or talented surgeons, often go where the money is, and that isn't Canada.

Skuterud says countries like Canada that have a richer safety net and less income inequality attract people at the lower end of the global skill distribution. "The crème de la crème of talent will tend to go to the U.S. because that's where they're going to get the big returns," he says.

NEXT- GENERATION COMPUTING



The Mike & Ophelia Lazaridis Quantum-Nano Centre is shared by the Institute for Quantum Computing (IQC) and the Waterloo Institute for Nanotechnology (WIN). The centre provides Waterloo researchers with the tools and opportunities they need to unlock the amazing power of quantum information science and the boundless potential of nanotechnology.



There are millions of data points
that make up our digital lives. How will
they fit into a quantum future?

CANADA'S STAKE IN THE QUANTUM RACE

We are on the cusp of a completely new technological era: the quantum age. The race for the economic benefits of quantum technologies is Canada's to lose.



RAYMOND LAFLAMME, O.C., FRSC
PROFESSOR, FACULTY OF SCIENCE

- > DEPARTMENT OF PHYSICS AND ASTRONOMY
- > INSTITUTE FOR QUANTUM COMPUTING (IQC)
- > MIKE AND OPHELIA LAZARIDIS "JOHN VON NEUMANN" CHAIR IN QUANTUM INFORMATION
- > CANADA RESEARCH CHAIR IN QUANTUM INFORMATION

The quantum race will not be won by the first to develop a quantum computer.

It will be won by those who see the breadth of the quantum opportunity. Just as we saw classical computing evolve from large, room-sized machines to ubiquitous small devices, some carried in our pockets, we will witness a similar transformation in the quantum age. Only this time, instead of the United States dominating the sector, Canadian companies are poised to take the lead.

Why am I so confident?

Because 15 years before the United States, China and the United Kingdom started dedicating significant resources to collaborative quantum research, the University of Waterloo's Institute for Quantum Computing (IQC) was already conducting cross-disciplinary research and creating an ecosystem ready to support early-stage, high-risk/high-reward opportunities in quantum technologies.

Built with the purpose of attracting the best quantum physicists, engineers and mathematicians from around the world, IQC is now home to more than 200 researchers, postdoctoral fellows and students working in a world-class facility that is the model for those nations now looking to invest in quantum research. Waterloo, Ontario and Canada invested early in people, highly specialized lab and education programs to ensure we have the best shot to compete

Today, quantum computing has moved from theoretical endeavours to experimental explorations that further discovery and understanding – sparking a nascent quantum industry. As we get closer and closer to the realization of a practical quantum computer, we also learn more and more about the quantum world and the incredible opportunities it presents.

When will we have a quantum computer?

I am frequently asked, “When will we have a quantum computer?” But that question is missing the broader opportunity of quantum technologies: sensors, detectors, unbreakable cryptographic protocols and other devices that will allow us to understand and harness our environment like never before.

New quantum-resistant cryptographic protocols have already been produced and quantum sensors, some available today, offer such extreme precision they are useful in areas like geological exploration such as well logging, or for medical applications such as identifying and understanding biological processes in our bodies. Imagine if we could detect rogue cells on the verge of turning cancerous or better understand how proteins misfold and lead to diseases like Alzheimer’s or Parkinson’s. These and other major research challenges might not be insurmountable in a world with quantum technologies.

What will quantum technologies tell us about our world and what impact will they have on our lives? Who will win in the global quantum race? The short answer is: we don’t know yet. The long answer is: if we don’t continue to support quantum research in Canada, we may never know. Or worse, we will once again be a

consumer in a worldwide market dominated by others.

Canada’s 15-year advantage in the quantum race

We are on the cusp of a completely new technological era. The quantum age will have a profound impact across sectors and we can imagine the opportunities. Canada has a 15-year advantage over countries now realizing the importance of investments in quantum research. We have the research environment to tackle the challenges of harnessing the quantum world. We are building an ecosystem to turn quantum technologies into practical, commercial products. With our research colleagues across the country, Canada can continue to lead the quantum race.

Now is not the time to stop investing. The United Kingdom invested £270 million in a national quantum technologies program. The European Union is establishing a €1 billion flagship initiative in quantum technology. Just last fall, China announced it will initiate a \$10 billion quantum computing research program. Such companies as Google, IBM, Microsoft and others are investing in quantum as well.

Investments in quantum research in Waterloo Region alone surpassed \$1.5 billion over the past 15 years. IQC’s private-public partnership has positioned this region and Canada as a global player in quantum. We are successfully competing with the world in quantum research. The technologies that result from these investments will be game changers. They will transform our economy and spark new industries, new jobs and new opportunities.

We are a strong contender in this quantum race. But we can’t get too comfortable and we can’t stop investing. The race is Canada’s to lose.

Visionary support

Extraordinary vision and generous support enable transformative research. Over the past 15 years, Mike (DEng ’00) and Ophelia (BMath ’85) Lazaridis have enabled tremendous advances across the University of Waterloo. With gift commitments totaling more than \$122 million, Mike and Ophelia have helped ensure the University of Waterloo can attract the world’s best talent, conduct breakthrough research and train the next generation of scientists, technologists and entrepreneurs. In recognition of their contributions, the Mike & Ophelia Lazaridis Quantum-Nano Centre is home to the Institute for Quantum Computing and the Waterloo Institute for Nanotechnology – two world-leading centres in transformative research.



NEXT-GENERATION COMPUTING



Hiding censored websites inside cat videos

CECYLIA BOCOVICH (MMath '14)

PHD STUDENT, FACULTY OF MATHEMATICS

- > DAVID R. CHERITON SCHOOL OF COMPUTER SCIENCE
- > CENTRE FOR APPLIED CRYPTOGRAPHIC RESEARCH

It's hard for Canadians to imagine going online and finding a website blocked by the government. Yet some organizations estimate two-thirds of internet users live in countries where a government or ruling authority censors parts of the web. Cecylia Bocovich, a computer science PhD student, is determined to do something about it. She and her colleagues are developing a free, open source, anti-censorship decoy routing system called Slitheen, named after a family of Doctor Who aliens who disguise themselves by taking human form. Users of the system make connections to innocuous web pages and request uncensored content, such as cat videos. With the help of friendly Internet Service Providers that route traffic between the user and the cat website, Slitheen replaces these videos with content from censored sites. This decoy routing traffic is indistinguishable from regular web traffic, so even if the censors know about the system, they can't distinguish between the Slitheen connection and a normal connection to the uncensored site.

\$445
BILLION PER YEAR

Cost of
cybercrime
globally

WORLD ECONOMIC FORUM





Building a practical quantum computer

MATTEO MARIANTI

PROFESSOR, FACULTY OF SCIENCE

- > DEPARTMENT OF PHYSICS AND ASTRONOMY
- > INSTITUTE FOR QUANTUM COMPUTING (IQC)

The dream of building a practical quantum computer is coming closer to reality in Matteo Mariani's lab. Mariani describes it as a grand project, comparable to putting a man on the moon. But controlling many "qubits" is hard. Mariani has what is regarded as one of the leading labs in the world developing technology toward a medium-scale quantum computer of several hundred qubits. He makes chips that have "superconducting circuits" cooled down to just a fraction above absolute zero (about minus 273 degrees Celsius.) His lab has developed a strong and reliable wiring technique that could be used for a medium-sized quantum computer system. It is also working on stacking these chips in multiple layers to improve the scalability while keeping the error rate low. Excitement is building in the quantum computing research community these days. With developments like those in Mariani's lab, a moon shot is on the horizon.



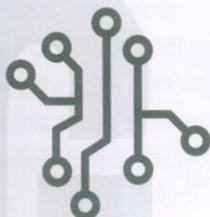
Meet the man protecting your secrets

DAVID JAO

PROFESSOR, FACULTY OF MATHEMATICS

- > DEPARTMENT OF COMBINATORICS AND OPTIMIZATION
- > DAVID R. CHERITON SCHOOL OF COMPUTER SCIENCE, CROSS-APPOINTED
- > CHIEF CRYPTOGRAPHER, EVOLUTIONQ INC.
- > DIRECTOR, CENTRE FOR APPLIED CRYPTOGRAPHIC RESEARCH

A quantum computer future is exhilarating and terrifying. This new type of computing, which exploits the strange laws of quantum physics, might enable researchers to run powerful simulations leading to fantastic new materials or drug designs. But if a hostile agent gets access to one, it could also break all of the encryption currently used to protect banking, personal information, government, military and corporate secrets. David Jao leads a large research group in "post-quantum" cryptography at the University of Waterloo, where he works on ways to defend against this future threat. He's also chief cryptographer at evolutionQ Inc., a Waterloo startup helping institutions and corporations secure information in advance of large-scale quantum computers. "The sooner we do this the better," Jao says, "because it's going to take time to switch everything over."



2.5 QUINTILLION

bytes of data are created every day

IBM

NEXT-GENERATION COMPUTING



Machine learning that helps Siri understand you better

JIMMY LIN

PROFESSOR, FACULTY OF MATHEMATICS

> DAVID R. CHERITON SCHOOL OF COMPUTER SCIENCE

You've just told Siri to play you some jazz but the smartphone assistant responds with, "That's not nice." Jimmy Lin, a professor in the Faculty of Mathematics, is working to clear up those misunderstandings using advanced machine-learning techniques that can leverage the massive amounts of data that are generated when user activities are transmitted to vast remote data centres. User queries are processed using natural language processing technology before responses are sent back to your device. To protect your privacy, his research group also works on improving the ability of the digital devices themselves to understand users even when disconnected from "the cloud." Lin's research team works on neural networks that can spot patterns in vast quantities of data as part of the hot research area known as artificial intelligence. These capabilities include everything from text processing algorithms that can summarize what people are saying on social media to data mining algorithms that can help online retailers uncover customers' tastes in fashion.



Forming the building blocks for quantum computers

DAVID CORY

PROFESSOR, FACULTY OF SCIENCE

> DEPARTMENT OF CHEMISTRY

> INSTITUTE FOR QUANTUM COMPUTING (IQC)

> CANADA EXCELLENCE RESEARCH CHAIR LAUREATE IN QUANTUM INFORMATION PROCESSING

There are untapped resources waiting to be mined deep in the heart of nature, at the quantum level where atoms, molecules, photons and electrons interact. It is a richer realm of the natural world where the sometimes strange and counter-intuitive rules of quantum mechanics operate. But to really be able to use those resources, we need to build devices that preserve quantum properties where noise reduces quantum information to conventional classical states. This involves engineering information at the nanoscale. Physical chemistry professor David Cory, the Canada Excellence Research Chair Laureate in Quantum Information Processing, is a pioneer in this cutting-edge field. He leads an experimental research lab at Waterloo's Institute for Quantum Computing, where his team develops quantum sensors and actuators, devices that in themselves have practical uses in areas like navigation and sensors for biomedicine, but will also form the building blocks for future quantum computers and other technologies that we have only begun to envision. His team works with a range of physical systems, and collaborates extensively with partners across Waterloo's Quantum Valley ecosystem. Such a unique setting acts as a powerful accelerator for device development with local access to multidisciplinary expertise, fabrication facilities and venture capital. Cory's work in experimental quantum physics and quantum engineering has led to a number of start-ups and is already being used in a range of applications, from the medical field to the oil industry. His ongoing work at Waterloo will help reveal the exciting potential of the quantum future.



Keeping hackers out of your devices

CATHERINE GEBOTYS (PhD '91)
 PROFESSOR, FACULTY OF ENGINEERING

- > DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
- > CENTRE FOR APPLIED CRYPTOGRAPHIC RESEARCH

Could a hacker get into a digitally controlled insulin pump? It's possible. Numerous medical devices, from pacemakers to insulin pumps and defibrillators, are now digital. Anything digital may be attackable. Hackers can also steal information or cause disruption by attacking vulnerabilities in smart TVs, home security cameras, connected cars, Fitbits or even a Google Home Mini. These devices are windows to hackers in an Internet of Things world and if the opening in the window is large enough, they can jump through. In the lab of Catherine Gebotys, a professor in the Faculty of Engineering, researchers are deliberately attacking chips embedded in our Internet of Things devices with technologies such as laser beams or electromagnetic pulses to figure out the vulnerabilities and design countermeasures. We may not be able to protect everything from hackers, "but our goal is to make it harder for the attackers," says Gebotys.



Accelerating innovation by printing circuit boards in minutes

KATARINA ILIC (BASC '13)
 ALUMNUS, FACULTY OF ENGINEERING AND FACULTY OF SCIENCE

- > CO-FOUNDER, VOLTERA INC.

Electronic devices are becoming cheaper and faster to make, thanks to Voltera Inc., a University of Waterloo alumni startup. The Waterloo team, co-founded by Katarina Ilic, a nanotechnology engineering alumna from the Faculty of Engineering and Faculty of Science, along with co-founders Alroy Almeida (BASC '13), James Pickard (BASC '13), Jesus A. Zoya (BASC '13) – all mechatronics engineering alumni – developed the V-One. The compact printer allows circuit boards to be created in minutes by printing them instead of waiting weeks for prototypes to come back from the factory. The V-One is now being shipped to 60 countries, mainly to innovators and engineering teams in large companies that need to iterate on circuit board designs quickly. The award-winning technology has put the company at the leading edge of a revolution in printed electronics, a growing sector that includes revolutionary products like self-heating clothing. Printed electronics is expected to become an \$18 billion industry by 2021. Voltera's technology helps make it happen.

50.1
BILLION

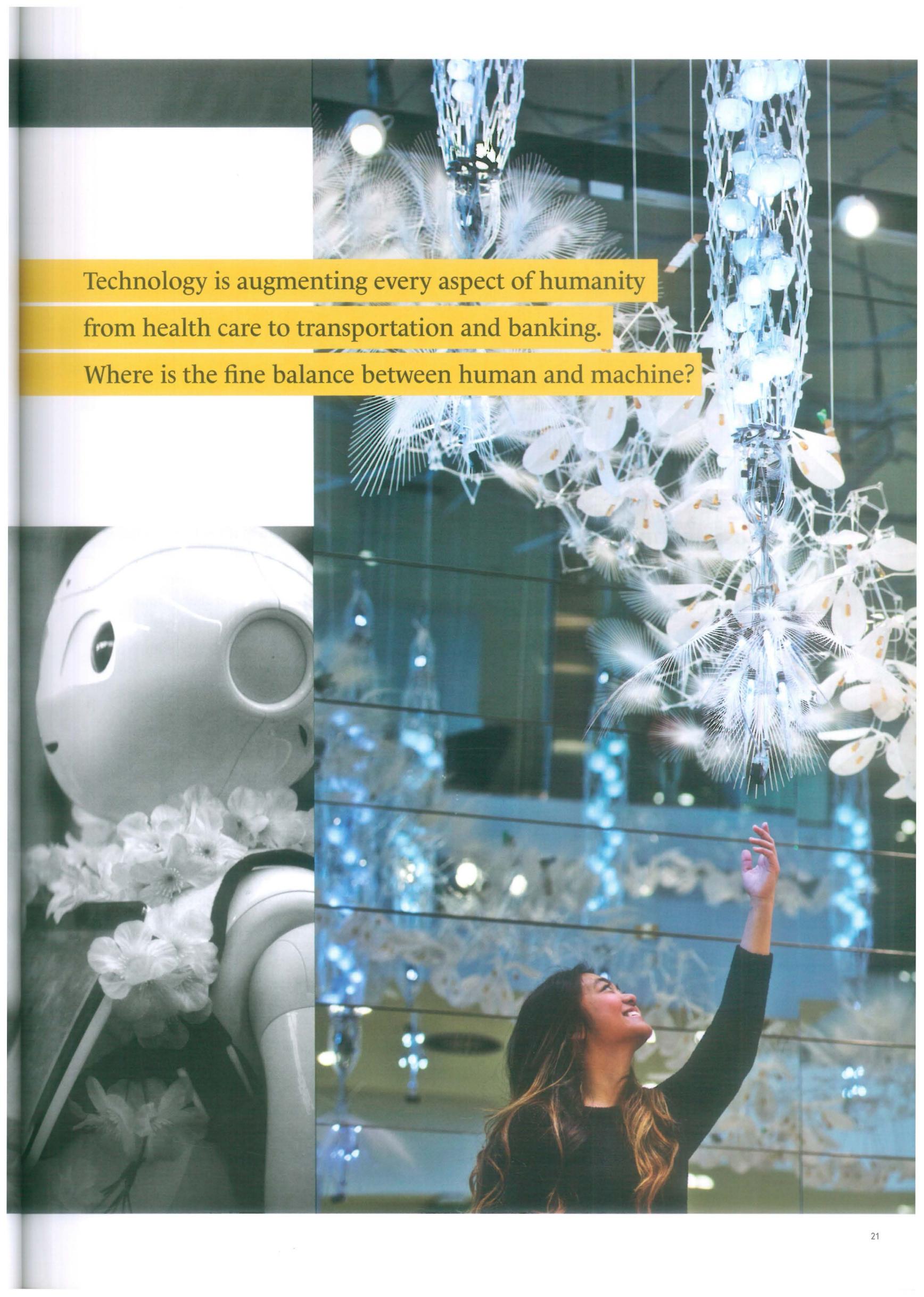
devices connected to the
 Internet of Things by 2020

COMPTIA

HUMAN- MACHINE INTERACTION



Photo credit: Andy Kelly on Unsplash.



Technology is augmenting every aspect of humanity
from health care to transportation and banking.

Where is the fine balance between human and machine?



HOW SHOULD WE MANAGE THE MACHINES?

**Responsible innovation for the 21st century:
Machines may become better drivers than us but
should we let them speak for us in our own voices?**



HEATHER DOUGLAS
PROFESSOR, FACULTY OF ARTS

> WATERLOO CHAIR IN SCIENCE AND SOCIETY
IN THE DEPARTMENT OF PHILOSOPHY
> FELLOW, AMERICAN ASSOCIATION FOR
THE ADVANCEMENT OF SOCIETY (AAAS)

How do you feel knowing there's artificial intelligence (AI) that can listen to a recording of your voice and mimic it – nearly perfectly?

You might think this advanced AI is a cool innovation. But the potential impact becomes worrisome when you consider that a public talk or interview could be used to train such AI systems to say anything in your voice.

What would happen if AI created fake audio recordings of politicians making damning statements or threats? What about the extortion of families who might believe their loved one is in danger? The voice on the other end of the phone line might sound like your partner or child – but it can now be machine generated.

Why did researchers think that this was a laudable achievement? They were lured in by the technical sweetness of it – the technical challenge was interesting in itself and they did it because they could.

As our ability to develop sophisticated machines proceeds rapidly, we must confront the complex social and ethical terrain that comes with these developments. As we develop

more powerful technologies, researchers must think about more than whether they can push the envelope in a particular direction. They must also think about whether they should.

Safer roads and massive unemployment with driverless cars

Researchers must confront the likely side effects and unintended uses of new technologies. Those who pursue driverless cars are increasingly worried about the likely side effect of massive unemployment as the technology becomes more widespread. Addressing the broader societal impact is essential for responsible innovation, and must include both intended – safer roads and fewer accidents – and unintended effects, like unemployment. This will require imagining the impacts of technology on society before deployment and in the midst of development.

Even if we focus on what we intend to accomplish with machines, substantial challenges of getting the aims of the machine correct remain. For example, what should driverless cars aim to do: reduce accidents and death overall, or preserve particular lives? In our pluralist society, there will continue to be competing values at play. Machines must be made with that in mind. Indeed, such value pluralism makes it likely that most machines will only successfully work in circumscribed settings, such as an Amazon warehouse, or to do narrow tasks such as drive on well-ordered roadways.

Machines beat humans at chess – but should they sentence prisoners?

Machines do not have the strengths of humans, and vice versa. Machines excel at repetitive straightforward tasks with clear criteria of success. It is in cases where success is murkier that structuring the aims of machines becomes a challenge.

It is amazing that machines can outplay us at complex games like chess and Go, and it is likely that machines will be better drivers than us. But success is very easy to assess in playing games (whether you won or not) and easy, albeit a bit more complex, in driving (whether you arrived safely and in a reasonable amount of time – already, two criteria are at play.)

What we should not do is deploy machines to make decisions in contexts where their abilities are not easy to assess by such obvious criteria.

Cases like the use of AI to make sentencing or parole decisions are deeply problematic, not just because the data used to train the system reflects such structural injustices as racism, but because we cannot tell readily whether the AI recommendations are the right ones.

How do we assess whether machines are doing a better job?

We can track whether a parolee reoffends but we cannot track whether a person who remains a prisoner would not have reoffended. We can assess whether an increase in parolees overall reduces prison populations in the long term, but not without confounders that are difficult to control. Without clear criteria that are easy to assess, we cannot tell whether the machine is doing a better job than a human, much less whether it is doing a good enough job.

It's time to recognize both the limits of machines and the needs of complex human societies if we are to develop our capacities responsibly in the 21st century.

We may not mind letting machines drive our cars – but do we want them speaking for us in our own voice?

HUMAN-MACHINE INTERACTION



Autonomoose: A self-driving car for safer roads and less stress

NIKOLAS STEWART (BASC '08)

ALUMNUS, FACULTY OF ENGINEERING

> AUTONOMOUS VEHICLES PROGRAM MANAGER

People who commute in harrowing bumper-to-bumper traffic look forward to the day when they can relax and let their driverless car take over. We are still a long way from a completely driverless vehicle, but the Autonomoose team at the University of Waterloo is paving the way toward vehicles that are rapidly becoming much more autonomous through work done by students, professors and industry partners. Autonomoose is a modified Lincoln MKZ that serves as a research platform for autonomous vehicle system development. Team members built the software stack and added state-of-the-art sensors, a sophisticated GPS, cameras, Lidar and other instruments. It was the first car to get the special licensing needed to test driverless technology on Ontario roads. Nikolas Stewart, a mechanical engineering alumnus and now the autonomous vehicles program manager for the University of Waterloo's WAVE and WISE labs, says the team is looking forward to their "public drives" throughout 2018.



Artificial intelligence will contribute

\$15.7 TRILLION

to the global economy by 2030

PWC REPORT, 2017



Wearable tech that speeds healing from injuries

ALEXA ROEPER

CO-FOUNDER, PENTA MEDICAL

> VELOCITY GARAGE

When avid athlete Alexa Roeper broke her foot, the most frustrating part was the wasted time between medical appointments. She couldn't be active or do much to speed up the healing. That led her to launch a startup company, Penta Medical, now located in the University's Velocity Garage. Roeper, along with co-founder and engineering alumnus Daniel Choi (BASc '16), developed a wearable device called Helios. It looks like an arm band and delivers laser therapy treatments while the person goes about their day. An app helps track and quantify the healing so the therapy can be adjusted. Penta Medical is doing pilot projects with sports teams but hopes to eventually expand into other products and markets. "Our vision is to create safe, non-invasive devices that give clinical levels of care at home," says Roeper.



How computer simulations are preventing workplace injuries

CLARK DICKERSON

PROFESSOR, FACULTY OF APPLIED HEALTH SCIENCES

> DEPARTMENT OF KINESIOLOGY

> CANADA RESEARCH CHAIR IN SHOULDER MECHANICS

Work-related injuries, such as shoulder and lower-back injuries from lifting objects, are a leading cause of pain, suffering and disability. These injuries are also enormously expensive for employers. According to the largest workers' compensation insurance provider in the United States, overexertion injuries – from lifting, pushing, pulling, holding, carrying or throwing objects – cost U.S. employers \$13.4 billion every year. In Canada, it is estimated that occupational shoulder injuries affect nearly 10,000 workers and account for more than \$450 million in disability benefit and compensation payments. Clark Dickerson, a professor in the Faculty of Applied Health Sciences, is helping to prevent injuries before they happen. His research group uses specialized biomechanical simulations to replicate the human shoulder and related body movements to pinpoint the parts of jobs that pose higher injury risk. From there, researchers work with engineers and ergonomists to design work stations and jobs to reduce future problems.

HUMAN-MACHINE INTERACTION



An artist explores the human-technology interface

JANE TINGLEY

PROFESSOR, FACULTY OF ARTS

> DEPARTMENT OF FINE ARTS AND THE STRATFORD DIGITAL MEDIA CAMPUS

From Roomba, the robotic vacuum cleaner, to a friendly customer service robot called Pepper, machines are increasingly moving into our homes and workplaces. Meanwhile, sensors and devices are also increasingly becoming a part of our clothing and even being attached to the human body. But how will this affect us in the future? Jane Tingley, a professor in the Faculty of Arts, is exploring the interactions between people and technology and what those interactions may mean on a social, cultural or political level. She has created a biomechanical dress and her interactive sculptures have sensors and lights that react to human movement. “We need to start understanding what technology is doing for us in both the negative and the positive sense, and become more involved in determining what our technologies do,” says Tingley.



40%
of millennials
believe automation
threatens their jobs

DELOITTE

5M

jobs lost by 2020
due to automation

FUTURE OF JOBS REPORT,
WORLD ECONOMIC FORUM



Algorithms to help vulnerable people in disasters

JOHN HIRDES

PROFESSOR, FACULTY OF APPLIED HEALTH SCIENCES

> SCHOOL OF PUBLIC HEALTH AND HEALTH SYSTEMS

When such natural disasters as Hurricane Irma and Hurricane Harvey strike, it's older citizens and people with disabilities who are often the most vulnerable. When the electricity goes out, seniors can be trapped without access to elevators, air-conditioning, phones and medical devices. John Hirdes, a professor in the Faculty of Applied Health Sciences, helps first responders find vulnerable older people during a disaster with an algorithm he developed that uses systems already in place to assess people for home care needs. His algorithm, which puts people in risk categories for disasters, was implemented during an earthquake in Christchurch, New Zealand. A couple of years later, when an ice storm hit eastern Canada, Hirdes and his PhD student Sandy van Solm used that event to refine and improve the algorithm. Today, it continues to help vulnerable people when disaster strikes – an example of technology being put to use to save lives.



The making of an artificial kidney to improve survival rates

MORTEZA AHMADI (PhD '13)

PHD ALUMNUS, FACULTY OF ENGINEERING

> CO-FOUNDER, QIDNI LABS

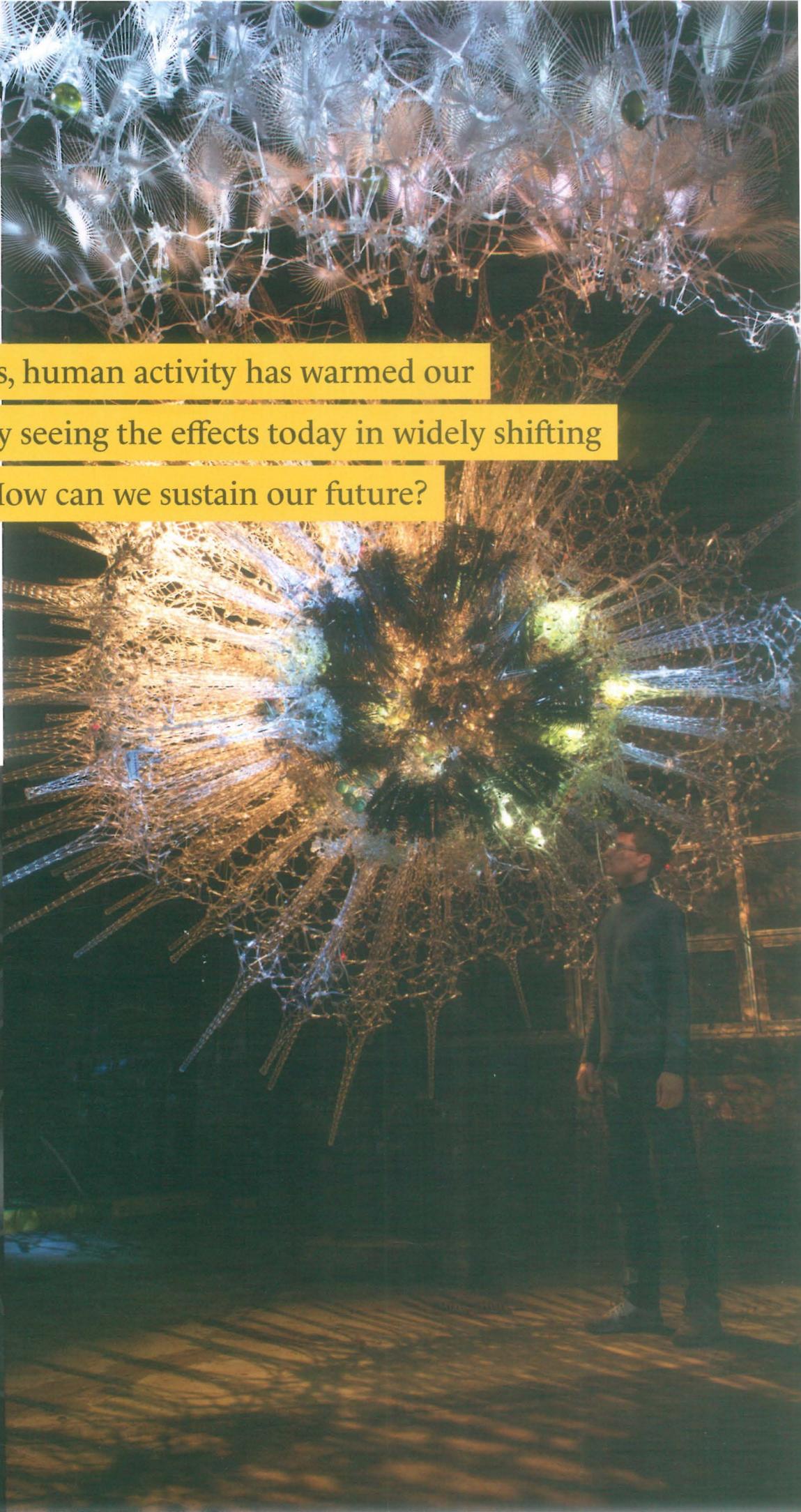
> VELOCITY GARAGE

Kidney disease is one of the most gruelling health problems. More than two million patients around the world suffer from end-stage renal disease, an illness that ties them to regular hospital visits for dialysis treatments that filter their blood. They also live each day with the knowledge that the majority of people with late-stage renal disease die within five years. Morteza Ahmadi wants to change that. After completing a PhD in the Department of Systems Design Engineering, Ahmadi launched a startup called Qidni Labs to develop a device that can be implanted in the body to filter blood continuously so people won't have to go to the dialysis clinic three times a week. Qidni Labs, based at the University of Waterloo's Velocity Garage, is working toward the larger goal of actually improving survival rates for people living with the disease.

CLIMATE RESILIENCE AND NATURAL WONDERS

The first image of the cosmic web, which is mostly dark matter, that links galaxies.

Photo credit: Mike Hudson, professor of physics and astronomy, and Seth Epps, a former Waterloo master's student.



Over the past 50 years, human activity has warmed our planet. We are already seeing the effects today in widely shifting patterns in climate. How can we sustain our future?

THE SLOW ROAD THROUGH CLIMATE CHANGE

Breakthroughs in big data, alternative fuels and energy storage offer hope for a sustainable future. But the real challenge is social and political – not technical.



SARAH BURCH

PROFESSOR, FACULTY OF ENVIRONMENT

> DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL MANAGEMENT

> CANADA RESEARCH CHAIR IN SUSTAINABILITY GOVERNANCE AND INNOVATION

Scarcely a day passes that doesn't bring with it some news of a climate change catastrophe, green-technology game changer or contentious policy proposal. Pervasive floods covered one third of Bangladesh while 27 trillion tons of water were dumped on Texas and Louisiana in 2017. Elon Musk offered to restore power to Puerto Rico using Tesla batteries and solar power. Prime Minister Justin Trudeau committed to phasing out coal in Canada but approved the twinning of the Trans Mountain Pipeline.

The push and pull of these contradictory trends comes at a time of great change for humanity. Everywhere we look, society is being reordered. Economies are modernizing. We're becoming more global and more urban while information and ideas are exchanged without friction. New technology is arriving every day that stretches our imagination. For many people, managing all of this change can be overwhelming – especially when a changing climate literally means disaster for many people.

Technologies to reduce emissions have existed for decades

One way we cope with these unsettling changes is to hope that some of the miraculous new technology arriving at our fingertips daily will pull humanity away from the brink of climate disaster at the last minute. Recent breakthroughs in artificial intelligence, alternative fuels, energy storage and big

data offer some hope that a sustainable low-carbon pathway is possible. But many of the technologies needed to dramatically reduce our greenhouse gas emissions and pursue a sustainable future have existed for decades. It's also clear that, despite major new climate policy proposals, Canada is not on track to meet its much-heralded commitments under the Paris climate agreement. Why has the uptake been so desperately slow? Why are experiments in low-carbon communities so scattered, disconnected and often incremental?

Research on the transition to sustainable communities (neighbourhoods and urban spaces that aren't just low carbon, but also economically prosperous, socially just and ecologically rich) suggests that three crucial factors are at play.

Although it's common to yearn for technical solutions to environmental problems (shared autonomous electric vehicles, aircraft fuelled by algae), the transition to sustainable communities is largely a social and political challenge, not a technical one. Why do so many Canadians jump in their cars instead of hopping on bikes or taking a stroll? Owning a car, and the prestige and convenience that comes with it, may be deeply linked to our identity, our self worth and sense of independence.

The Dutch example

This is of course not true everywhere in the world: to be Dutch, for instance, is to cycle. Between 35 and 45 per cent of Dutch citizens say that cycling is their primary mode of transportation (compared to only about seven per cent of Canadians – even when walking is combined with cycling). But 'twas it always thus in Amsterdam? It was only in the 1970s that a strong public push to get out of cars and onto bikes started to pervade the national conversation in the Netherlands, mostly in response to car-related child deaths – not environmental concerns. This demand was met with ever-improving cycling infrastructure, facilitated by dense urban design and accelerated by social pressure, which has resulted in the remarkable cycling culture we see today. In other words, the technology always existed, but facilitating its use was

a social and political decision, and required a deeper shift in values and cultures. A culture shift is possible.

The other reason we might choose a car over active or mass transportation is rather more out of the control of individual Canadians. The shape and function of our cities forces us to choose particular modes of transportation: if bike lanes are non-existent or unsafe, if we have to travel 40 kilometres from our home to our work, if mass transit is unreliable or uncomfortable, we're left trapped in old patterns of behaviour. In other words, our cities create inertia that locks us into high-carbon, unsustainable lifestyles – even when the technologies exist that could free us.

Crucial role of a compelling vision

The final ingredient of a transformation toward sustainability that is often ignored in favour of the endless search for technological innovation is the crucial role of a compelling, inclusive and desirable vision of what a sustainable future might look like. Should a sustainable neighbourhood in Toronto look and feel the same as Inuvik? Clearly not. There are three dimensions to this vision that research has shown will be more likely to trigger action: the inclusion of different voices (all genders, ages, ethnic and socio-economic backgrounds, for instance) in the creation of the vision; the use of imagery, story-telling and games to communicate and shape this vision; and a focus on the interplay or synergies among multiple values that we hold dear (equity, justice, environmental integrity, good jobs, affordable housing, public health) rather than a narrow preoccupation with just one.

We know that existential fear is more likely to create paralysis and apathy, while a story about opportunity and the potential for a better life, in which we see our own voice and values, opens up possibilities. The search for climate change solutions reveals a powerful opportunity to pursue the more holistic and transformative challenge of sustainability. Although new and emerging technologies will inevitably be a part of this transition, it is a deeper conversation about what we value that will accelerate change.

CLIMATE RESILIENCE AND NATURAL WONDERS



Building a bridge between Indigenous knowledge and NASA data

MELANIE GOODCHILD

PHD STUDENT, FACULTY OF ENVIRONMENT

> SENIOR INDIGENOUS RESEARCH FELLOW

> WATERLOO INSTITUTE FOR SOCIAL INNOVATION AND RESILIENCE

Indigenous communities are among the places hardest hit by climate change. With their strong history and culture of systems thinking, Indigenous voices have never been more crucial to the climate conversation. Melanie Goodchild, a PhD student in the Faculty of Environment, is building a bridge between Indigenous knowledge systems and NASA's geospatial data systems. First Nations increasingly need access to new data to inform their systems of knowledge, as climate change affects their ways of life. With rapid changes to ecosystems affecting traditional food sources and warming weather affecting safe travel routes, Goodchild, an Anishinaabe member of the Biigtigong Nishnawbeg community in northern Ontario, is collaborating with a team of interdisciplinary tribal and non-tribal members to determine how First Nations can use NASA's data to reduce the vulnerability of people living in northern communities.



16 OF THE 17

warmest years
on record
have occurred
since 2001

NASA

Climate change may
push more than

100M

people into extreme
poverty by 2030

WORLD BANK



First image of dark matter web that connects galaxies

MIKE HUDSON

PROFESSOR, FACULTY OF SCIENCE

> DEPARTMENT OF PHYSICS AND ASTRONOMY

How do you take a picture of something that's invisible?

Waterloo scientists have created the first image of the cosmic web, which is mostly dark matter, that links galaxies. Mike Hudson, a professor in the Faculty of Science, and Seth Epps (MSc '16), a former Waterloo master's student, used a technique called weak gravitational lensing. Even though it can't be seen, dark matter has a gravitational pull that affects the path of light, causing the images of distant galaxies to warp slightly. The composite image was produced from a multi-year sky survey at the Canada-France-Hawaii Telescope, combining lensing images from more than 23,000 galaxy pairs located 4.5 billion light years away. It confirms predictions that galaxies across the universe are tied together through a cosmic web connected by dark matter that has until now remained unobservable.



Data-driven 3D maps that inform homeowners of flood risks

JASON THISTLETHWAITE (PhD '11)

PROFESSOR, FACULTY OF ENVIRONMENT

> SCHOOL OF ENVIRONMENT, ENTERPRISE AND DEVELOPMENT

Due to climate change, flooding has now replaced fire as the greatest risk to Canadian property owners – with homeowners paying close to \$600 million out of pocket annually for flood damage. But as flood risk intensifies every year, most Canadians have no idea they're at risk, and even fewer know what to do to protect their most valuable asset.

Jason Thistlethwaite, a professor in the Faculty of Environment, and his colleagues have teamed up with the insurance industry in a unique partnership to be Canada's first line of defence from climate-related property damage. They're building data-driven 3D maps of flood-risk areas to convince governments at all levels to take action to protect at-risk homes.

Meanwhile, as federal policy is shifting the burden of responsibility for flood recovery to property owners, Thistlethwaite and his researchers are working on the first national climate change flood risk framework designed to empower Canadians with the knowledge they need to protect themselves.

CLIMATE RESILIENCE AND NATURAL WONDERS



Using artificial intelligence to preserve water and save money

THOUHEED ABDUL GAFFOOR (MASC '17)
ALUMNUS, FACULTY OF ENGINEERING

- > CO-FOUNDER, EMAGIN
- > VELOCITY GARAGE

Humans make most of the decisions around how a city's water supply is managed, but now artificial intelligence-supported software can do it better – preserving water resources and saving money.

Thouheed Abdul Gaffoor, a Faculty of Engineering alumnus who holds a BSc in Environmental Engineering and an MSc in Civil Engineering, is co-founder of EMAGIN, a new startup that is helping water utilities become more efficient and resilient. EMAGIN's software works with sensors to offer facility operators more accurate and timely information and recommendations. During a storm, for instance, EMAGIN's software can allow operators to more effectively treat incoming wastewater and prevent overflows.

Water is the one of the last utilities to be digitized, says Gaffoor, likely because in Canada “we have the luxury of abundance.” The company works with several U.S.-based companies and a few Canadian municipalities. By late 2018, EMAGIN expects to double in size and expand its work with utilities in Canada. Gaffoor says, “I'd like to see us grow in our own backyard.”



Human and natural pressures on our water quality

PHILIPPE VAN CAPPELLEN
PROFESSOR, FACULTY OF SCIENCE

- > DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
- > CANADA EXCELLENCE RESEARCH CHAIR IN ECOHYDROLOGY
- > WATER INSTITUTE

Most people know that pollution poses a threat to water quality. But few of us grasp how complex water issues really are. How do human pressures, such as industrial activity, agriculture and climate change, impact the quality of our streams, lakes and groundwater – and ultimately our drinking water? Philippe Van Cappellen, a professor in the Faculty of Science, leads a multidisciplinary team tackling such questions. As the Canada Excellence Research Chair in Ecohydrology, Van Cappellen examines how the damming of rivers is driving major changes in the amounts of nutrients reaching the world's oceans, with far-reaching consequences for coastal ecosystems. He also develops new modelling tools to link land-based human activities to changes in water quality and ecological health in the Great Lakes, the world's largest freshwater resource. “The key outcome of this research,” says Van Cappellen, “is a better understanding of how humans impact water quality which, in turn, helps inform more effective management practices that balance the water needs of society with those of natural ecosystems.”



Bringing renewable energy to developing regions around the world

KAYLA HARDIE

UNDERGRADUATE STUDENT

FACULTY OF MATHEMATICS AND FACULTY OF SCIENCE

> WATERLOO INSTITUTE FOR SUSTAINABLE ENERGY (WISE)

Cell phones give people in developing regions access to work, education and the economy. But in many countries there's limited access to energy, so charging cell phones is difficult and expensive. Kayla Hardie, an undergraduate student of computer science and physics, is developing technology that will bring renewable energy to even the poorest and most remote regions of the world. Working with Srinivasan Keshav, a professor in the Faculty of Mathematics, Hardie has built a micro-utility prototype that shopkeepers in developing countries can use to sell units of solar energy. She calls it SPEED: self-serve, pre-paid, emissions-free energy delivery system. Built around an inexpensive Raspberry Pi computer, solar panels, batteries and microinverters, the unit allows shopkeepers to generate, store and sell units of power for charging small items like cell phones or solar lanterns. With a solid return on investment, Hardie hopes SPEED will encourage small business owners in underserved areas to stake a claim in renewable energy.



Satellite images show loss of polar ice in the past 20 years

JULIE FRIDDELL

FACULTY OF ENVIRONMENT

> DIRECTOR, CANADIAN CRYOSPHERIC INFORMATION NETWORK/POLAR DATA CATALOGUE

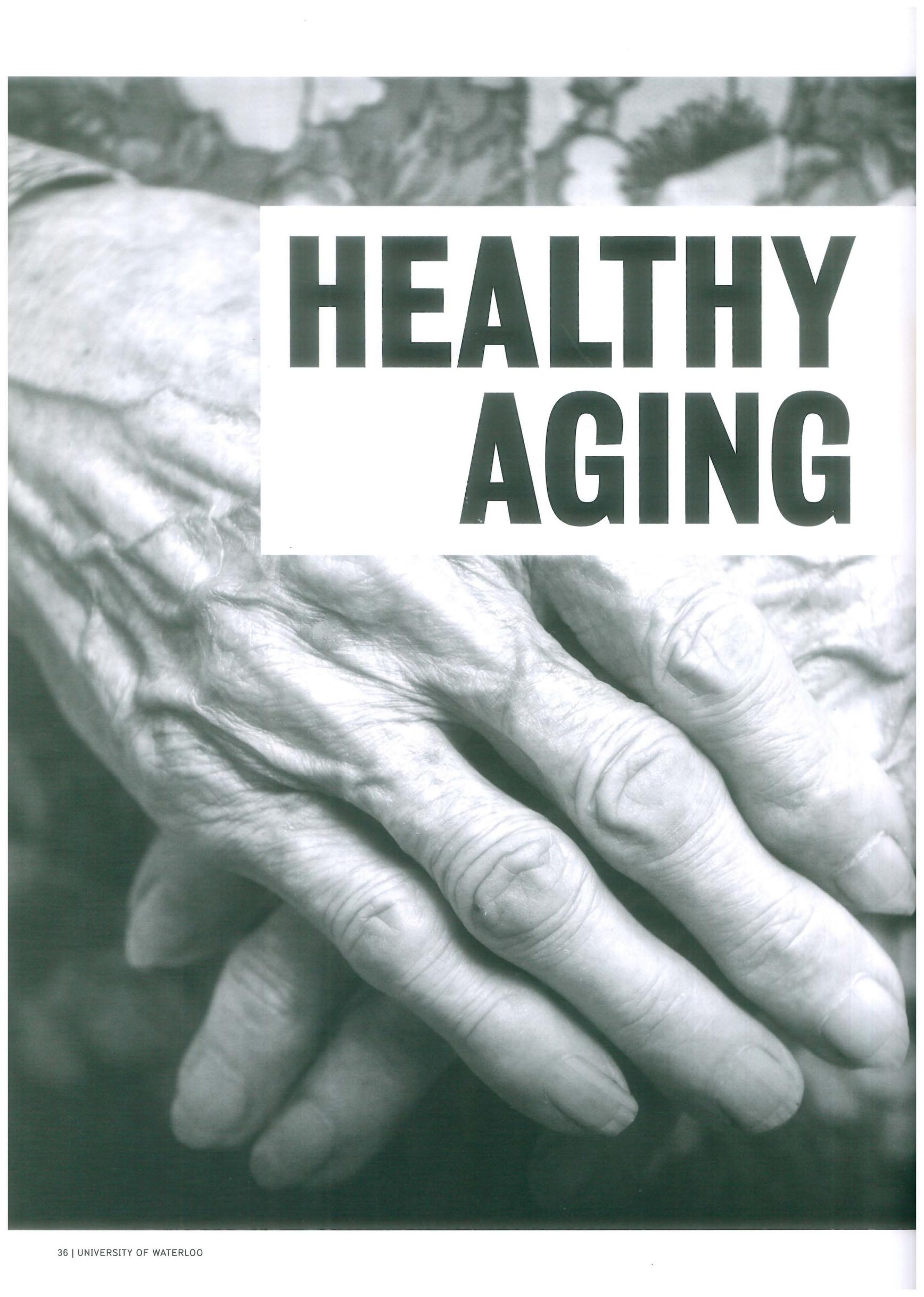
With glaciers and ice sheets being so sensitive to temperature fluctuations, some of the most disturbing evidence of the Earth's changing climate can be found in Canada's polar regions and the Antarctic. That's why Julie Friddell, the director of the Canadian Cryospheric Information Network/Polar Data Catalogue (CCIN/PDC), and her team are sharing dramatic satellite images as animated GIFs online so that ordinary people can view in a few seconds the disappearing polar ice that has occurred over the past 20 years.

Friddell emphasizes that part of the mandate of the PDC, which is based at the University of Waterloo, is to make data accessible for everyone. "We want to reach all kinds of people. A visualization is easier to digest than tables and rows of data." The online visualizations are created using satellite images taken by the Canadian Space Agency and the satellite provider MDA in 1997, 2000 and 2008.

3.3 MILLIMETRES

average annual global sea level rise

NASA



HEALTHY AGING



People in many parts of the world are having fewer children and living longer. How will we live when there are fewer family supports?



HOW SOCIETY FAILS OLDER ADULTS

After helping her family navigate the complex system of care for her grandmother, Rachel Thompson says, “Our seniors have dementia, yet we are the ones who are forgetting.”



RACHEL THOMPSON (BSc '15)

ALUMNUS, FACULTY OF APPLIED HEALTH SCIENCES

> FOUNDER, MARLENA BOOKS, MARLENA BOOKS CREATES THERAPEUTIC RECREATION PRODUCTS FOR INDIVIDUALS WITH ALZHEIMER'S DISEASE AND DEMENTIA.

I was 15 years old when my grandmother started forgetting who I was.

Diagnosed with early-onset vascular dementia, the woman I had looked up to my entire life slowly began to change and I watched life get increasingly difficult for my grandparents. As my grandmother's dementia advanced, I watched my grandfather struggle to take care of her. He told me how lonely he felt. Many of his friends had stopped visiting, not knowing what to say to my grandmother.

While he was feeling forgotten, our family was being introduced to a forgotten generation: Canada's seniors.

For the first time in census history, there are more seniors in Canada than children younger than 14, yet older Canadians face a lack of infrastructure so severe it affects everything from long-term care placements to community activities. Around the world, each country has its own infrastructure and cultural context for senior care, but the reality remains that many countries are grappling with similar issues. Globally, the population aged 60 and older is growing faster than all younger age groups.

There are almost six million Canadian seniors today, many of whom are trying to access limited resources for complex health issues that require advanced care. For example, 50,000 seniors will fracture a hip and more than half of them will need ongoing care in hospitals, rehabilitation centres or long-term care homes.

An 800-day wait for long-term care

People are waiting two years to get into long-term care homes. Care co-ordinators advise families to place loved ones on the wait list years before their anticipated entry into the care system. When emergencies occur, families are often left with difficult decisions such as placing family members in homes with poor ratings or homes outside their preferred geographical location. After dealing with my grandmother's dementia for eight years at home, our family decided to place her on the list. She waited more than 800 days to be placed in long-term care.

Outside of long-term care, our society continues to let seniors down. People who have contributed to their communities and countries for decades do not have access to the care they need. Adult day program wait lists are on the rise, and the home-care system is stretched so thin, there are reports of workers leaving before their scheduled time, citing they do not have enough time in their day to fit in all their clients. This translates into poor care for older Canadians who use home care for daily activities such as light housework or bathing.

Yet someone has to pick up the slack. The sandwich generation: those aged 35-50 who are taking care of their aging parents, are stressed, overworked and frustrated with the system. Almost three in 10 in this age range take sick days and vacation days to care for their aging parents. My aunts arranged all

of my grandmother's homecare, a system far too complex for my grandfather to navigate.

Change in infrastructure for older adults is slow

And still the system forgets. We are very good at divulging research on these problems. A simple search returns hundreds of anecdotes from Canadian families in similar situations to my grandmother with statistics to back it up. We know wait times for long-term care are too long and that the time on a crosswalk is too short for those with slower mobility to cross the street, but we see little change.

My grandmother was placed into long-term care more than two years ago, yet wait times can still be 700 days. Change cannot come without funding, and yet another flaw in this design lies within the per capita funding scheme. Imbalances are noticed between provinces, with Alberta receiving more seniors' funding than Atlantic provinces, although Albertan seniors make up 13 per cent of the population and Atlantic seniors represent 20 per cent. The Canadian Medical Association has recognized this flaw, yet the framework has not changed.

This problem isn't going away, with Canadian senior rates set to rise to more than 10 million by 2036 and dementia rates set to increase 60 per cent in this time frame. It is up to us, our communities and our government to ensure seniors are given the quality of care they deserve.

I visit my grandmother weekly in her long-term care home. She still cannot recognize me and can no longer speak. We are walking back to her room following lunch one day when she winks at me.

I know deep down she hasn't forgotten, so how can I?

HEALTHY AGING



Using artificial intelligence to detect cancer

ALEXANDER WONG (PhD '10)

PROFESSOR, FACULTY OF ENGINEERING

- > CANADA RESEARCH CHAIR IN MEDICAL IMAGING SYSTEMS
- > DEPARTMENT OF SYSTEMS DESIGN ENGINEERING
- > DEPARTMENT OF MECHANICAL AND MECHATRONICS ENGINEERING, CROSS-APPOINTED
- > DAVID R. CHERITON SCHOOL OF COMPUTER SCIENCE, CROSS-APPOINTED
- > RESEARCH SCIENTIST, SCHLEGEL RESEARCH INSTITUTE FOR AGING
- > CENTRE FOR BIOENGINEERING AND BIOTECHNOLOGY
- > WATER INSTITUTE

A new device that uses artificial intelligence and deep-tissue scans of our bodies can detect skin cancer earlier – without doing biopsies.

Alexander Wong, a Canada Research Chair and professor in the Faculty of Engineering, and his research team are sharing the technology through their spinoff company, Elucid Labs, which was named among the Top 20 Most Innovative Technology Companies in Canada by the Canadian Information Exchange.

“I’m very proud of my students who went on to create the company,” Wong says. “Recently we’ve made a breakthrough in building deep-learning artificial intelligence that when combined with our deep-tissue scanning technology provides state-of-the-art cancer screening and assistance to clinicians.”

Wong says his research team is inspired by research that makes a difference in people’s lives today. “One of the key things that’s unique about Waterloo is the fact that we’re not only just about developing the big ideas. We’re also about executing and translating those big ideas into something that can actually have a strong economic and social impact.”

425M

people older than 80 years old in 2050,
compared to only 137 million today

UN DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS



Studying Alzheimer's at a molecular level to find a cure

ZOYA LEONENKO

PROFESSOR, FACULTY OF SCIENCE

> DEPARTMENT OF BIOLOGY AND DEPARTMENT OF PHYSICS AND ASTRONOMY
> WATERLOO INSTITUTE FOR NANOTECHNOLOGY (WIN)

A lack of understanding of Alzheimer's disease at the molecular level is one of the biggest obstacles to finding a cure, says a Waterloo researcher.

Zoya Leonenko, a professor in the Faculty of Science, is leading nanoscale biophysics research with the hope her team's work will one day be used by the pharmaceutical industry to develop new strategies for the prevention and cure of Alzheimer's disease.

She and her team are using advanced biophysics and nanotechnology methods with promising preliminary results. The ultimate goal is developing preventive strategies using molecules such as melatonin and novel amyloid-inhibitor drugs that work at the single-molecule level.

"Alzheimer's is a devastating disease that affects so many people and families," she says. "Without understanding the science of it, we cannot develop drugs or a cure. This research is extremely important because once we understand what's going on at the molecular level, then maybe we can propose how to cure this."



What the lives and brains of Roman Catholic nuns tell us about aging

SUZANNE TYAS

PROFESSOR, FACULTY OF APPLIED HEALTH SCIENCES

> SCHOOL OF PUBLIC HEALTH AND HEALTH SYSTEMS

Nearly a century of data on hundreds of North American nuns is driving new discoveries into how early life may affect your risk of developing Alzheimer's disease.

"We have data not just from convent archives on their early life and annual assessments during later life, but also after death because all 678 nuns in the study agreed to brain donation," says Suzanne Tyas, a professor in the Faculty of Applied Health Sciences. "In some people who show no memory loss during their lives, the brain can still show the signs of Alzheimer's after death. We call this cognitive resilience – and early-life factors can provide clues to how some people resist these brain changes."

The research will ultimately reduce the impact of the disease. "This could help inform public policy targeted to early life, focusing on enrichment and how important it is to build a robust brain that then can better buffer all the insults that happen over a lifetime."

HEALTHY AGING



Moving a wheelchair with your mind

MEI LIN CHEN

MASc CANDIDATE, FACULTY OF ENGINEERING

- > MEMBER, WATERLOO ENGINEERING BIONICS LAB,
DEPARTMENT OF SYSTEMS DESIGN ENGINEERING
- > CENTRE FOR BIOENGINEERING AND BIOTECHNOLOGY

Mei Lin Chen is developing technology that will one day predict what you want to do – before you do it. “This cutting-edge research is going to change the world in the next 10 years,” says Chen, a graduate student in the Faculty of Engineering. “It’s going to enhance the aging experience.”

The ability to read brain signals of people who can’t move their arms or legs could have huge implications for amputees and stroke victims. Chen is part of Waterloo’s Engineering Bionics Lab, which is led by her supervisor Ning Jiang, a professor in the Faculty of Engineering. The hope is to develop a virtual-reality wheelchair-control system for people who are paralyzed.

“We are detecting thoughts – the intention to move – and translating that into different controls: left, right, straight, stop. People without the use of their arms or legs will be able to control it in a 3D space,” Chen says. “Right now, it’s a training ground for people to improve their mobility, and ultimately to be able to control a device like this in real life.”



of older adults live
in countries with
universal long-term
care coverage

UN DIVISION FOR SOCIAL
POLICY AND DEVELOPMENT

71 years

was the average life expectancy
globally in 2015, compared to
66 years in 2000

WORLD HEALTH ORGANIZATION



Sending nanomedicine to the back of your eye to cure glaucoma

MARIANNA FOLDVARI

PROFESSOR, FACULTY OF SCIENCE

- > SCHOOL OF PHARMACY
- > WATERLOO INSTITUTE FOR NANOTECHNOLOGY (WIN)

What if gene therapy could not only treat age-related diseases but cure them altogether? It's a lofty goal – but one that's well within reach.

Marianna Foldvari, a professor in the Faculty of Science, is one of a handful of researchers worldwide focusing on non-invasive gene therapy and drug delivery, using nanotechnology to treat and cure such neurodegenerative diseases as glaucoma.

"A focus right now is to develop nano-sized transporters that can reach the back of the eye to improve vision, especially in the treatment of glaucoma," Foldvari says. Along with two of her PhD students, Foldvari formed a company to develop these technologies. The safety and efficacy of the nano-formulations that will deliver the therapy are being assessed so they can work toward clinical trials.

Given there is no cure for glaucoma, it's a huge step forward, says Foldvari, who is working to revolutionize how drugs and treatments can be administered to the body in a non-invasive manner.



Can exercise protect against dementia?

LAURA MIDDLETON

PROFESSOR, FACULTY OF APPLIED HEALTH SCIENCES

- > DEPARTMENT OF KINESIOLOGY, CROSS APPOINTED TO SCHOOL OF PUBLIC HEALTH AND HEALTH SYSTEMS
- > RESEARCH SCIENTIST, SCHLEGEL-UW RESEARCH INSTITUTE FOR AGING

People who exercise have a lower risk of dementia, and now researchers are working to pinpoint what *kind* of exercise is best and whether combining it with other lifestyle interventions helps people at risk.

Laura Middleton, a professor in the Faculty of Applied Health Sciences, is partnering with researchers across Canada to examine how combinations of exercise, cognitive training, diet and vitamin D affect those at risk for dementia.

"Our hope is that by combining therapies, we may be able to amplify the benefits," says Middleton.

She is also working with researchers, people with dementia, and community stakeholders to increase the number, quality and variety of dementia-friendly exercise opportunities available to Canadians. "People with dementia are broader than their diagnosis. We're engaging with people with dementia so they can show us what they need."

INSIDE IMAGES



PROSPERITY AND SCARCITY

**Epiphyte Spring:
Hangzhou, China
2013 PBAI®**

Could insecure communities work together, building their own new kinds of spaces for living and working? Using reconfigurable lightweight parts, people can create their own responsive environments that are closely matched to constantly evolving conditions.



NEXT-GENERATION COMPUTING

**Aerial Well Study:
Hong Kong
2014 PBAI®**

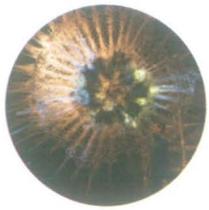
New kinds of powerful computing can be created by tiny interlinked microprocessors organized in dense meshes. This computing can learn and adapt, and can even show curiosity as it evolves.



HUMAN-MACHINE INTERACTION

**Aurora:
Edmonton, Canada
2013 PBAI®**

Could buildings know us, talk to us and care about us? Artificial intelligence in buildings can create new kinds of “conversations” between people and surrounding spaces.



CLIMATE RESILIENCE AND NATURAL WONDERS

**Astrocyte:
Toronto, Canada
2017 PBAI®**

Similar to natural cycles of growth, new kinds of buildings could repair and renew themselves. The skins of new architecture can help to renew the environment by capturing carbon and generating fresh air and renewable energy.



HEALTHY AGING

**ProtoCell Mesh:
Nottingham/
London, England:
Cambridge, Ontario
2012/13 PBAI®**

Nourishing environments can actively reinforce memory and understanding as we grow and age. Innovative neuroscience integrating cycles of feedback could reinforce memory and understanding.





THE LINES WE CROSS ARE THE ONES THAT DEFINE US

Vinh Nguyen, a University of Waterloo professor who was a child refugee, has said the line that separates him from the millions of people who died fleeing their homes is “**the thinnest line imaginable.**” As we work to restore our planet, build our economy and reimagine society, let us move forward with the knowledge that the lines that appear to separate us are the thinnest imaginable.

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