CSPC
CANADIAN SCIENCE POLICY CENTRE

The Canadian SCIENCE POLICY

-Magazine-

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NEW DECADE, NEW REALITIES: HINDSIGHT, INSIGHT, FORESIGHT

MESSAGE FROM THE EDITORIAL COMMIITTEE

It begins to become cliché to say that “2020 is an unprecedented year” but nothing better describes the rippling effects of COVID-19 seen across all areas of the science policy community. As health researchers and biomanufacturers work hand-in-hand with politicians to keep our communities safe, natural scientists and engineers direct their efforts to scalability and production, and social scientists consider the lasting implications on our global society in a time of great challenge, this year has affected us all.

If there’s a positive side to this year, the prevalence of scientists, doctors, and researchers as trusted experts in the media has become the norm. The pandemic also directed a spotlight on inequalities, and we saw communities and institutions renew commitments to reducing barriers and disparities. It has become a task to us all to build the safety of our communities, to stay informed, to dispel misinformation, and to uplift those who have faced systemic restrictions. This year we learned to be more comfortable with uncertainty, but it has also sharpened our drive to be better, as people and as a society.

This year has been a series of Grand Challenges - for the World, for Canada, and for the CSPC, which is why we’ve adopted that as the theme of our 2020 Magazine and Conference. Our volunteers from around Canada and the world have been working tirelessly to provide the highly renowned CSPC experience available to your home offices wherever that may be. This year’s Canadian Science Policy Magazine comes to you now in an entirely digital format and continues to feature some of Canada’s greatest minds in the science policy landscape. Their unique perspectives on these Grand Challenges look to address immediate challenges with optimistic forward-thinking approaches. We’re delighted to present the Second Edition of The Canadian Science Policy Magazine and we look forward to seeing how Canada will continue to lead the world in these “unprecedented times”.

Peter Serles & Alessandra Zimmermann
CSPC Editorial Chairs, Canadian Science Policy Magazine Chief Editors

Sarah Laframboise
Production Director, Volunteer, CSPC Editorial Committe

MESSAGE FROM THE COVER ARTIST, YUKA SAI

“Twenty years into the new millennium, policy-making in science and technology is more complex than ever. The policies we shape today will define a new era where lines are blurred between science, industry, education, and innovation, each re-defining the other as we develop new tools to deal with crises both foreseen and unforeseen. On the cover of the 2020 edition of the Magazine, various elements of our scientific ecosystem are built into a puzzle cube to represent what modern science policy looks like: an ever-evolving vision, made up of many interconnected pieces of a whole.“

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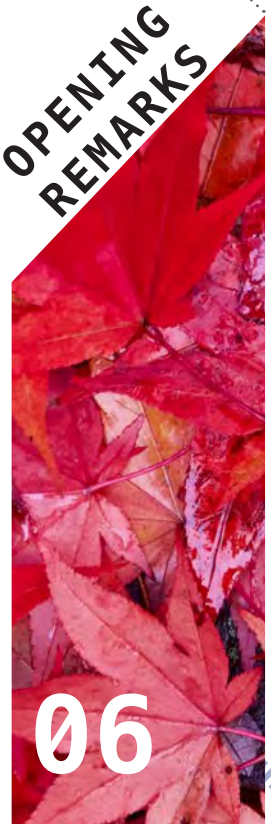
OPENING REMARKS



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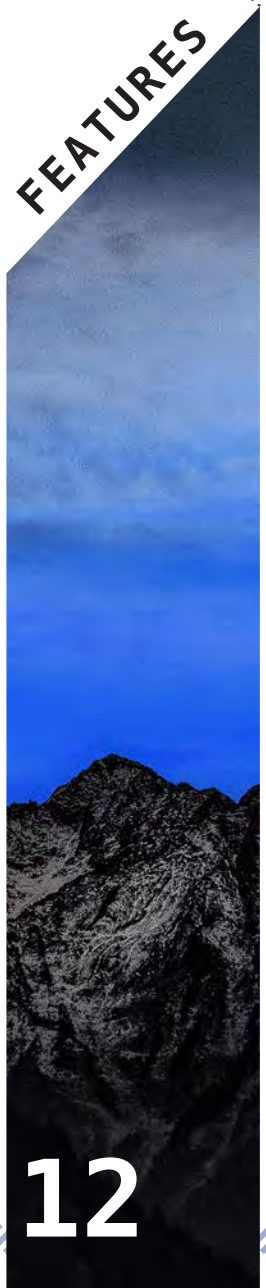

GRAND CHALLENGES

SCIENCE + SOCIETY

SCIENCE + POLICY

NEXT GENERATION

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LETTER FROM THE PRESIDENT AND CEO OF CSPC

Mehrdad Hariri

President and CEO of Canadian
Science Policy Centre

I am pleased to offer you the second edition of the Canadian Science Policy Magazine.
When the Canadian Science Policy Centre launched the inaugural issue of the Canadian Science Policy Magazine in November 2019, I could not have imagined that our world would change so drastically in a matter of months. In the face of unprecedented global and local challenges, science policy is more important than ever, and the role of science to inform policy is of undeniable importance.

We are at a pivotal time of our modern civilizations. The grand challenges we have been facing remain the same, and have become much more complex, much more interrelated and much more global as a result of the pandemic. There are no solutions to all these issues, they have endangered the very foundations of our societies. Shattered economies, unknown futures, serious health care crises, significant and multifaceted social issues, including our challenges to social fabric and education system. These all are in addition to major exciting challenges, which we had not yet been able to meet, including climate change, food security, inequality, mass migration, terrorism, systemic racism, marginalization, threats to our democracies, political polarization and radicalism, diminishing trust to societal institutions, and many more.

Looking at the degree of the shift, it seems that the business as usual - or better said, as before - is not a viable option. It is time to rethink and renew many foundations of our civilizations. Bold actions are required at this time: for climate change, for the pandemic, for growing inequality and for weakened democracies. As part of this, it is more important than ever before that science becomes an integral part of policymaking. The time is unprecedented and unprecedented times require extraordinary actions and new directions. We must fundamentally change the mechanism of policymaking, and engage both the public as well as scientists and experts.

The second issue of Canadian Science Policy Magazine includes such timely topics as: achieving net-zero emissions, Canada's quantum plan, battling misinformation, innovation and science funding during COVID, and Indigenous knowledge and data governance. We are honoured to have featured

articles from The Honourable Navdeep Bains, Dr. Steven Liss, and Dr. David Suzuki, discussing science as a tool to battle COVID, global collaborations and partnerships, and perspectives and outlooks on the power of science respectively.

While the magazine presents the perspectives of the most notable names on this changing landscape, Andrew Ruttinger and Fatou Sarr present the younger generation perspective and how CSPC has changed their vision. This impact where we have been able to contribute to the new generation of science policy leaders is what I am most proud of, and is one of the best values of CSPC.

In the shifting landscape, CSPC continues to serve our growing community by embarking on various programs focused. We continue with the core pillars of our strategic directions, and are increasing programming around the COVID-19 Pandemic.

Convening 16 virtual sessions and three volumes of editorials (66 publications) throughout the year have provided invaluable opportunities to discuss the pandemic, as well as its policies and social aspects. CSPC also launched a resource page to include all pandemic related sources, both within Canada and globally, in a database.

Expansions of our programs have included the launch of the workshops, a new website, a new round of Science Meets Parliament, and very soon, launching a membership program for organizations to become more engaged with all CSPC activities, helping with its programs and strategic directions.

Additionally, our Survey Development Committee has embarked on an ambitious project to understand how Parliamentarians' views on the use of science in policymaking have shifted due to pandemic. We look forward to sharing the results with the community.

In November, we hold the 12th annual Canadian Science Policy Conference, under the theme "New Decade, New Realities: Hindsight, Insight, Foresight". It is set to be the largest forum for science and innovation policy discussions in Canada. With panelists from across Canada and five continents, CSPC is engaging the global community in conversations on pressing issues of our time. Though the virtual format is new, CSPC is, as always, committed to delivering the best opportunities to connect and strengthen Canada's policy community. .

CSPC is proud to be at the forefront of advancing Canada's science and technology policy community, and nowhere is this better reflected than in the Canadian Science Policy Magazine. On behalf of the Canadian Science Policy Centre, I hope that you find insight and reflections within this issue that give you hope and motivation for our new decade. Thank you for your support, and we look forward to connecting with you - through whatever means, virtually or in person - as we look towards the year ahead.

Building Bridges between Science, Policy, and Society

CSPC2020

Établir des liens entre les sciences, les politiques et la societé

12th e

Canadian Science Policy Conference

November 16-20, 2020

Conférence sur politiques scientifiques canadiennes

New Decade, New Realities: Hindsight, Insight, Foresight

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Anticipated Participants Participants attendus	Presenters from 5 Continents Intervenants des 5 continents	Live Panel Sessions Groupes de discussion en direct	Symposia and Pre-conference Sessions Symposiums et sessions pré-conférence

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CSPC

CANADIAN SCIENCE POLICY CENTRE

Strengthening Science Policy Through:

Convening
Connecting
Capacity Building
Catalyzing Research

SCIENCE MEETS PARLIAMENT

The objective of this initiative is to strengthen the connections between Canada's scientific and political communities, enable a **two-way dialogue**, and promote mutual understanding of science and public policy. This initiative aims to help scientists become familiar with policy making at the political level, and for parliamentarians to explore using scientific evidence in policy making.

The first **Science Meets Parliament in 2018** was a great success, and the project received positive feedback from both SMP delegates and as well as the participating parliamentarians.

For more information about the 2021 cycle of this program, please visit https://sciencepolicy.ca/

PROFESSIONAL DEVELOPMENT WORKSHOP MODULE

We invite you to continue on your path of professional development as we embark on the future of science policy in Canada.

Workshop topics include:

- Science Policy 101
- Science Diplomacy: New Approaches to International Relations
- Equity Diversity & Inclusion in Science: Creating an EDI Culture
- Best Practices in Evidence-Based Decision Making
- Science Communication: Linking Research to Policy and the Public
- How to Become a Science Entrepreneur

Professional Development Workshops will be assembled upon request by organizations and a certificate of completion will be provided.

EDITORIALS

CSPC aims to promote the voice of the Canadian public, calling for members of the science and policy communities to publish editorials on pertinent issues with us. Previous editorial calls have included Canada's Chief Science Advisor, the G7 Summit, the Cannabis Act, and in 2020 we had a 4-volume, 70+ editorial series on the COVID-19 pandemic, our largest editorial call yet.

Editorials are published year-round, through open calls or individual submissions and available at sciencepolicy.ca/editorials.

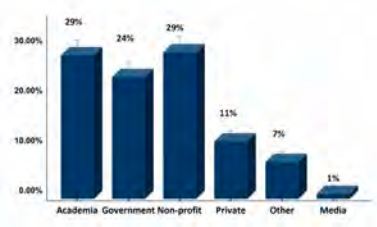
If you have an opinion you feel the CSPC community should hear, we welcome submissions to editorial@sciencepolicy.ca.

CSPC VIRTUAL EVENTS

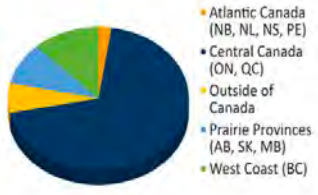
Experts from diverse sectors "meet the audience" virtually and participate in engaging Q&A sessions

Within weeks of COVID-19 pandemic hitting the world, CSPC launched a series of virtual events for timely discussions on pressing issues of science policy for Canada with the aim to facilitate Canada's scientific and political response to COVID-19.

Who was in the audience?



85 people, on average, attended per session, representing all of Canada



99% Attendees rated events favorably!

Created by Adrien Coquet from Noun Project

MOBILIZING SCIENCE IN THE FIGHT AGAINST COVID-19

The Honourable Navdeep Bains

Minister of Innovation, Science and Industry

The outbreak of the COVID-19 pandemic has been an enormous challenge for countries around the world, including here in Canada. It has required a mobilization of science, industry and innovation on a scale with few precedents in our lifetimes.

Many have looked to the Second World War as the last comparable national effort to the scale of what we are witnessing today. At that time, Canada's great scientific minds came together with industry and government in programs focused on common goals. It saw us push forward with the use of frozen blood serum to save injured troops and the development of the mass production of penicillin. Research programs aimed at protecting our navy led to an increase in skilled radar technicians. These programs had long-term impacts. As an example, because of this groundbreaking research, Canada remains a leader in satellite technology today.

Seventy-five years later, we are facing a problem that requires our collective efforts to overcome. Today it is clearer than ever that our present and future successes, including the health and economic wellbeing of Canadians, depend on relying on research and science-based policy.
Strong collaboration from researchers, industry and the health care system has anchored Canada's response to the current pandemic.

Since the outbreak of the COVID-19, our government has worked to provide Canada's researchers and businesses with the support they need to develop tests, treatments, vaccines and other innovative solutions to protect the health and safety of Canadians. Through these efforts, we are working with nearly 3000 companies that have offered their expertise and capacity. Canadian scientists and researchers have spent sleepless nights in their labs and at their desks, helping to contribute to our fight against this disease. Throughout this critical period our government has been there to help.

Since mid-March, more than $1.2 billion in federal support has been committed to a national medical research strategy to fight COVID-19. This includes important investments in the Saskatoon-based Vaccine and Infectious Disease Organization-International Vaccine Centre (VIDO-InterVac) to accelerate development of a vaccine against COVID-19 and upgrade their biomanufacturing

"WE HAVE RELIED HEAVILY ON RESEARCHERS AND SCIENTISTS, WHO ARE THE DRIVING FORCES SPEARHEADING CANADA'S CRITICAL COVID-19 ADVISORY BODIES, SUCH AS THE VACCINE AND THERAPEUTIC TASK FORCES."

capacity, as well as in the National Research Council to prepare its Human Health Therapeutics Research Centre in Montreal for the production of vaccines for clinical trials.

Another example of our support includes a $600 million investment through the Strategic Innovation Fund to support COVID-19 vaccine and therapy clinical trials led by the private sector, and biomanufacturing opportunities. We have complemented this funding with close to $170 million through the federal granting agencies. We have also worked closely with all levels of government through our response to the pandemic, and several of our initiatives have been bolstered by provincial collaborations and contributions.

Another important example of our investments to support important research in this period is our investment of $40 million in the new Canadian COVID-19 Genomics Network (CanCOGeN), led by Genome Canada. This network is helping track the virus, improve patient outcomes, and provide information to public health authorities and decision-makers as they put in place measures to control the pandemic. The initiative will also help ensure that Canada has a sustainable national genomics infrastructure in the event of future pandemics.

Thanks to our government's unprecedented investments in fundamental research, beginning well before the pandemic, we are on good footing to focus our efforts on this pressing challenge. From the beginning of our first mandate in 2015, we have invested billions in Canadian science and research. This support included the largest investment in fundamental research in Canadian history. This focus on fundamental science and research meant that our scientists and researchers had a broad base of support going into the pandemic. Canada's existing expertise and capacity has allowed us to hit the ground running.

Despite these investments, the COVID-19 pandemic has represented a once in a lifetime challenge for government and public health officials. Our government's strategy to combat this pandemic continues to rely on scientific expertise throughout our decision-making. Over the past few months, we have sought out reliable information on how best to manage the pandemic. We have relied heavily on researchers and scientists, who are the driving forces spearheading Canada's critical COVID-19 advisory bodies, such as the Vaccine and Therapeutic Task Forces.

Since June, scientific experts and industry leaders have been providing advice to our government on how to target our investments in projects with the greatest chance of success. Following the Vaccine Task Force's expert advice, we have announced an investment of nearly $56 million to support clinical trials at VBI Vaccines' Ottawa research facility.

On October 23rd, we announced an investment of up to $173 million through the Strategic Innovation Fund in Quebec City-based Medicago to advance their virus-like particle vaccine, developed on the company's unique plant-based production platform, through clinical trials. The project, valued at a total of $428 million, will also establish a large-scale vaccine and antibody production facility to increase Canada's domestic biomanufacturing capacity. That same day, we also announced an investment of up to $18.2 million in Vancouver-based biotechnology company Precision NanoSystems Incorporated (PNI) through the Strategic Innovation Fund. This investment will support a $24.27-million project to help advance the development of a COVID-19 vaccine candidate through pre-clinical studies and clinical trials.

Further to these investments, we also laid out our support of up to $23.2 million in funding through the

National Research Council of Canada to advance six Canadian COVID-19 vaccine candidates in various stages of clinical trials.

More investments in this critical area will follow, supported by the continuing work of the task forces. We base these decisions on expert scientific advice, which has allowed us to prioritize which opportunities to pursue based on the best evidence available.

We know that good policy and decision-making must be based on strong and valid data. Statistics Canada has embraced the challenge presented by the pandemic by accelerating data collection to help the country respond to, and recover from, the social and economic impacts of COVID-19. Statistics Canada recently committed to publishing disaggregated data to better understand the impact of COVID-19 on specific groups; from the economic impact among visible minority groups to social and economic concerns of new Canadians, this data will ensure that decisions taken by our government will support the work of our world-class scientists and researchers.

As our historically strong industries grapple with the effects of COVID-19, Canadians are looking to their government for leadership. I want Canadians to know that we will continue to refine our approach and work hand-in-hand with the academic and scientific communities to realize the potential that science and innovation hold for our common future and in the fight against COVID-19.

SUSTAINING AND ENHANCING CANADA'S FUTURE THROUGH GLOBAL COLLABORATIONS AND PARTNERSHIPS–

A FRAMEWORK FOR OUR MISSIONS ABROAD AND FOR OUR UNIVERSITIES

Steven N. Liss

Vice-President Research and Innovation & Professor, Ryerson University, Toronto, Ontario;
Professor Emeritus, Queen's University, Kingston, Ontario

The author wishes to acknowledge support from Global Affairs Canada and the Canadian Ambassador to Israel for financial support for work undertaken resulting in a report Pivoting in an Innovation Ecosystem: Enhancing Canada's Capacity in Israel for Collaboration and Partnerships with Canadian Academic and Industry Partners (2020).

INTRODUCTION

With the rise of the innovation economy and the need to address complex grand challenges (e.g. climate change and COVID-19), Canada's place in the world, and the manner in which the country engages globally is ever so important. The impact of globalization and shifting geopolitics, on one hand, ostensibly drives a nationalistic or internal focus, and on the other, requires global solutions and collaboration. Canada has seen many positive developments in supporting trade, and academic and private sector partnerships, in many parts of the world and building on historically close relationships. That said, Canada (government, universities and business) could be presenting itself to the world more effectively by reframing and strengthening specific bilateral agreements and programs.

Supporting bilateral relationships and trade in an innovation economy requires a shift in mindset, skills and approach. Many of the leading economies around the world have already pivoted, and are building on a deepening foundation of innovation and technological breakthroughs. Capturing an array of activities in a highly dynamic and rapidly evolving and changing ecosystem challenges us to seek synergies, break down silos and recognize the intersections and relationships that are key to success in an innovation economy. This will be particularly important post-COVID-19. From afar, Canada is well regarded and respected, possessing many attributes that make it well poised to compete in a global economy, including a highly valued balance between government and private investments. Canada may be seen as having many of the key ingredients important to the underpinnings of an innovation economy including having a relatively high share of post-secondary (universities and colleges) graduates among working-age population, and generating greater than 4% of global knowledge, considering the country represents less than 1% of the world's population. Companies are increasingly looking to dynamic global centres like Montreal, Toronto and Vancouver where they can base their international presence and gain access to capital (e.g., TSX Ventures/ Toronto Stock Exchange, pension funds), expertise (e.g., neuroscience and AI), and markets and collaborations (e.g., cybersecurity and fintech). Canadian universities are also excellent, and our research is world class. Although the level of private-sector investment in research and development is low, Canada receives considerable praise for the level of government investments and leveraged programs.

Canada, however, still struggles to scale, evolve and retain global enterprises. Several key questions remain: Has Canada officially pivoted in our approach in the global and dynamic innovation economy, including our approach to trade and relationships that support S&T and bilateral relationships? How well do we understand the global innovation ecosystem and how are we engaging in that ecosystem? How can Canada leverage its activity in a more coordinated and strategic way? How can universities scale international engagement with greater engagement and impact? How can we harness the important intersections of the innovation economy with government, business and universities to build relationships, triangulate multi-lateral opportunities, and to generate impact? There is an apparent gap in a broad-based policy framework that can be applied globally, perhaps with a focus supported by science and technology partnerships, and broader academic activities.

The rest of the world is quickly catching on. In contrast to the robust and dynamic range of collaborations and partnerships by Canadian researchers (as evidenced by total publications, movement of people, and impact[1]), Canada's global innovation performance by numerous measures and ranking (e.g. Conference Board of Canada, Bloomberg Innovation Index, and Global Innovation Index –World Intellectual Property Organization, Cornell and INSEAD) is relatively low and has declined over the years. There is a global demand for talent, and many countries are considering ways to increase the pool of talent to fuel their economies. An entrepreneurial spirit and maturing innovation economies across eastern and northern Europe and Southeast Asia are levelling the playing field and intensifying competition. General observation of other countries indicates their trade representatives engage in a vibrant global setting provides insights into strategies, including being in proximity to leading multinationals positioned abroad to catch the wave of talent, innovations, new collaborations and entry into other global markets. This is a clarion call to Canada to unlock the constraints, remove barriers, become more agile, nimble and streamlined, and be less risk averse in a globally dynamic innovation economy.

UNRAVELLING THE INNOVATION ECOSYSTEM AND CANADA'S MISSIONS ABROAD

The innovation ecosystem is fast-paced and the dynamics can be dramatic. Anyone who travels abroad, even on a frequent basis, will view the innovation ecosystem in other jurisdictions at a relatively high and superficial level. As informative and interesting as this can be, to understand and penetrate the many layers of the ecosystem requires a well-developed network, relationships and friendships, as well as the time to engage and explore beyond the confines of the office and outside the prescribed standard workday.

There are many paths to a deeper understanding of innovation globally and these can vary from region to region. The extensive presence of multinationals, and the opportunity to engage with other countries may be the most important advantages for being abroad. To be present globally may not necessarily be solely about the local markets, particularly in relatively small markets. Instead, there is technology, talent, access to multinationals, experience in scaling, capital, the door to other markets and opportunity to triangulate with other countries. When thinking about reimaging Canada's missions for an innovation economy, there are four key considerations:

1. AGILE AND NIMBLE

The ability to be agile and nimble is key to being able to effectively function within a highly dynamic innovation economy and ecosystem and adapting to ever-changing conditions and situations.

2. ADAPTING AND SHIFTING MODELS

The Canadian Trade Accelerators (CTAs) and Trade Commission should represent Canada's best effort;

and, location matters. Programming and location(s) that create conditions for collisions that drive towards trading around intangible assets, access to expertise and capital, and preparing start-ups and SMEs for global markets. Leadership, staffing, resourcing and location are key factors that will either limit or ensure success. Is Canada in a position to appropriately frame and measure the metrics for trade in an innovation economy? What lessons can be learned from the CTA network and the Trade Commission's experience in other countries?

It is to our advantage to draw upon the successes and expertise within Canada when considering how to position Canada abroad. Canada has evolved a significant economy around incubation and acceleration. Toronto, Montreal and Vancouver, in particular, possess considerable experience in leading initiatives supporting innovation and entrepreneurship, particularly within university-based or led programs.

There is an opportunity to bring forward in a global setting a value proposition that incorporates or includes social innovation, principles of equity, diversity and inclusion (reflected in a range of programs and initiatives aimed at women entrepreneurs), preparing talent for the future of work (availability of talent in an era of disruption) and opening inclusive pathways to the labour market.

3. VERTICALLY MINDED AND SOLO VS SEEKING CONNECTIONS HORIZONTALLY AND COLLABORATING

Artificial constructs, and framing efforts along verticals and domains, are typically a natural consequence of local focus and effort. The alignment of resources and effort along the particular verticals or domains can instill deep understandings and build expertise in key areas. But, it also sets conditions that builds walls, creates silos and imposes limitations on agility, nimbleness and collaboration, and results in missed opportunities.

Innovation, entrepreneurship, business and technologies cut across sectors or verticals, and looking up, down, to the side, and sometimes completely outside the box has to be part of a playbook to effectively support efforts in a global innovation economy.

4. SIPPING AND SLURPING AT THE FIREHOSE

It is ever more common that individuals and organizations are inundated by the veracity (as well as the velocity and volume) of big data, and information more generally, and the increasing demands to be more connected, informed and effective. For Heads of Missions abroad, and for those supporting bilateral relationships, including trade, and for those seeking services to engage globally, there are two flowing ends of the firehose with which to contend.

The problem is complex and hinges on how federal departments seek to better align, explore synergies through collaborations, streamline processes and develop a more integrated approach including their support of the missions abroad, and the Trade Commission in particular. On the ground, opening up the doors and windows with a greater external-facing focus, and fostering collaborations amongst team members would help to mitigate against the risks of not having the right information.

HIGHER EDUCATION AND UNIVERSITIES

Canada has a stronger and more defined innovation focus, such as superclusters, economic roundtable strategies and scaling SMEs, and the country's international ascendance includes sources of capital such as banks and pension plans and talent. Universities are a key feature of this ascendency, drawing on fundamental, interdisciplinary and translational research.

Canadian universities and key sectors also need to change their approaches in order to convey national strengths, encourage strategic collaboration and foster follow-up and implementation, to draw sufficient

"A BROAD-BASED POLICY FRAMEWORK IS REQUIRED TO SUPPORT CANADA'S EFFORTS TO UNLOCK THE CONSTRAINTS, REMOVE BARRIERS, TO BECOME MORE STREAMLINED, TO BE MORE NIMBLE AND AGILE, AND TO BE LESS RISK AVERSE IN A GLOBALLY DYNAMIC INNOVATION ECONOMY."

attention, activities and investment to Canada. The change in approach is especially important to promote more globally dynamic cities and regions to capitalize on leadership strengths in AI, cybersecurity, agri-food and biotechnology gaining greater international attention.

Universities should explore the intersections within the innovation ecosystem, and opportunities that would enhance bilateral (or multilateral) university-university and/or university-industry (business) partnerships and collaborations. Two particular aspects to this come to mind.
Opportunities for joint funding not yet realized such as EU schemes or philanthropic support through the Canadian friends and alumni of universities around the world.

Development of a robust and current science and technology (S&T) framework that supports the bilateral relationships that may also be more reflective of dynamic changes in the economy.

It may be that the extent that the current Science & Technology (S&T)/Innovation Framework shaping and supporting bilateral relationships is limiting. There may be other strategies that open up possibilities for framing investments in support of the international S&T focus in the key countries Canada has prioritized. Would Canada's interests be better served by a directed allocation of funds or drawing in the constellation of investments into a pooled program directed to those priority countries? Would harnessing diasporic and philanthropic interests, or private sector funding, to country-specific initiative and/or university collaborative efforts with international partners be more effective and provide new pathways for Canada's research universities?

SUMMARY

The attributes of Canada's missions abroad and Trade Commission (Global Affairs Canada), need to evolve to better reflect bilateral, multilateral relations and trade relationships in an innovation economy. There are considerable lessons to learn from the experiences in particular regions of the world and our CTAs, but there

are dynamics, opportunities, and challenges for Canada's orientation in a broader global economy. A broad-based policy framework is required to support Canada's efforts to unlock the constraints, remove barriers, to become more streamlined, to be more nimble and agile, and to be less risk averse in a globally dynamic innovation economy. Addressing these challenges and exploring opportunities will require strengthening efforts and approaches by the Government of Canada, provinces, Canada's missions abroad, organizations including CIFAR and Mitacs, universities and industry. It is incumbent upon Canadian research universities to seize the opportunity and their role in Canada's ascendency internationally in innovation drawing on both fundamental, interdisciplinary and translational research. There is an opportunity to explore with their international partners relationships and partnerships that transcend the collaborations of the past. There has been some early success on particular initiatives such as Canada's leadership, for example, on the Dimensions: equity, diversity and inclusion Canada and the Dimensions Charter[2], support of the San Francisco Declaration on Research Assessment (DORA)[3], leadership in advancing women in entrepreneurship and innovation[4], future of work[5], and global economic security (e.g. cybersecurity)[6]. There are many connections and opportunities to explore in social innovation and in design that represent important aspects of entrepreneurship and innovation, and are increasingly important to economic development and sustainability goals.

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Digital defence in a connected world

Ryerson is collaborating with national leaders on cybersecurity and privacy issues to find solutions to the most urgent threats facing society today. Our expertise and excellence in innovation, training and research will have far-reaching impacts as we work to protect our communities, businesses and digital infrastructures of all sizes.

The Rogers Cybersecure Catalyst at Ryerson is teaming up on initiatives that are dedicated to advancing public policy in cybersecurity and digital privacy, exploring solutions to everyday problems as well as the risks posed by the COVID-19 pandemic on Canadians. Our accelerated cybersecurity certification programs provide learners from diverse backgrounds with the skills they need to launch careers critical to the challenges we are confronting in our connected world.

Our researchers are also pioneering research partnerships across a broad range of sectors:

Atty Mashatan

Ryerson professor of information technology management and director of the Cybersecurity Research Lab Atty Mashatan is safeguarding the financial sector against emerging data security and privacy threats such as quantum computing through her development of next-generation solutions.

Ali Miri

As data security concerns rise, Ryerson professor of computer science Ali Miri is developing a privacy-preserving data-market platform for medical research and health information using blockchain technology that ensures both the privacy and validity of personal data.

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June 2020 : Signature of the *San Francisco Declaration on Research Assessment (DORA)*

Mars 2020 : Utilisation des principes de la déclaration *Partager les données et les résultats de la recherche concernant la flambée du nouveau coronavirus (COVID-19)* de la fondation Wellcome
March 2020 : Use of the principles of the Wellcome fondation statement *Sharing research data and findings relevant to the novel coronavirus (COVID-19) outbreak*

Avril 2020 : création du Réseau québécois COVID
April 2020 : creation of the Québec COVID Network

Mars 2020 : création de la biobanque Québécoise de COVID
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SCIENCE AND SOCIETY PERSONAL LESSONS LEARNED

DAVID SUZUKI

I write this from the perspective of an elder and grandfather. My life has been punctuated by a series of lessons acquired by experience, observation and thought, and I will share some of them.

Soon after the COVID-19 lockdown in March, pundits described the prolonged and profound changes as the "new normal" thereby implying pre-COVID-19 life had been "normal." It was not. For decades, ecologists, climatologists and conservation biologists had issued alarms about various impacts of human depredation on the biosphere. This is a personal take on the timely theme of this Grand Challenges issue of the Canadian Science Policy Magazine.

It is easy to promise rights and freedom when times are good, but they matter most in times of crisis. My grandparents emigrated from Japan to Canada between 1902 and 1906. My parents were born in Vancouver as were me and my sisters. We were Canadians making a life post-Depression when Japan attacked Pearl Harbor in 1941 and transformed us into a threat to Canada solely based on our genetic origins from the enemy. There were enormous repercussions of our biological and cultural relationship with Japan, but that was not evidence to justify the actions taken. We were Canadians, but the War Measures Act suspended all basic democratic rights of citizenship – freedom of speech, equality before the law, freedom of movement - and we were displaced and incarcerated in camps or sent to other provinces and ultimately ejected from BC at war's end.

I returned to Canada in 1962, after gaining a top post-secondary education in the United States (BA Amherst College, PhD University of Chicago, post doc Oak Ridge National Labs) between 1954 and 1962. In my new position at the University of Alberta, I was shocked as I received my first grant from NRC of $4,200 and was told it should have been $3,500 but had been increased because of my postdoctoral experience. At that time, assistant professors in science in the U.S. were receiving grants in the tens of thousands. Canadians needed to know why science matters, is worth funding, and how it affects their lives. That's why I seized the opportunity to do a program for "Your University Speaks", a weekly television series on the local CBC station in Edmonton. I ended up presenting eight shows on my area of genetics.

Reductionism, the way most scientists examine the world, does not provide enough information to anticipate or control the impacts of what we do. The same year that I returned to Canada, Rachel Carson published her seminal book, Silent Spring, about the effects of pesticides. As I read her book, I was stunned to realize that in focusing on a part of nature we fail to see the context within which the studied part fits. Paul Mueller earned a Nobel prize for his work on DDT in 1948, when this was hailed as a safe conquest of "pests" but in the real world, seasons change, winds blow, rain and snow fall, and a pesticide ends up in all kinds of places and organisms outside the scope of the study. The biological phenomenon of biomagnification was only "discovered" when raptors began to disappear. Recognition of the

catastrophic extinction crisis of insects only came seven decades later.

When I moved to UBC, most of my students were pre-meds and interested in the human implications of cloning, gene manipulation for health and economic benefits, and some asked about social responsibility. To answer them, I had to read, and to my horror, I realized the impact that geneticists had had in the past. Eugenics was a discipline early in the 20th century dedicated to the improvement of the human condition through discouraging individuals with undesirable traits from having children while encouraging those with desirable qualities to have more offspring.

I remember H.J. Mueller, Nobel laureate, discussing mutations in reproducing cells and advocating eugenics practices because most mutations are deleterious. One of the widely used early eugenics texts was written by Harvard professor, Edward M. East, and stated that "the Negro is inferior to the White" as a scientific fact. Today, eugenics is a discredited field, considered pseudo-science and we realize "inferior", "superior" and "improvement" are not scientifically meaningful terms, they are value judgements.

Scientists are not immune to confusing their own beliefs and values as scientifically validated fact or truth, and when encouraged by money or politics, this can have enormous repercussions. As I learned about the history of genetics, I realized that the incarceration of me and my family was the direct consequence of the claims or boasts of scientists. In Canada, one MP is recorded in hansard claiming that in nine times out of ten inter-racial marriage led to offspring who were "mongrel wastrels". Most shocking to me was my discovery that Josef Mengele, the infamous doctor of death at Auschwitz, was a geneticist who specialized in studying twins among the victims.

We cannot avoid long-term consequences of powerful innovations because our knowledge is so limited. When Rachael Carson's book came out in 1962, there was not a single department, committee, or portfolio on the environment in any country in the world. Carson's book galvanized a powerful movement as people became aware that the "environment" was important and I, like millions of people, was swept up in it. I thought we needed departments of the environment to enact laws to regulate how much and what we removed from our surroundings and put back into it, and to enforce those laws. But I kept referring to Carson's book and wondered how we could "regulate" chemical pesticides when we did not even know about such an important biological phenomenon as biomagnification. There had been numerous justifications for developing atomic bombs, but when they were dropped on Japan, scientists did not know about radioactive fallout, electromagnetic pulses of gamma rays or the possibility of nuclear winter or fall. After CFCs had been used in massive quantities as refrigerants or inert additives to spray cans, scientists discovered that high above Earth, ultraviolet rays cleave chlorine free radicals that scavenge ozone. Too often, we end up trying to manage after the negative effects are found.

> "THUS, BY SCAPEGOATING A NATURAL PREDATOR WITHIN A COMPLEX WEB OR RELATIONSHIPS, WE AVOID REIGNING IN THE PRIMARY CAUSE OF THEIR DECLINE – HUMANS, THE DEADLIEST PREDATOR."

To "manage" anything sustainably, we need at least two things: an **inventory** of everything in the management purview and a **blueprint** of how all the items in the inventory are connected. In the environmental movement, there are committees and groups mandated to manage our natural resources but it is done based on simple models. Take an example: almost all caribou populations across Canada are declining precipitously. They are migratory animals that require vast tracts of the planet's surface, most of it already "developed" or coveted by humans. Our models downplay human depredation like deforestation, roads, mines, pipelines, and pollution and instead focus on premises like wolves eat caribou, so killing wolves will improve the numbers of caribou. Thus, by scapegoating

a natural predator within a complex web or relationships, we avoid reigning in the primary cause of their decline – humans, the deadliest predator.

Our inventory of biodiversity must be seen as a fraction of what we think exists. The oceans, which cover 70% of the planet, are an alien world where we know little of the diversity within them. The same is true of invertebrates like insects and soil microorganisms like fungi on which large organisms depend. It was long assumed that phytoplankton were the foundation of marine food and energy systems. Then it was discovered there are organisms that are ten times smaller, undetected because they pass easily through the mesh of plankton nets. These picoplankton are now considered a fundamental part of the marine web of life. We have no idea how vast life's diversity is, although estimates range between 10 and 100 million while E.O. Wilson has enumerated those that have been classified falls short of 2 million.

Life flourishes in a complex web of relationships with other species, air, water, soil and sunlight about which we know almost nothing. How much of a blueprint do we have? "Identifying" a newly discovered organism means someone has keyed out the biological lineage of a dead specimen. It doesn't mean that we know anything about their habitat, food, reproduction, life cycle, population, or other fundamental facts. We have that kind of information on a small number of species, usually the ones we like or find useful. It is a total myth to believe we can manage anything other than ourselves and when you look at our track record of over-fishing, pollution, poaching, greenhouse gas emissions, it's clear we can't even manage ourselves.

Scientists now point out that humans have taken over the planet with our numbers, consumptive demand, and wastes. We are one species among millions of others, yet we claim the right to at least 88% of the land (Brundtland Commission) and few countries are willing to accede 12% to the rest of life. Humans are now the major factor altering the physical, chemical, and biological properties of the planet on a geological scale and that's why some scientists have proposed this geological period be called the Anthropocene.

The COVID-19 pandemic was in a sense, a gift. An opportunity for humankind to deliberately undertake a huge slowdown of activity and time to reflect on the conjunction of massive issues such as climate change, species extinction, poverty, immigration, rampant consumerism, and systemic racism, all of which are the consequence of human activity. To sustain our current level of consumption indefinitely is concluded to require up to three or four planets. Nature has been temporarily given a break from our incessant demands.

When I became involved in environmental issues, it always seemed that we were locked into zero-sum debates: the economy or the environment, logging or spotted owls, jobs or forests. Always, the economy was unassailable and central to the arguments. Environmentalists constantly search for economic justification of their proposals by creation of jobs or the costs of not doing anything. But this avoids grappling with the underlying assumptions that drive our activities in the first place. Many of the "victories" in battles I was part of in the 1970s and '80s turned out to be pyrrhic: we stopped a dam at site C on the Peace River in BC, we stopped a proposal by Panarctic to drill for oil in Lancaster Sound in the Arctic; we stopped legislation that would allow drilling in the Arctic National Wildlife Refuge, the calving grounds of the Porcupine caribou herd in Alaska; we stopped a dam from being built on the Xingu River in Brazil. Today, all of these projects are being done or will commence soon because, in focussing on stopping an immediate threat, environmentalists failed to shift the values underlying the drive to "develop" in the first place. What we call wilderness or natural are undeveloped only to humans; to the animals and plants that have occupied an area for hundreds of millennia, their homes are fully developed and fully occupied.

For Indigenous people, the knowledge and insights acquired and passed on has enabled them to flourish for thousands of years in diverse surroundings. For most of human existence, we were another ape, hunting and gathering by following plants and animals through the seasons. But eventually, some of us moved, motivated perhaps by curiosity or search for food, resources or adventure, and as we penetrated new places, we were an invasive species. We had to acquire knowledge through observation, trial-and-error, and experiences, and the memory of the insights, mistakes, successes and failures of ancestors was vital to survival. The accumulated

knowledge was a fundamental blueprint for survival and is the essence of Indigenous knowledge all over the world. That's different from science whose practitioners nowadays publish the results of their work and reap promotions, raises, reputation, and sometimes prizes.

An ecocentric perspective sees us as deeply embedded in, and utterly dependent on Nature for our survival and well-being. No government or corporation or community can claim the track record of Indigenous people who have survived in place for thousands of years. Despite the horrific history of genocidal policies of invaders who massacred, infected, conquered, colonized and ruled Indigenous people, pockets of resistance continue through the maintenance of culture and language, that are based on the understanding that nature is everything, that Earth is literally our Mother. DNA analysis confirms this relationship; we share most of the genes found in all eukaryotes, plants, and animals, that reflect our common evolutionary history. Surely, we treat our kin with love, respect and reverence, a different way from what we would do if they were merely "resources" or "commodities."

The rise of science indicated through Francis Bacon (knowledge is power), Rene Descartes (I think, therefore I am) and Isaac Newton (the universe is a clockwork mechanism) separated mind from body and moved it from Nature. Humans are no longer constrained by biology, only our imagination. And so, we moved from an ecocentric vision of our place in the world to an anthropocentric perspective that put us at the centre while everything around is about and for us. Through an anthropocentric lens, we have designed political, legal, and economic systems that determine the way we live and act on this planet. But the game in each realm is fixed with us firmly in the centre and no recognition of our utter dependence on Nature, our ignorance or responsibility. Therein lies the essence of our crisis. If we do not acknowledge the gifts of Nature and how little we know, we will continue along the destructive path we are on.

When I was still in graduate school, geneticists began to exploit molecular techniques to analyze and compare products of single genes in different individuals. It was found that each gene in a population had a variety of states, now called genetic polymorphism, and is the very measure of the health of a species. Diversity at the gene level is critical for survival by ensuring options as conditions change. At the ecosystem level, those with a great variety of species can tolerate assaults like fire, floods, drought or pest outbreaks while ecosystem diversity has enabled life to flourish in diverse areas across the globe. Diversity is built into the level of genes, species and ecosystems, thereby conferring greater resilience and adaptability as Earth's conditions change. The Sun is 30% warmer now than when life first appeared, continents have moved apart or smashed together, ice ages have punctuated warm periods, oceans have filled and drained, and all the while, life has persisted and flourished. Diversity has been the key. Just as in the biosphere, diversity of language and culture within the human ethnosphere is every bit as critical to human survival as we encounter the multiple crises of this moment. Monoculture, widespread uniformity of genetic makeup, species, ecosystems and culture renders greater vulnerability to change like disease, parasites or climate. Like the Canadian experiment in multiculturalism, **we must celebrate and treasure the diversity within our society as a critical component of sustainability.**

Does technology have a role to play in the struggle with climate change and other problems? Of course, but our ignorance is so great, we have to apply technology with extreme caution. As one example, it has been found that when carbon dioxide is pumped under pressure into depleted oil wells, more oil can be recovered and the carbon dioxide doesn't come back out. Carbon capture and storage or carbon sequestration has been the hope of both the fossil fuel industry and governments as the way to enable the continued use of fossil fuels.

But what is the sequestered carbon doing? Much of it is trapped in pockets under layers of limestone or dissolved in water as carbonic acid (which is what is causing ocean acidification). But acid etches limestone, so how long will it remain sequestered? It was once thought that all life ends at bedrock so below that Earth is sterile. Now we know that

bacteria can be found kilometers below Earth's surface and they are like nothing we know above ground. Entire new phyla have to be created to show where they belong in life's array. Stephen Gould pointed out that life above ground is a very thin layer while life underground is kilometers deep. He calculated that the weight of protoplasm beneath Earth's surface could be greater than the weight of all the trees, fish, whales and all other life forms on the surface. When I asked Princeton's Tullis Onstott, one of the world experts on microorganisms found deep under Earth, what carbon sequestration might do to them, he replied "I have no idea, but the methanogens will love it." What are methanogens? Bacteria that consume carbon dioxide and release methane which is a greenhouse gas that is up to 80 times more potent than carbon dioxide!

As Janine Benyus points out, nature has had almost four billion years to solve the same problems we have – what to eat, how to get energy, how to fend off or recover from disease, how to avoid predators, how to reproduce. With great humility, we might find solutions in nature that might avoid the unexpected. It is an approach called biomimicry, learning from nature rather than dominating it.

Let me close with a story. I was beginning my last year as an undergraduate at Amherst College when, on October 4, 1957, the world was electrified by the announcement that the Soviet Union had launched a satellite, Sputnik, into space. Sputnik blared out Soviet technological superiority. The three branches of the US armed forces each had their own rockets which upon launch, every one exploded. Meanwhile, the Soviets scored a succession of impressive firsts - the first animal, the first man, the first team of cosmonauts, the first spacewalk, the first woman.

This was a time when the U.S. and Soviet Union were locked in a Cold War and Soviet technology was most impressive. Americans created NASA and began to inject funds into universities and students. And then in 1962, President John F. Kennedy announced, "we choose to go to the moon", an audacious proposal to win the "space race" by getting Americans to the moon and back within a decade. There was no clear way to do it, only the resolve.

"LIKE THE CANADIAN EXPERIMENT IN MULTICULTURALISM, WE MUST CELEBRATE AND TREASURE THE DIVERSITY WITHIN OUR SOCIETY AS A CRITICAL COMPONENT OF SUSTAINABILITY."

The results were impressive. Not only did they succeed within a decade, America is the only nation to put humans on the moon. To me, what is most impressive is that more than fifty years later, when Nobel awards are announced in science, American scientists or scientists working in America continue to garner most of them because of the enormous success of the program to get to the moon first. Every year, NASA publishes Spinoff, a magazine that documents hundreds of innovations from laptop computers to satellite communications, GPS, and ear thermometers that resulted from the American determination to get to the moon first.

What enabled Americans to win the space race was the commitment to do it. I tell my American friends it is not the America I knew that responds to issues like climate change as too costly, not pressing, or impossible. Once committed to space, consider all of the collateral, unexpected and unpredictable spinoffs that resulted and continue to be generated. That is precisely what will happen once we make the commitment to shift all avenues of society to the goal of a cleaner, greener, more just society.

This is an abridged version for print. The long form will be available online at sciencepolicy.ca

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GRAND CHALLENGES

FIVE WAYS TO TACKLE THE WORLD'S GRAND CHALLENGES AMID THE PANDEMIC

Richard Florizone

President and CEO of the International Institute for Sustainable Development

How can we continue to make progress on the big challenges facing the world amid the global COVID-19 pandemic?

In 2015 the United Nations adopted the Sustainable Development Goals (SDGs), a framework of seventeen global objectives to deliver a better and more sustainable future by 2030. The SDGs target the big challenges facing humanity, including poverty, inequality, climate change, peace and justice.

Then along came COVID-19, shattering lives, disrupting economies and testing governments around the world.

COVID-19 is a humanitarian crisis that requires a response focused first on fighting the virus, mitigating its impact, and supporting those who are directly impacted by it. At the same time, we must also look to the horizon and plan for a longer-term recovery that builds back better.

The full impact of the pandemic and its aftershocks won't be known for years. However, for those of us working in science and innovation here are five ways we can still make progress on the grand challenges embodied by the SDGs:

1. INVEST IN RESILIENCE.

In the early days of the pandemic it was heartbreaking to see lives put at risk because of shortages of critical medical and safety equipment, including masks that cost less than a dollar. A lack of planning and the subsequent shortages demonstrated the critical importance of resilience – being able to anticipate, cope and adapt to shocks and stresses. In the years ahead, let's invest in the research and innovation that can build more resilient systems – not just to respond to future public health emergencies but also to prepare for the longer-term challenges posed by climate change.

2. ADVOCATE FOR A GREEN RECOVERY.

As they begin to get a handle on the virus, several countries in Europe and Asia are pursuing a "green" recovery, with investments in areas like clean energy, energy efficient buildings and transportation, green workforce development and R & D. In July, the European Union committed at least 30 percent of its multi-year budget to climate objectives. Let's reject the false compromise between economic growth and environmental impact and invest instead in a green recovery that tackles the climate challenge and creates the jobs of the future.

3. TACKLE INEQUALITY.

The pandemic has amplified inequalities, with greater impacts on women, front-line service workers, communities of color and others least able to absorb its health and financial fallout. This is even more true in developing countries, where the World Bank has warned that the past decade's progress in building human capital is at risk due to the pandemic. In recent years the Canadian research community has increased its attention to inequality through efforts like diversity initiatives, outreach and engagement, and inclusive innovation and economic development. There is clearly much more to do. Addressing inequality builds a better world, but it also strengthens science. By removing economic barriers and embracing a diversity of perspectives we ensure science has access to the very best ideas and people.

4. REDOUBLE PUBLIC ENGAGEMENT.

Science communication is more important than ever amid rising populism and the misinformation rife in the pandemic. Public engagement has been a growing priority in Canadian science the last decade. As we've unfortunately seen in the few years, scientific facts don't always win the day. We have to find new ways to connect with the public and decision makers on complicated scientific and technical issues, especially when lives are at stake. And we can never back away from our commitments to evidence and the fundamental importance of science and the scientific method.
As members of the science and innovation policy community, these important tasks fall directly on our shoulders. If we don't do it, who will?

5. ENCOURAGE CANADA TO GO GLOBAL.

Our government's first priority has been on the health and well-being of its own communities and citizens – as it should be. At the same time, the pandemic has taught us that disease anywhere is a risk everywhere. Viruses don't need visas to travel. We must not forget these interconnections – and responsibilities – to others around the world. Let's continue to advocate for international development assistance and global science partnerships, to build a stronger and more sustainable world for all.

The COVID-19 pandemic is a humanitarian crisis, and our attention must stay focused on its direct impacts while looking towards the horizon. In the words of UN Secretary General António Guterres, "We need to turn the recovery into a real opportunity to do things right for the future." With the SDGs as a guide, we can indeed build a better Canada – and a better world.

"COVID-19 is a humanitarian crisis that requires a response focused first on fighting the virus, mitigating its impact, and supporting those who are directly impacted by it. At the same time, we must also look to the horizon and plan for a longer-term recovery that builds back better."

CAN WE AFFORD NOT TO PARTICIPATE IN THE QUANTUM RACE?

Geneviève Tanguay

Vice-President Emerging Technologies,
National Research Council

SECURING CANADA'S QUANTUM FUTURE IS ESSENTIAL FOR S&T SOVEREIGNTY AND ECONOMIC PROSPERITY IN THE POST-COVID-19 WORLD.

- What if we could build a new type of computer that solves problems in mere seconds — problems that all the computers in the world today cannot solve?
- What if that computer could solve a problem in 10 seconds with the power required to keep a few light bulbs lit instead of using enough to power a few city blocks?
- What if we could image the human body from within with spectacular resolution without fear of radiation damage?
- What if we could "see" through walls and underground by measuring small changes in gravity?
- What if we could design materials, atom by atom, with whatever properties we desire?
- What if we could have unbreakable encryption to protect our personal information?

Transforming these "what ifs" into reality is only possible through continued investment and advances in quantum science and technologies. The pioneers of quantum mechanics could never have thought that one day we could master quantum science to such a degree that it could help resolve some of the world's most pressing challenges.

Saying that we are currently living in challenging times is an understatement as Canada and the world continue to face loss of lives and livelihoods due to COVID-19 and a pandemic-ravaged global economy. COVID-19 is compelling us to think strategically to ensure the prosperity and well-being of Canadians. We must urgently consider how to not only spur short-term economic recovery, but also to develop long-term resilience and growth. At the same time, there is an opportunity to take advantage of emerging technologies to build the economy of the future.

Predicting the future, however, even in the short term, is difficult. That's why we need to place "bold bets" and think big. Let's focus on the industries and technologies that are most likely to create innovation, growth and jobs and enhance Canada's global competitiveness for tomorrow's economy. These bets are most likely to pay off in areas where Canada is already a leader, and does not need to catch up to other countries.

The pandemic has also put the spotlight on the need for more self-reliance in infrastructure, key industries and emerging technologies. The shift to economic sovereignty, particularly for strategic emerging technologies such as quantum technologies, is driving the agenda of many nations.

"Quantum technologies are a sound "bold bet" for Canada."

Quantum technologies are a sound "bold bet" for Canada. Securing Canada's quantum future and capitalizing on ourits early lead at the eve of the second quantum revolution is an important element of the new economy and path to future resilience. Quantum technologies are poised to revolutionize a myriad of industries and create new businesses with a potential global market size of over US$1 trillion by 2035, according to a recent McKinsey & Company report[1].

Quantum technologies are transformational, encompassing not only ultra-fast quantum computing, billed by German Chancellor Angela Merkel as "the next fundamental leap in technology", but also high-precision sensors, secure communications, enhanced imaging, customized materials and drug design. These technologies have the potential to be the next enabling and foundational technological platforms; they straddle a number of industries such as health, defense and security, telecommunications, natural resources, environmental management, finance and pharmaceuticals.

In particular, quantum technologies will be transformational in healthcare, the environment and climate change, and cybersecurity. Here are but a few of the many promising applications.

In health, quantum sensors promise more accurate medical imaging, for example, by allowing MRI machines to examine at the molecular level. Quantum magnetometers use the magnetic properties of atoms to probe tissues, advancing the diagnosis of dementia, cancers and cardiac disease. Quantum computing could help accelerate the discovery of cures for a range of diseases and lead to completely simulated clinical trials that do not use humans or animals to test a drug or device. It could also accelerate the sequencing and analysis of the genome, enabling personalized medicine, and early detection and mitigation of diseases by analyzing genetic information, personal health information and vast amounts of health system data.

In the face of the COVID-19 pandemic, much attention is focused on how emerging technologies such as quantum technologies can help us more effectively predict, prepare for and respond to future health crises. Quantum machine learning – the capability to handle massive quantities of data intelligently – is particularly promising for accelerating drug discovery and development. These technologies can work more quickly to identify potential candidates for drug development, create a vaccine, and determine how to slow disease transmission. They can constantly monitor data, and detect signs and identify patterns to avoid a potential pandemic. They can also target the global supply chain, and help accelerate responses to shortages or surpluses and position the right emergency personnel in the right place at the right time.

Quantum technologies have many potential applications that could produce new solutions in tackling climate change and safeguarding our environment. Early developments are expected in sensors, which promise significant improvements in sensitivity and precision measurement. Better sensors will allow more precise and robust monitoring and management of valuable natural resources, including our oceans and forests. Quantum sensors that will detect, for example, metal ores for rare earths willto reduce our dependence on foreign sources. Advances in quantum computing could generate simulations of large complex molecules that reveal cheaper and more efficient catalysts for carbon capture, energy storage and transmission, and fertilizers. They could also enable more precise climate change modelling.

As quantum computing technology continues to rapidly progress, the need to enhance Canada's cybersecurity and build quantum-safe systems to secure Canadian infrastructure and industries is becoming increasingly critical. New quantum-enabled technologies, such as quantum key distribution and quantum random number generation, can provide a new security foundation for the digital infrastructure of tomorrow's economy. Developing our own quantum technology capacity means that Canada will not be dependent, in 10 years' time, on foreign countries' technology to protect our personal information, banking systems, electricity grids, smart cities infrastructure and national security. Enhancing Canada's cybersecurity will help protect our economic prosperity in the quantum era.

A strong argument for further investing in quantum technologies is that Canada is currently a global leader in key areas of quantum research and development, and we have a robust ecosystem in place. Canada's overall investment over the past decade is estimated at over $1 billion. We have globally recognized research excellence hubs that attract top talent and ideas to Canada. In the areas surrounding these centres, research is translated into real-world applications in some of the first companies in the world based on quantum technologies.

On a relative scale, Canada's rate of quantum entrepreneurial activity is much higher than in other jurisdictions. We have the biggest investments in quantum companies in the world on a per capita basis, and our firms and institutions hold the second highest number of patents in the world, after the U.S. Canada ranks sixth globally in quantum technology publications and fifth in the number of quantum technology applications. B.C.-based D-Wave has the most applications in the world.

Many nations are making strategic investments in quantum technologies, placing Canada's global leadership and competitiveness at risk. The U.S., U.K., EU, Germany, China, Australia and others are all implementing and allocating resources to quantum strategies. A few countries have specifically included quantum technologies in their post-pandemic economic recovery plans. Germany has allocated 2 billion of its June 2020 130-billion-euro economic stimulus plan to quantum technologies and investment in two quantum computers.

In August, the U.S. announced investment in "industries of the future", including artificial intelligence and quantum information science (QIS), investing up to $625 million over five years in five QIS centres, with an additional $300 million from industry and academia. The stated aim is to create "transformative benefits for the American people in healthcare, communications, manufacturing, agriculture, transportation, security, and beyond."

Quantum science and technology has already been identified as an area of national interest from both an economic and security perspective. Canada's quantum ecosystem, including universities, research institutes

and quantum-based companies, hasve come together with common goals and a shared vision for the development of a national quantum strategy for the country's continued leadership in quantum science and technologies.

As we rebuild Canada's economy, there is an opportunity to capitalize on this national asset to help secure our S&T sovereignty and create new opportunities for businesses. This will be essential to sustain our economic prosperity in the quantum era. In times of hardship and uncertainty, we must dare to have big ideas and act on a bold vision for Canada's economy of the future. Doing so gets us that much closer to making those earlier "what ifs" a reality for the benefit of all Canadians.

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A QUANTUM CANADA FOR ALL

Steven Rayan

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While Covid-19 has laid waste to the best-intentioned plans of 2020, the “19” in its name reminds us that this troublesome virus originated some time in 2019. Just two months prior to the first reported cases of the novel coronavirus was a major scientific announcement, all but drowned out now by the constant hum of pandemic-related news. That announcement was of Quantum Supremacy, a feat claimed by Google on their Sycamore quantum computer.

The breakthrough has raised many questions in the general public. Obviously, what is “Quantum Supremacy”? Another question concerns the existence of quantum computers themselves. What are they? Are they “real”?

I will hold off on entertaining these questions for a moment. There’s nothing wrong with a little suspense. At the same time, this allows me the opportunity to set the stage in a different way, by focusing on a few historical scientific developments that led us here. By the end of this note, I will reflect on Canada’s contributions to the grand challenge of quantum innovation and how we can maintain a leading edge.

IN THE BEGINNING, THERE WAS QUANTUM MECHANICS

Quantum mechanics is a tour de force chapter in the history of science. In a period of less than 30 years in the first half of the 20th Century, physicists went from the first inklings of a new theory to a robust and well fleshed-out system of mathematical rules through which we now view the behaviour of matter at the tiniest of length scales. Yet, the famed physicist Richard Feynman still quipped, “I think I can safely say that nobody really understands quantum mechanics.” That hasn’t stopped anyone from using it, thankfully. I like to interpret his comment in the most positive way possible: that quantum science has many more gifts to give us than we can possibly predict.

Like all good science, quantum mechanics was a solution to a problem. New and better laboratory devices in the late 19th and early 20th centuries paved the way for new experiments, ones that could peer for the first time at the inner structure of matter. The results of some of these experiments defied common scientific sense. Surely a beam of electrons fired squarely at a strip of solid material between two closely-spaced openings will be repelled by the material and not cross to the other side. Experiments revealed the opposite, however, with the beam resolving on a wall on the other side. What must be is that electrons behave not only as particles but also as waves, which can disperse and send their energy through the slits. If subatomic matter and waves are indistinguishable, then that means that the position of a subatomic particle is just a probability rather than a certainty. With such considerations in mind, quantum mechanics was born.

Has quantum mechanics affected our everyday lives? Certainly. What one might dub “Quantum 1.0” is the first

wave of technologies influenced by these ideas. Quantum 1.0 is all around us, operating in plain sight for decades. Its devices include not only basic components such as transistors, but also life-saving inventions such as MRI machines, which depend crucially on the quantum-mechanical property of spin.

Writing Quantum 1.0 comes with the obvious promise of Quantum 2.0, which is what this article is really about. Just as deciding when such eras begin and end is a somewhat arbitrary game, so is deciding which technologies are definitely part of 2.0 and not 1.0. I would like to take a stance here, cutting through the noise of so much innovation to isolate two things that I believe are setting Quantum 2.0 in motion: quantum computing and quantum materials.

QUANTUM COMPUTING

We need to talk about this one first. If there is a poster child for the nascent quantum revolution, it is the quantum computer. It is an awesome feat of engineering and perhaps one of the most daring things that humanity has set its collective mind to: control the fates of individual, probabilistic electrons enough to produce reasonable outcomes interpretable as "answers" to calculations, yet at the same time take advantage of their inherently unpredictable nature to explore a vast range of possible outcomes all at once.

A traditional computer is based on switches that occupy an "off" or "on" state, equivalently a "0" or "1", at any given moment. Such a switch might arise in a simple way from a voltage differential (above a certain threshold, the value is "1") or be realized as an integrated "flip-flop" circuit that can be forced into one state or another, which in and of itself is a Quantum 1.0 device. These circuits are valuable because we have an extremely high degree of confidence about what the state is at a given moment. Below its surface, though, are building blocks of matter that have a switch-like nature of their own — for instance, an electron with spin up or spin down — but which are subject to the uncertainty of quantum mechanics. We might say that the electron is occupying both states simultaneously with some probability for each.

Controlling an individual electron is incredibly hard work, requiring an experimental setup that is super-cooled to temperatures just barely above absolute zero. Why try to turn one into a switch when we have macroscopic circuits that work perfectly well? Why trade confidence for uncertainty? From a computational point of view, an electron in a superposition of two states is akin to saying that two calculations can happen at once — the calculation that would result from picking 0 and the one that would result from picking 1. If you manage to harness two electrons, then you can perform 4 calculations at once (00, 01, 10, and 11). And so it goes like this, exponentially.

Given that classical switches are called bits, the custom is to call their quantum counterparts qubits. There are various models for physical realizations of qubits, including superconducting qubits such as the transmon type found in IBM's "IBM Q" quantum computers — and yes, quantum computers are here and they are real, even if they are still considered prototypes.

The speed-up possible with qubits is important for any problem in which we must select the best outcome from a vast expanse of possibilities. One such problem is factoring an extremely large integer into its prime factors. This is exactly what Google's 53-qubit quantum computer Sycamore achieved in 2019. This has immense implications for computer security, which currently depends on our inability to factor such primes rapidly on classical computers. What would take even the most powerful classical computers 10,000 years to do, Sycamore was able to do in just over 3 minutes: this is Quantum Supremacy.

While the feat leads to well-justified fears regarding "quantum attacks" against which our current standards of cryptography have no chance, we are not yet living in a world where the average hacker has a cryogenically-cooled array of 50 or more qubits sitting in their basement. In the meantime, we can consider other problems for which

quantum computing is ideally suited. One that feels very close to home at the moment is vaccine development. At the heart of this problem is protein folding. An individual protein consists of an arrangement of amino acids bound together. One wants to determine the configuration that minimizes the energy of the protein, which is its so-called "native structure". Given the vast number of possible configurations in three-dimensional space (a protein chain of 100 amino acids has roughly 10^{47} configurations), the problem is a classical nightmare. But this is exactly the kind of problem that quantum computers find easy. Given that protein structures play a central role in antigen and vaccine design, it would seem that quantum computers have a role to play in resolving pandemics quickly.

QUANTUM MATERIALS

Quantum computers need quantum ingredients. In particular, the production of easily deployable and commercially-viable quantum computing technology will require materials with robust physical properties, such as electrical conductivity with little to no variance despite extreme conditions of operations. There exist novel phases of matter, the so-called topological materials, that behave in this manner and whose theoretical prediction was awarded a Nobel Prize in Physics in 2016. Today, hundreds of examples of these materials are known. The "topological" in their name is a nod to the mathematics behind the scenes in this amazing discovery. Topology is the branch of mathematics concerned with geometric properties that are preserved when we stretch and deform objects. The now-mandatory illustration of topology is that, to a topologist's eyes, there is no difference between a donut and a coffee mug. They share an essential topological feature, which is the donut hole (equivalently, the hole in the mug's handle).

How and why does topology enter the world of conductivity? It is reasonable to model conductivity as the hopping of electrons from one site to another in the microscopic, crystalline structure of a material, especially at the super-cool temperatures involved in quantum computing. These electrons and the quantum-mechanical equations that govern them give rise to a geometric surface, made up of all of the allowable energy levels that the electrons may occupy. It turns out that, for some materials, the topology of this surface controls the conductivity of the overall material. As long as the topology is protected — that is, as long as we don't tear any holes in this quantum surface — the conductivity is robust and perfectly controlled. Most defects in the outward physical engineering of the material have no effect here, making these materials incredibly desirable for sensitive applications. (Incidentally, the Nobel Prize Committee attempted to demonstrate this on stage by tearing apart pastries.)

Topological materials are just one example of a wider class of quantum materials with novel behaviours emerging from genuinely quantum effects within them. These materials are quickly leading to new models of data storage and medical imaging devices, in addition to providing new possibilities for cultivating stable qubits.

BUILDING A QUANTUM CANADA

With so much happening in quantum technology, we ought to ask ourselves: *how much of it is happening here in Canada?*

The answer is quite a lot. Canada is home to an ever-growing number of established firms, start-ups, and research institutes all with a primary focus on quantum science or quantum technology development. Compiling an exhaustive list is not easy and one is bound to leave out important names. Sticking therefore with just a few, it would be impossible to not mention the Burnaby, BC-based D-Wave Systems, the world's first company to manufacture commercial quantum computers. With the rise of quantum computing has come a need for quantum programming. Quantum software companies such as Vancouver's 1QBit are leading the pack here. On the academic side, Canada enjoys the presence of the Institute for Quantum Computing at the University of Waterloo, the Institute for Quantum Science and Technology at the University of Calgary,

and the very new Quantum Algorithms Institute at Simon Fraser University, as well as several other institutes and centres centred around quantum technology, computing, and information. The Stewart Blusson Quantum Matter Institute at the University of British Columbia represents Canada's leadership in the development of quantum materials, and there are other bright sparks on the horizon due to the Pacific Institute for Mathematical Sciences' recent investment in quantum topology in the Prairie provinces.

This flurry of activity makes Canada a definite contender for the title of "quantum country". How will we maintain momentum in this direction and prevent stagnancy as other countries ramp up their quantum infrastructure?

HERE ARE TWO THOUGHTS:

1. INTERACTIONS BETWEEN INDUSTRY AND ACADEMIA.

First of all, these interactions need to exist. Once they are in motion, they need to be authentic, substantial, and sustained. These collaborations will be the fuel for widespread quantum innovation in Canada. The problem with fostering these interactions is a fundamental incompatibility in the way these spheres operate. Companies are looking for products — better yet, ones that people will purchase.

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Academics are looking for publishable results — better yet, ones that people will cite. These types of collaborations need to be incentivized, especially within academia. Academics working with quantum companies need these collaborations to be on par with publishing, as far as tenure and promotion are concerned.

This is not to say that these interactions are not occurring. They certainly are. But they can be happening much more often and much more routinely. Shared infrastructure is another catalyst for these interactions. An excellent model is the recently-established Chicago Quantum Exchange, a partnership between four universities, two government laboratories, and a number of industry partners, involving over 100 researchers at the time of writing. There is no reason why this model cannot be implemented in multiple regions in Canada.

2. QUANTUM TRAINING.

It should go without saying that quantum technology development requires quantum ready workers. Who staffs today's quantum companies? These firms attract highly qualified individuals: mathematicians, physicists, chemists,

computer scientists, electrical and nanoscale engineers, biologists. A great many of these workers possess PhDs, obtained in Canada or internationally. If they are lucky, they may have had direct exposure to quantum computing or other quantum technologies during their studies. Many will not have, though. Many of them will enter the industrial job market after their terminal degree or a postdoctoral fellowship and are hired into tech start-ups by open-minded recruiters and project managers, often after some retraining through a Python or machine learning bootcamp, etc. Even after being hired, there is likely much more retraining involved — after all, quantum computing is as much about refrigeration as it is about math and quantum mechanics.

There was a time not too long ago when there was no such thing as a degree in computer science. It is fair to say that, in most cases, the emergence of classical computer technology preceded the existence of computer science programs. Many such programs were spun out of mathematics and engineering programs (and today dwarf mathematics programs and rival engineering programs for students).

Might programs of study focused around quantum computing or quantum technology begin to find a footing of their own? I can imagine cries that one cannot or should not learn about anything quantum without a solid grounding in other disciplines first or that an undergraduate degree around quantum technology is either too ill-defined or too focused, paradoxically. I bet there were similar protestations around the emerging computer science programs some time ago.

This provides yet another opportunity for me to take a stance: I believe such bold, new 21st Century academic programing is inevitable. In addition to producing quantum-ready workers, quantum training will introduce students to new ways of thinking that could spark innovations that we cannot yet predict, in much the same way that computer science has paved the way for computational statistics and, subsequently, artificial intelligence and machine learning.

There is no better time than to start now. While the study of quantum materials is still best approached with prior training in physics, quantum computing and the related subject of quantum information rely on firm, axiomatic principles and stand on their own as well fleshed-out subjects that can be taught from the ground up and with an interdisciplinary perspective.

Again, this is not to say that training opportunities do not exist. In Canada, the Institute for Quantum Computing offers dedicated graduate level studies in quantum computing. The newly-founded Quantum Algorithms Institute at Simon Fraser is also slated to host a quantum computing graduate program. On the US side, the Chicago Quantum Exchange is another excellent example, with undergraduate and graduate degrees in quantum information through the University of Chicago and the USA's first master's degree in quantum computing delivered through the University of Wisconsin-Madison. The Exchange also offers certificate programs in quantum engineering and technology. I would like to see these programs become widespread in Canada and for quantum training to begin in earnest at the undergraduate level, if not earlier. If the Ontario math curriculum has been recently updated so that students are introduced to basic ideas around coding in Grade 1 (bravo, by the way!), then why can't they be encouraged to explore basic ideas around quantum coding in Grade 10? A quantum Canada, if it is to be an empowering agent for all, must begin in the classroom.

What is certain is that we are in the very early days of a quantum revolution, one that promises disruptive and potentially life-saving technologies. What I want to be certain about is that Canada will continue to be a leader on this front, powered by sustained academic, industry, and government collaboration, and that we will produce a generation equipped with the quantum thinking required to make the most of these innovations. I do believe that quantum thinking — akin to how it rapidly converges to the winning vaccine from a vast range of possibilities — will rapidly select for us the best and brightest future. So let's take the bold steps necessary to empower the quantum generation in this country.

How Canada can meet the climate challenge of net-zero

Phil De Luna

Director, National Research Council

2020 will forever be etched into our minds as the year that felt like a decade – a global pandemic that halted economies and took far too many lives far too soon, social unrest as institutions faced a reckoning around systemic racism, perhaps the most consequential US election in recent memory, all while the world continued to burn with the Northern California skies wrapped in a blood orange glow.

The pandemic is a global short-term shock with impacts that are felt by everyone. There's a strange comfort in knowing that we're facing similar challenges and a shared, albeit bleak, experience. By contrast, climate change is a long-term burn with gradual and delayed effects that will persist for generations to come. The impacts of climate change we face today are the result of decades past of GHG emissions. In fact, studies show that continued emissions from committed fossil-fuel energy infrastructure account for more than the entire carbon budget that remains if global warming is to be limited to 1.5 degrees Celsius. In other words, unless massive capital investments, decommissioning of existing fossil-fuel based electricity generation, and a ban of new fossil-fuel plants are implemented – we may have already failed to reach our targets.

Thankfully in Canada our electricity generation is relatively clean as we are blessed with an abundance of hydroelectricity, continue to implement solar and wind, and have developed a robust nuclear sector. In Canada 52% of annual GHG emissions come from two sectors – oil & gas and transportation. These sectors are extremely

difficult to decarbonize through electrification alone. We can't out-efficient our way out of these emissions, we need fundamentally new technologies to address these sectors.

The International Energy Agency (IEA) recently released their 2020 Energy Technology Perspectives report which analyzed over 800 technology options to examine what would be needed to reach net-zero emissions by 2050 – a goal that the Canadian government has publically announced. They found that transforming the power sector alone would only get us one third of the way to net-zero emissions. When people think of clean technologies, they think of renewable electricity generation like solar and wind – even if we were to completely transition the world's economy to renewable power generation, this would only get us 1/3rd of the way there. Renewable electricity cannot decarbonize entire economies alone.

The next generation of clean technologies must address these gaps – primarily heavy industry and resource extraction. For Canada, this is particularly salient for the west. There are thousands of chemical engineers, technicians, pipefitters, and oil & gas workers in Alberta who are facing disruption amid cratering demand due to the pandemic. Growing up in Windsor, I know all too well what happens when a community is dependent on one entire industry and when that industry experiences a downturn. In 2008 my father was laid off from Ford as many automotive plants in the city closed – he's never found a job with a comparable salary or benefits since. It's unrealistic (and frankly a bit insulting) to assume that we can diversify and retrain a massive workforce by teaching them how to code. For many industrial workers, these jobs are their livelihood and identity. I spend much of my time thinking about how we can ensure a transition to a low-carbon economy in a dignified and fair way – a way that lets people feel pride in what they do.

There are two technologies that can both transition Canada to a low-carbon economy and utilize the unique skills and assets of Canada's industrial workforce.

The first is hydrogen, which has gained momentum in recent years as the fuel of the future. When combusted, the only emission from hydrogen is water. Canada has been a leader in hydrogen technologies for decades and the federal government is set to release its national hydrogen strategy this fall. Advanced economies like Germany and Japan have already signaled their investment into hydrogen in a significant way, and both of these countries will likely need to import hydrogen to fuel their economies – representing an opportunity for Canada to become a global hydrogen exporter.

The second promising technology is carbon capture, utilization, and storage (CCUS). As a species we got ourselves into this mess by taking fossil fuels from underground, combusting them to extract energy, and then pouring the leftover carbon in the form of CO_2 into the atmosphere. Logic (and mass balances) would suggest that the only way to get ourselves out of this mess is to capture the carbon in the atmosphere and then store it underground where it came from. Again, Canada has a strategic advantage here with world-leading firms like Carbon Engineering (direct air capture) and Svante (flue gas capture) leading the charge.

Both of these technologies rely on the same skills as the existing oil and gas industry. They require massive machines and plants with pipes, fluids, heat, and energy flows controlled in complex ways. The destiny of hydrogen and CCUS are intertwined in more ways than one as the future of emissions-free hydrogen in Canada depends largely on CCUS.

To sum up so far – renewable electricity generation is not enough to get us to net-zero, transportation and oil and gas are by far the biggest sectors and hardest to decarbonize, hydrogen and CCUS could be a uniquely Canadian solution that presents a massive opportunity. So how do we capitalize?

While these technologies hold great promise, much of it is pre-commercial. The IEA Energy Technology Perspectives report showed that about half of the technologies needed to reach net-zero are in the lab or at prototype/demonstration scale – highlighting the crucial role for research, development, and innovation.

At the National Research Council of Canada I run a $57M collaborative research program called the Materials for Clean Fuels Challenge Program, focused on disruptive technologies to lower the cost of hydrogen and CCUS. My program has three main thrusts, CO_2 conversion, clean hydrogen production, and artificial intelligence for materials discovery. At the heart of these technologies are materials such as catalysts and membranes that enable the transformation of CO_2 or the production of hydrogen. We need new materials to disrupt these sectors and we don't have the luxury of time that traditional R&D demands (20+ years to go from discovery to market). This is why we're also building AI-powered self-driving robotic laboratories to help us accelerate this discovery. Working with Natural Resources Canada, we're building a new facility in a Mississauga focused on these autonomous materials acceleration platforms (MAPs). We can't do this alone which is why we're collaborating with 20 world-leading research groups from academia and exciting start-ups in Canada, Germany, the UK, and the US to tackle this mission. This model of mission-driven focused collaborative research is exactly what Canada and the world needs to reach net-zero.

The pandemic has shown how quickly the world can mobilize to address a common threat. We can learn much from this urgency to tackle the next existential threat we face. Only by working together can we accomplish our goals, and what better place to start than collaboration in science, technology, and innovation. We are, after all, all in this together.

"We can't out-efficient our way out of these emissions, we need fundamentally new technologies to reach net-zero by 2050."

FUTURE DIRECTIONS FOR INNOVATION POLICY IN CANADA

David A. Wolfe

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The combination of the current global pandemic and the long-running challenge of mitigating the environmental and economic effects of global climate change are rapidly altering the context of, and challenges for, Canadian science, technology, and innovation policies. The economic aftershocks of the pandemic are occurring at the same time that two other longer-term trends are impacting the economy: the rapid diffusion of digital technology throughout every sector of the economy and the transition to a post-carbon economy. If anything, the pandemic has accelerated the adoption and diffusion of digital technologies in diverse fields such as online retail and commerce, remote working, and distance learning. Equally significant, the most effective measures for containing and controlling the spread of the pandemic have involved the application of digital technologies to link diverse databases in different national jurisdictions to facilitate contact tracing and reduce the need to lock down major portions of the economy.

These trends will persist and most likely accelerate as we gradually move to reopen the economy after COVID-19. The first trend involves the growing digitization of all aspects of the economy, placing greater reliance on cloud computing, mobile telephony, data analytics and artificial intelligence. For the past two decades, the pace of innovation has been accelerating, dramatically compressing the time it takes to disrupt established industries and bring new products and processes to market. The impact of exponential growth has been accentuated by the shift to virtual work and learning during the pandemic. The pandemic has accelerated a new wave of digitization across virtually every aspect of our lives. These changes will persist into the recovery.

"Environmental sustainability and public health have become the determining criteria by which we must judge the viability of all new innovations."

The second trend is the accelerating shift away from carbon-based forms of energy to renewable forms, including wind, solar, battery electric, fuel cells and hydro power. This shift has been occurring for the past decade, with the cost of renewable energy and energy storage falling steadily and rapidly approaching the cross-over point with natural gas. In many jurisdictions, wind and solar energy is already cheaper than coal power. The trend away from carbon-based energy sources has been underlined by the steady stream of announcements from leading investment firms and sovereign wealth funds of their divestment from conventional fossil energy producers. Recent reports underline the vulnerability of existing oil and gas reserves, much of which may well end up as stranded assets. While some demand will return with a restoration of economic activity, the next normal of remote working and distance learning may well persist.

Going forward, innovation policy must be aligned across all sectors of the economy to stimulate the diffusion and adoption of digital technologies, as well as their application in support of public health measures to mitigate the spread of this pandemic, as well as future ones, and to promote the transition of all economic sectors and our energy systems to sustainable sources of energy. Recognition is growing that it no longer suffices to focus innovation policies on great new breakthroughs in ICT, pharmaceuticals or clean technologies that drove the wave of innovation over the last 50 years. The combined impact of the global pandemic with the climate crisis raises more fundamental questions of how new forms of technology and innovation interact with nature and the environment and the extent to which they can improve our prospects for sustainability and our chances of survival, or jeopardize them. In effect, this means that climate change, environmental sustainability, and public health concerns are now the critical lens filter through which all potential innovations must be assessed and, consequently, both the goals and impact of innovation policy as well. Rather than just viewing 'cleantech' as one more subfield of innovation policy, environmental sustainability and public health have become the determining criteria by which we must judge the viability of all new innovations. This creates the imperative to fundamentally reorient our innovation policies to pursue this objective more effectively.

Recent policy debates around decarbonization have tended to focus on the need to reduce the consumption of greenhouse gases in specific economic sectors, particularly transportation and heating. However, new policy thinking suggests that an effective climate change strategy must focus on shifting our reliance from carbon-

based to alternative forms of energy, such as wind, solar and hydrogen, across every sector of the economy. This will necessitate both the development and application of new technologies that rely on these alternative energy sources, as well as the creation of the energy infrastructure needed to integrate the alternative sources into the grid. Digital technology can also play a critical role in optimizing the efficiency with which the alternative forms of energy are moved across the grid, as well as the efficiency with which they are used in different sectors of the economy.

The threats and opportunities created by these trends require a whole of government policy response. In addition to the growing clean energy sectors of the economy and the further expansion of the digital revolution underway for the past two decades, we need enhanced policies to support: the growth of domestic firms in new sectors of the economy linked to the development of transformation of existing industrial processes (cleantech); greater provision of renewable sources of energy, including, wind, solar and hydrogen; the rethinking and redesign of digitally integrated and enabled urban mobility systems, including public transit; more attention focused on our public health system, through the effective use of digital technologies to track diseases, the application of new computing techniques to accelerate the discovery and development of new vaccines and antiviral drugs and the use of these technologies to support and protect front line workers in the health sector and other parts of the service economy. The challenge is massive but many of the solutions are readily available in the form of existing technologies and the firms to develop them. What is missing is a national strategy to accelerate their deployment throughout the economy.

Partnering for a better world

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SCIENCE+SOCIETY

SCIENCE MUST HELP SAVE HUMANITY FROM ITSELF

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Today, there is a tendency to view science and social change as being disconnected. This view is a relatively recent development in the long history of science, when we consider the evolution of the scientific method and thought dating back from the Egyptians and Greeks to more contemporary times with names such as Bacon, Lippershey, Galilei, and Newton.

Bacon's inductive reasoning approach ushered hypothesis testing to progressing knowledge and understanding, and to this day defines the scientific methodology. Lippershey and Galilei set the foundation for observations, which led to a re-thinking of the Earth's place in the solar system, and directly challenged the primacy of the church's generally expressed view that the Earth was at the centre of the solar system.

It is evident that science has been a catalyst to social change and reconsideration of the social constructs of the time.

In 1969, humanity's curiosity to experience existence beyond the scope of our planet saw the journey to the moon, and Neil Armstrong setting a human foot on that body. This achievement allowed humanity to look back at itself for the first time from another stellar body, and from a sufficient distance to see this place we call home, Earth. In the process, it also gifted

us with the liberating sensation that comes from seeing racial, cultural or sociological differences between people washed away by the abstract connected form of our shared sphere that gives us all both life and protection.

The idea of a reflector or mirror telescope dates back to at least Newton. However, it was in the 1940s when the combination of ideas for a spaced-based mirror telescope would form the basis for what we now call the Hubble Telescope. Similarly, work that took place in the 1930s on the radio resulted in the establishment of radio telescopes.

Both the Hubble and radio telescopes have been instruments in assisting humanity to see further in distance and also further back into the early history of the universe. Through these efforts, we have refined our understanding of the formation and evolution of the universe, from its earliest moments to forecasts that look out billions of years into the future.

In just the past 10 years, the development of the Laser Interferometer Gravitational-Wave Observatory (LIGO) has led us to the detection of gravity waves, and using these to make inferences about the universe. From the early telescopes of Lippershey and Galilei to LIGO, when humanity turned its efforts towards the horizon and stars, we have found out more about ourselves and our place in the universe than when we have looked at each other through the lens of what Freud (1918) called “narcissism of minor differences”.

Today, humanity prepares itself for the journey to Mars through both public and private enterprise endeavours. We look forward to the establishment of permanent bases that can sustain human life for extended periods of time in places where we have not previously existed. We have already seen signs that suggest there may be life elsewhere in our solar system (e.g., Venus or even Mars) and, with a certainty informed by any reasonable probability limit, we are not alone in the universe, but we are still relatively rare. We therefore have an obligation beyond ourselves to preserve and maintain life on planet Earth, as well as to consider the values that we will be emerging with from this earthly cocoon, and taken out into our solar system and eventually beyond.

An examination of global affairs in 2020 highlights numerous challenges. We have multiple persistent conflicts; extremely divided and factional political discourse threatening state and even human governance and capacity; a pandemic that has exposed human tragedy and causality being more related to social disparity and marginalization than to any other pre-existing factor; justice systems in numerous democratic countries that cannot be called colour blind, while in other countries the resurgence of might-is-right and the interests of established or emergent oligarchs outweighing the welfare of the many; global warming being denied or ignored even as growing forest fires, extreme weather events and ocean rise threaten the most vulnerable; and the vulnerable who seek a haven from circumstance are instead corralled and branded, their humanity stripped by an unempathetic audience whose connectedness is often mediated by the 15-second news clip, just before the five minutes of commercials purporting the better life they crave.

Science has ignited our imagination to look beyond ourselves even as far as the universe. It has assisted us in realizing the possibilities of venturing to explore, learn, grow and exist beyond our home, Earth. Yet, the global affairs of 2020 suggest that science and, in particular, science in Canada must also join hands with the social sciences, humanities, and the arts to examine the question of what will be the values and proof-of-concept we exhibit here on Earth that will be left for future generations to inherit. We must consider if our conduct beyond our planet will not

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be riddled with the plight of narcissism of minor differences and the scars of unempathetic leaders and groups who prioritize their own interests over the trajectory of humanity being a multi-planet species whose values and conduct will shape not just our home, Earth, but our solar system and beyond.

It is insufficient for science today to solely focus on what it can make possible. It must also lend its voice to assist humanity in understanding the consequences of our choices, our conduct and our indifference.

I have full confidence that, one day, here on Earth we will receive a call from humans who have settled on Mars or elsewhere. Will they see humanity reflecting Martin Luther King's speech – I have a dream – or an ever coercion into lower levels of some metaphoric Dante's Inferno of global warming and heated social division?

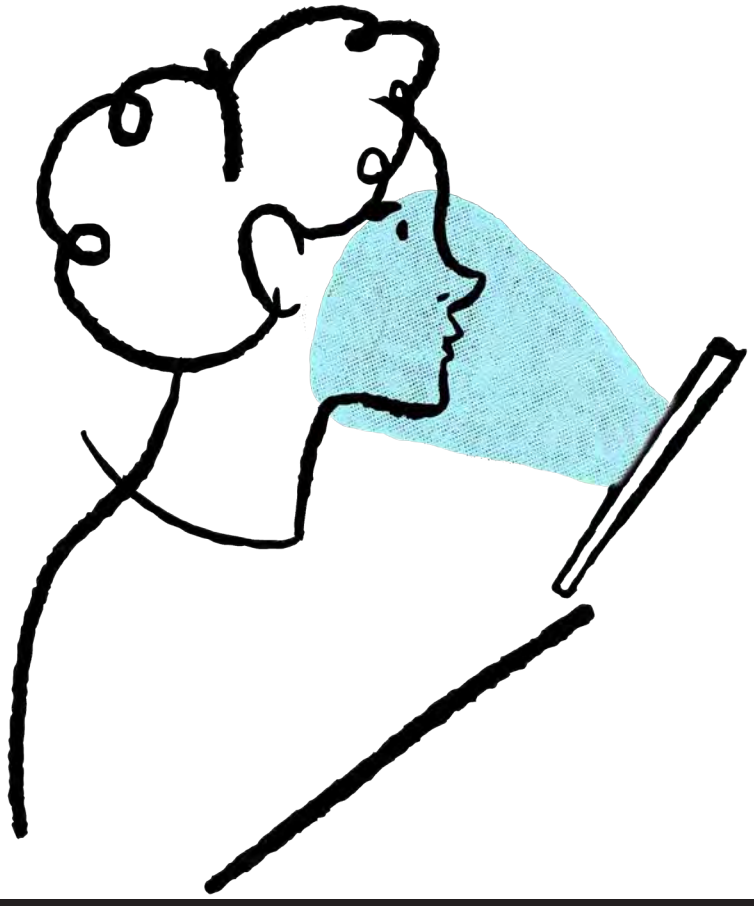
It does not require Isaac Asimov's psychohistory or quantum computing to predict the outcome of our current path. We have seen repeatedly that conflict interrupts human progress. Therefore, it will require scientists, and all of us, to articulate a change in our course of action, and a new destination, if we are hoping to get different results from our current path. I believe our Canadian scientists will join in with others to chart humanity's shared future.

Humanity working together certainly provides the basis for optimism noting the competing alternative yields limited hope. Indeed, Canadian scientists help to shape our future and their work is imperative to us all.

COMBATTING MISINFORMATION DURING A PANDEMIC

Kimberly Girling

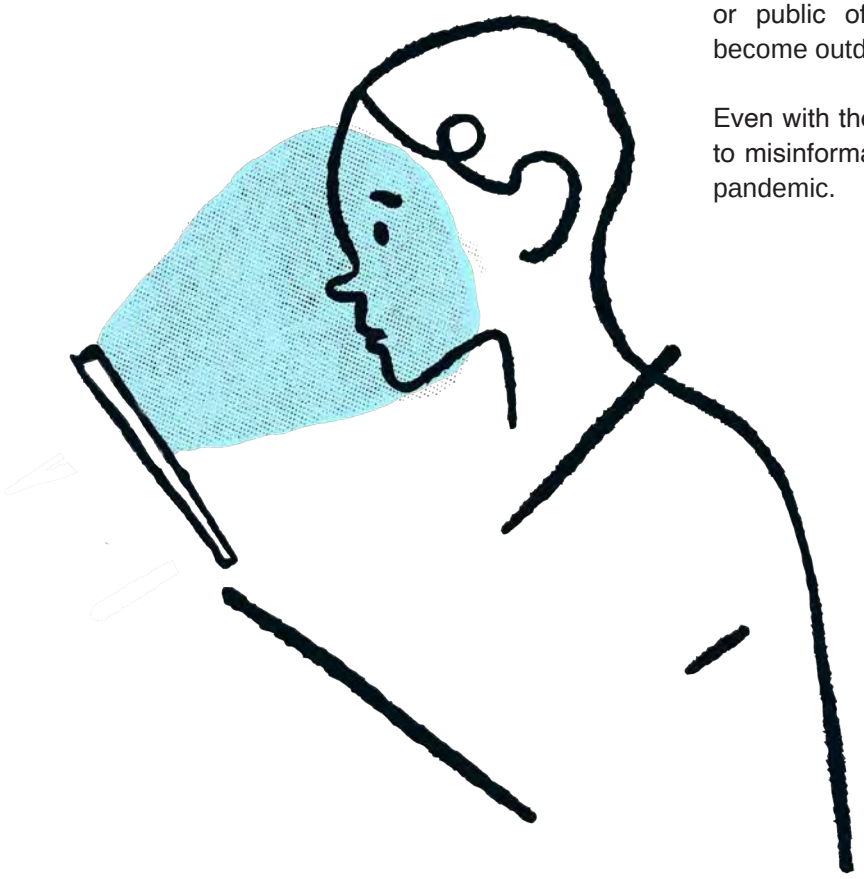
Interim Executive Director,
Evidence for Democracy



Since the COVID-19 pandemic began, misinformation has permeated all aspects of public knowledge, from early rumours about the disease being generated in a lab, to false information on preventing transmission or miracle drug treatments, to inaccuracies about how and why governments make the decisions they do. It's spread in many mediums: over social media, from family and friends, even sometimes coming from voices of power.

While the pandemic demands huge amounts of new information to effectively understand how the virus is transmitted, how people are affected, and how to limit its spread, this flood of new information also creates a perfect environment for misinformation to thrive. The consequences of this can be dire. Misinformation can undermine public health recommendations, threaten physical and mental health and safety, create deep social and political divides, enhance stigmas, and reduce the ability of communities to effectively respond to COVID-19. Misinformation during a pandemic truly can cost lives.

As we continue to wage war on the COVID-19 pandemic, how do we also battle against the accompanying "infodemic"?



THE DRAW OF MISINFORMATION: WHY ARE WE SO SUSCEPTIBLE?

The trouble is that misinformation can be difficult to detect. While "fake news" cyber hoaxes may be easily recognizable, often misinformation is subtle, like information that is partially true or misrepresented, which can make it harder to discern fact from fiction.

This is further complicated by pre-existing biases in our brains. As humans, our confirmation biases makes us quicker to believe information that aligns with our pre-existing beliefs, or that comes from people we trust who share similar views. Trying to make informed choices in situations of high emotion, like the stress and anxiety of a pandemic, can make us more vulnerable to false information, especially when we're seeking to alleviate our anxiety, or "doomsday scrolling" through our social media feeds without activating our analytical thinking. Misinformation itself can often spark intense emotions, making it challenging to look at what we're seeing critically.

Even more complicated is that the science around COVID-19 is developing rapidly. Good evidence-informed decision-making requires constantly updating and adjusting our perspectives as new information becomes available. However, this can be hard to cope with and can lead to distrust in science or public officials as previous recommendations become outdated.

Even with the best intentions, we are all susceptible to misinformation, especially in a rapidly developing pandemic.

> **"Misinformation itself can often spark intense emotions, making it challenging to look at what we're seeing critically."**

TAKING ACTION ON MISINFORMATION

In response to the infodemic, initiatives and programs designed to combat misinformation have sprung up around the world. Fact-checking websites have emerged to help the public navigate the COVID-19 pandemic and easily access robust information when they're confused about a potential claim. This includes websites like that of the Taiwan Fact Checking Centre, the WHO's Mythbuster site, Infogation (a collaborative effort of government advice), and the Poynter Institute's ##Coronavirus Facts Alliance.

Social media companies like Facebook and Twitter have also taken action by adding new features that detect potentially misleading information and flag it to readers, with the aim of identifying misinformation before it spreads.

Providing public access to experts can also be a good tool to close the gap between science and the public. For example, throughout the pandemic, the CBC has provided opportunities for the public to write in their COVID-19 questions to be answered by experts, sometimes live on air. As well, many scientists have taken to using creative digital tools like Instagram and TikTok to make robust science more accessible and shareable in a public forum (Science Sam is a great example of this!). These tools make science more accessible and inspire trust in experts and public health advice.

YOUR CHOICES HAVE AN IMPACT

Effective response to COVID-19 misinformation also requires individual action. Even with the best available information available, navigating an infodemic is difficult, and we all have a role to play in combating the threats of misinformation in our own communities. It's time for us all to take clear steps to reduce the spread of misinformation in our own lives. This means searching to find an original source, checking for information replication, visiting fact-checking sites, or consulting with an expert before sharing information. As well, given the fundamental role of our emotions and analytical thinking in belief in false information, it is worth pausing and considering: Am I reacting emotionally to this information? Am I thinking rationally? Taking steps can help us limit our own impact on misinformation spread.

The conversations we have with our community can also play a fundamental role. While it can be tempting to lash out at someone sharing something untrue, approaching conversations with patience and tact can be key. By challenging the information, rather than the person, we prevent talking down to them or making them feel stupid. Being patient, and trusting that most people are actively seeking the truth can lead to more productive discourse. As well, rather than propagating false information, experts recommend the "inoculation method", which can help prime people for recognizing misinformation. This includes giving the public a signal that they may encounter false information on a particular topic and providing them with good information ahead of time.

While misinformation around COVID-19 isn't going anywhere, we can all take action in de-cluttering the information landscape, and contributing to the battle against misinformation.

Evidence for Democracy is a non-partisan, non-profit organization mandated to promote the transparent use of evidence in government decision making. If you're interested in learning more about how you can take action on combating misinformation, visit E4D's training portal or sign on to the Truth Pledge, committing to take action to reduce the spread of misinformation in your own community.

INCREASING SCIENCE LITERACY– AND TRUST AND VALUE FLUENCY

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It's easy to spot concerning signs about the state of scientific literacy in Canada. Commentators point to a variety of survey findings as indicating diminished public confidence in science, such as low levels of trust in genetically modified foods (seen as unsafe by some 39% of Canadians in a September 2020 Pew Research study) or vaccine hesitancy (with Ipsos finding at the end of August that one-in-four Canadians would not take a COVID-19 vaccine if it were available). When you look at more abstract views on science, the results can be even more concerning: Pew also found that only 45% of Canadian respondents say they have "a lot of trust in scientists to do what's right," as compared to 37% with "some" trust and 15% saying "not too much" or "none at all."

Given this backdrop, it's hard to imagine being critical of the need for more scientific literacy. Like 'education' or 'health,' scientific literacy seems to be, by definition, an unequivocal good. Indeed, the challenges we face – from climate change to social inequality, and from pandemics to police reform – demand decision-making that's informed by the best available evidence. In turn, we need a public that sees value in science and insists politicians employ evidence-informed decision-making.

If Canada wants to realize the benefits of scientific literacy, however, we must come to terms with what it can and cannot offer – and some of the other fluencies that must be developed to maximize the value of scientific literacy. We need to foster a rich form of scientific literacy that focuses on process over individual facts, and a scientific literacy that acknowledges the centrality of trust and the importance of distinguishing between the roles of science and other values in decision-making.

It's important to acknowledge how far science literacy has already come. In the past, it's been rightly criticized for being unduly focused on spreading scientific

trivia and promulgating particular factoids. In contexts like COVID-19, forms of science literacy that focus on information alone become an impediment to personal and political decision-making. Evolving knowledge about airborne transmission, for instance, reminds us that the value of science comes not from fostering allegiance to a particular set of facts, but because of the commitment to following the guidance of synthesized evidence, reviewing and critiquing earlier findings, and adjusting our knowledge as needed.

In other words, science literacy in the context of COVID-19 must be much richer than disseminating facts. Instead, it requires developing widespread understanding of the internal processes and values that make science reliable; why changing knowledge is generally a good sign (not a bad one); and why frightening headlines (like vaccine trials being temporarily paused because of potential side effects) actually reveal the system working the way it ought to. This is the kind of scientific literacy we must develop widely.

At the same time, however, we must be cautious even with this richer version of scientific literacy. In the opening paragraph, I cited the incomplete public acceptance of GMOs and vaccines as often-lamented examples of insufficient scientific literacy and trust. All too often, broad public acceptance of the 'right' viewpoint on an issue is taken as a proxy measure for the achievement (or lack thereof) of scientific literacy. Within these admonishments is a common underlying assumption: that if trust and literacy in science was higher, members of the public would be more uniformly accepting of these safe, important technologies.

To be clear, I think GMOs and vaccines are safe and essential to environmental sustainability and public health. I worry, though, that it's dangerous to tacitly assume that increased scientific literacy leads to linear gains in consensus with our policy preferences. When this kind of linear relation creeps into our causal narratives, it can make problems of polarization and distrust worse, not better.

When members of the public are faced with complex decisions, they need to assess which experts and authorities can be trusted. While a richer understanding of science can address some concerns, there are other reasons to trust or distrust. Important research by philosophers Heidi Grasswick and Naomi Scheman highlights the many reasonable, rational reasons that community members may distrust scientists. Past exploitive relationships with marginalized communities, for instance, are a legitimate factor in the process of assessing whether scientists ought to be trusted now. Understandable distrust can also arise when scientists are perceived to be selectively fitting science to justify certain political positions, or reactionary or partisan in their public stances. For Grasswick and Scheman, then, the process of "rationally grounding trust" means attending to legitimate sources of distrust that may be broader than we've previously accounted for.

Our work monitoring the social dimensions of COVID-19 across Canada also highlights the many ways publics are already scientifically literate. Our survey research in March and April, for instance, found that 82% of respondents thought "scientific evidence" should be driving decision-making in (despite a smaller fraction, 56%, believing that it actually was). In ongoing, in-depth interviews with Canadians about vaccines and other topics, we're finding that many of those concerned aren't simply ill-informed; instead, they have much more subtle worries about political pressure circumventing normal scientific safeguards, and hold fairly sophisticated views in terms of looking for consensus among physicians and experts they trust. There generally aren't sweeping rejections of science, but rather – even if less jargon-heavy in articulation – nuanced concerns about inconsistencies between science and policies, about real barriers they see as unaddressed, or about policy-based evidence making.

In other words, while fostering rich scientific literacy is always important, we as scientists and decision-makers must also work to develop a variety of fluencies. We ought to be cautious about both historical and contemporary ways in which very legitimate distrust might be fostered, and view attending to these roots of distrust as at least equally important to promoting science. We must

"We need to recognize that scientific literacy is also dependent on fostering rationally grounded trust and maintaining science's role as an honest broker rather than issue advocate."

grapple with the other values that need to be included in deliberations alongside scientific evidence, and be cautious about overstating the normative advice science can provide on its own. Those of us who do scientific outreach must become masters not just at flashy presentations, but become even more skilled at listening to where hesitations and concerns come from and creating room to foster, embrace, and stay with value disagreements. We must, of course, draw firm lines around inclusivity, compassion, and justice – but we also need to be careful about tying science to what are ultimately values worth defending.

I'm less concerned, then, about levels of GMO acceptance or vaccine approval, as superficial measures can often obscure real concerns (such as the influence of industrial farming or observation of political pressures on drug approvals) that need careful attention. I'm more concerned about Pew Research's recent finding that 74% of "politically left" Canadian respondents "trust scientists a lot to do what's right," while only 35% of "politically right" respondents say the same (the second largest gap globally, only three points behind the United States). If we fail to attend to legitimate reasons for distrusting science; if we aren't careful to differentiate between the role of science and values in public decision-making; the risk is that this partisan divide could continue to grow with disastrous consequences.

What does this mean for promoting scientific literacy and bridging gaps between the public and science? We absolutely ought to support rich forms of education and public engagement that develop understandings of the process and values of science. But even more critically, we need to recognize that scientific literacy is also dependent on fostering rationally grounded trust and maintaining science's role as an honest broker rather than issue advocate. Efforts towards science literacy will be hampered when they're predicated on an assumption that increases in scientific literacy will directly result in increased support of one's own preferred actions. While half the battle of scientific literacy is ensuring the public understands the values that make science reliable – the other half is building not just literacy, but fluency, in maintaining public trust and reminding ourselves of the important complementary roles of science and other kinds of values in decision-making, and the importance of remembering the distinctions between them.

SCIENCE DIPLOMACY AFTER COVID-19

William Colglazier

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Advancement of Science (AAAS)

The year 2020 has been a sad reminder that predicting the future is hard. At the World Science Forum in November 2019, I ended an optimistic talk on "Twenty Years of Science Diplomacy" with my list of the most important issues for science diplomacy to address. I did not include a worldwide pandemic.[1]

Every four years the U.S. intelligence agencies produce a report on Global Trends that is released after the presidential election. Each report looks to the future in examining mega-trends, game-changers, and potential worlds . The 2012 report, Global Trends 2030, listed a number of "black swans" that have a low likelihood annually but could be greatly disruptive globally.[2] Here are two of the black swans in that report: a severe pandemic and a US global disengagement. These two turned out to be interconnected and cataclysmic for 2020.

With COVID-19, I was stunned that my country was unable to act early and effectively in responding to the threat.[3,4] The U.S. failures were not just the fault of politicians even though our President has much to answer for — his malfeasance made even more graphic by the revelations of Bob Woodward's new book.[5] Significant failures were also made by major scientific institutions (with testing, PPE stockpiles, etc.). The failures were also more than just the science-policy interface. Large segments of the American public have viewed the pandemic as a hoax, and many have been unwilling to wear masks or social distance. The interacting failures among science, policy, and society resulted in many more deaths, much misery, much greater economic cost, and significant damage to the U.S. brand and influence internationally. It affected U.S. national security and science diplomacy. A number of other countries did much better.

As the Science and Technology Adviser to the U.S. Secretary of State from 2011 to 2014, I had many interesting conversations with scientists and officials around the world looking to strengthen capabilities in science, technology, and innovation (STI) and science advisory ecosystems. Most countries were focused on this task deemed crucial for their security, prosperity, and competitiveness. The U.S. reputation for STI was then an asset for our science diplomacy. I stressed the importance of having a strong science advisory ecosystem with expert scientific advice from the scientific community to government leaders and the public.

In reflecting on the COVID-19 failures, I was reminded of something that I had forgotten to emphasize in those earlier discussions. For important policy decisions, what matters as much – if not more so – than science are culture, values, ethics, trust, leadership history, and politics. They are powerful determinants of decisions. Weaknesses arising from these factors can only be altered by the will of the public and its leaders.

For American culture, individualism and individual initiative have been very good for our innovative capacity and our economic vibrancy. They have not been so good for social cohesion in dealing with a pandemic, especially when aggravated by politicians that divide the country, ignore science, and do not tell the truth. Changing aspects of a culture without political leadership is difficult.[6]

The challenges at this stage in the pandemic are especially complex because of the uncertainties regarding the future path of the virus, the economic impact, individual behavior, availability of a vaccine and therapeutics, and government policy. It is clear that countries are relying on science to help us escape from this pandemic. Once again science, technology, and innovation — in partnership with policy and society — are essential at the national and global level.

What then is the role for science diplomacy? Many foreign ministries are now paying close attention to science diplomacy. I have asked science counselors and diplomatic professionals in several foreign ministries what now is their highest priority in science diplomacy. The universal answer is vaccine diplomacy.

The UNDESA policy brief "The COVID-19 pandemic: a wake-up call for better cooperation at the science-policy-society interface" highlights several priorities

where science diplomacy can help not only with the pandemic but with many of our global challenges.[7] Science diplomacy can facilitate the sharing of knowledge and data internationally, promote collaborative research, ensure universal access to solutions, and encourage nations to act with greater urgency on global scientific assessments related to our challenges.

One of the greatest successes of science diplomacy was the Montreal Protocol. But it was not science alone that made the difference. Getting support for the Montreal Protocol in the U.S. required the science of Rowland and Molina, the technological advances in new refrigerants made by private companies, and the persistent leadership of the science diplomats in the U.S. State Department during the Reagan administrations.[8] As reflected in the Paris Climate Accords, we need an international partnership among science, policy, and society to deal with climate change.

To effectively connect our pandemic responses to our global goals, science diplomacy can help by promoting objectives such as: (1) ensuring COVID-19 rescue funds accomplish the multiple goals of eliminating the pandemic, restoring livelihoods, and achieving greater sustainability of our societies, (2) reducing barriers to international scientific collaboration and enhancing international collaboration and coordination among countries, (3)

"Science, technology, innovation – in partnership with policy and society – are essential for achieving a prosperous, secure, just, and sustainable future for all countries and the world. Science diplomacy can help us in that quest."

strengthening public trust in science, and (4) reducing inequalities in societies.[9] All four tasks are absolutely essential for the making the world more resilient and sustainable.

What about the five issues that I highlighted in 2019 where there is a need for science diplomacy to provide new pathways for progress? They are also important:

1. Controlling new technologies of war, which can be used by nation states and terrorists, and advancing arms control treaties to reduce the dangers and proliferation of these weapons (e.g., nuclear weapons and delivery systems, autonomous weapons utilizing artificial intelligence, hypersonic weapons creating the fear of first strike, cyber weapons and offensive information warfare, biological weapons, etc.),
2. Providing foresight and facilitating dialogue on the implications of rapid technological developments that can be disruptive (good and bad) to societies in order to maximize the benefits and minimize the negative consequences and threats from technological advances (e.g., AI, gene editing, synthetic biology, robotics, big data, blockchain, social media, etc.),
3. Maintaining a channel of communication between nations that have estranged relations and conflicts and a potential for a new Cold War (e.g., Russia, China, Iran, North Korea, etc.),
4. Accelerating progress on the global goals, especially the global environmental goals (climate, oceans, biodiversity), to safeguard our planet and help countries understand and commit to their share of global responsibilities, and
5. Building capacity in science, technology, and innovation in developing and emerging economies to help them achieve their social, economic, and environmental goals.

Science, technology, innovation – in partnership with policy and society — are essential for achieving a prosperous, secure, just, and sustainable future for all countries and the world. Science diplomacy can help us in that quest.[10]

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BRIDGING INTERNATIONAL NETWORKS IN SCIENCE, TECHNOLOGY AND INNOVATION

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Canada has been collaborating in Science, Technology and Innovation (STI) with other countries for decades, but the COVID-19 crisis has illustrated just how critical these partnerships are. Right now, Canadian public, academic and private researchers, often funded by federal and provincial programs, are working with their counterparts in the United States, Europe and Asia, to find a global vaccine and develop new therapeutics.

Canada's international STI collaborations extend well beyond the public health sector to cover clean energy, life sciences, climate change and strategic national priorities such as quantum computing and artificial intelligence. Several federal departments fund and support these partnerships, including Innovation, Science and Economic Development Canada; the National Research Council; the Canadian

Institutes of Health Research; the Natural Sciences and Engineering Research Council; the Social Sciences and Humanities Research Council, for Innovation, and various science-based departments and agencies.

Global Affairs Canada promotes STI partnerships by bridging international STI networks in three ways:

First, it leverages Canada's 15 STI agreements with leading innovation nations and the European Union. This helps Canadian SMEs and researchers access international research and development programs - such as the Eureka Network or the European Union's Horizon 2020 - and institutional linkages for the joint development and commercialisation of technology. Programs such as the Canadian International Innovation Program and CanExport Innovation help support this access.

Second, Global Affairs Canada helps Canadian small and medium-sized enterprises (SMEs) access foreign markets by providing information and opportunities, including introductions to key players in foreign STI markets and helping to organize technology pitch sessions in Canada.

Last, the Department supports Canadian start-ups in their fundraising efforts, connects international venture capital funds to Canada's innovation ecosystem and helps Canadian companies protect their intellectual property.

Canada's Trade Commissioner Service (TCS) plays a key role in promoting these STI partnerships. The TCS has 25 dedicated STI counselors and officers at 19 embassies and consulates in 11 leading innovator nations. They are supported by other members of the TCS at headquarters in Ottawa and at six regional offices across Canada.
The activities of this network are generating tangible economic benefits for Canadians. In 2019-2020, the TCS supported 159 new international research partnerships, which contributed more than $152 million to the Canadian economy. The TCS also delivered nearly 450 services to venture capital clients and provided STI-related services to more than 1,200 Canadian companies and 200 Canadian partner organizations. Events organised in partnership with the Canadian Venture Capital Association have directly resulted in new investments in Canadian venture capital and private equity funds by countries such as Norway and Mexico.

Being a global leader in STI means securing Canada's economic future. The benefits from research, development and innovation determine our national prosperity, our competitiveness and our well-being. They also generate other key strategic benefits, such as supporting our response to the COVID-19 pandemic, or assisting our efforts to address climate change. Perhaps now more than ever, our ability to collaborate on an international scale will touch the lives – and help save the lives – of many Canadians. Global challenges require global solutions.

As you form your international STI plans, Global Affairs Canada and the TCS can help. With modern collaboration agreements in leading innovating countries around the world, a dedicated cadre of STI experts abroad, as well as deep and expanding domestic partnerships within the Canadian innovation ecosystem, the TCS is poised to assist you. To find out more, please go to www.tradecommissioner.gc.ca.

CULTURAL SAFETY: THE CRITICALITY OF INDIGENOUS KNOWLEDGES AND DATA

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Who would have ever thought that "data governance" would become a trendy topic or a corporate priority? Some of us may remember the days when it was, at best, considered a necessary evil. Heightened by the use of analytics throughout the COVID-19 pandemic, the accuracy, timeliness, relevance, quality, privacy, trustworthiness and contextualization of data has become increasingly important. This is a welcome shift for many data practitioners.

Still today, relatively little is being explored regarding cultural safety and the important relationship between data and the people who share this information with us. This is critically important as it relates to First Nation, Inuit and Metis Peoples in Canada who not only have unique Worldviews about what data is and how it should be governed, but for whom a key social determinant of health and well-being is the ability to self-define and self-govern these activities.

In 2007, the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) was adopted to advance the inherent rights of Indigenous Peoples globally, including as it relates to knowledge and data sovereignty. This document outlines key Principles that collectively define the basic standards for the dignity and well-being of Indigenous Peoples. Although Canada is a signatory, until these Principles are fully implemented domestically there will remain a lack of formal protection against various data collection challenges.

In Canada, most data are collected from First Nation, Inuit and Metis Peoples to support government planning and decision making, for instance through the federal census or health surveys, or to comply with funding agreements from federal and provincial governments. Furthermore, large amounts of data have been and continue to be collected by non-Indigenous researchers who have limited to no relationship with or understanding of the communities they are researching. Increasingly, data are being collected by First Nation, Inuit and Metis communities themselves, to support their own planning and decision making. However, there is relatively little acknowledgement about or respect for the expertise they carry when it comes to self-determined and self-governed data collection.

Image: Example of Protocol for each major stage of the inquiry and learning cycle

Within First Nation, Inuit and Metis contexts, knowledge is generally believed to be learned or created in three ways: teachings passed down from Elders (Traditional Knowledge), dreams or visions (Revealed, Spiritual or Ancestral Knowledge) and through observation, experimentation and experience (Empirical Knowledge). First Nation, Inuit and Metis Peoples have always learned empirically through their deep relationship with the land, using a "plan-do-check-act" cycle that has been critical to their survival and evolution, for example always knowing where food, medicines and water are. Although there is no word for research within most, if not all, Indigenous languages, Indigenous Peoples have perfected forms of inquiry and learning that meet their needs and that are framed within their Worldviews and contexts.

Within these inquiry processes, data is broadly understood as any information that is shared between people for the purposes of learning. It includes the unique and shared Indigenous Knowledges that frame this information within a particular Worldview. Across First Nation, Inuit and Metis communities, there are many ways of understanding what Indigenous Knowledges are and how they are created, all of which are informed by an inseparable interconnection within local contexts. As such, with no universal definition, Indigenous Knowledges can only truly be understood at a local level through consideration of the intersectionality within, and between, the various dimensions of ourselves, the land we are on and the people we are with. Despite these differences, Indigenous Knowledges are almost always (if not entirely) moral in nature, meaning they share how to live a good life that respects our place in, and interconnectedness with, all of Creation.

To respect personal and collective rights to self-determination and self-governance, various Protocols have been developed by First Nation, Inuit and Metis communities to self-govern the collection and use of Indigenous Knowledges and data in Canada—for example the First Nations Principles of OCAP© (Ownership, Control, Access, Possession), the Six Principles of Ethical Metis Research or various guidelines developed by the Inuit Tapiriit Kanatami*. A shared common purpose of these Protocols is supporting knowledge and data sovereignty while using this information in a way that prioritizes the needs of,

provides a relevant context to, maximizes benefit for and, most importantly, minimizes harm to Indigenous Peoples.

Unfortunately in Canada, centuries of colonial policies and practices have privileged dominant Eurocentric Worldviews while marginalizing Indigenous Worldviews, resulting in generations of imposed, invasive, oppressive and culturally unsafe data collection from (not with or by) First Nation, Inuit and Metis Peoples. This has led to large-scale appropriation and misuse of Indigenous Knowledges, data and intellectual property and perpetuation of false information. All of this has resulted in a widespread and pervasive mistrust by Indigenous peoples towards any form of data collection. This includes but is not limited to:

APPROPRIATION:

Indigenous Knowledges or data are published or used without the consent of, or credit to, the knowledge owners

LACK OF TRANSPARENCY:

Indigenous Knowledges or data are collected without approval or, if approved, are collected and used in ways that were not consented to or known about, including unethical research

LACK OF RECIPROCITY:

Data collection requirements are imposed and are often irrelevant to the community which does not support their own planning and decision making needs

LACK OF STEWARDSHIP:

Indigenous Peoples do not have ownership of or access to the Knowledges and data they share with others

AGGREGATE DATA:

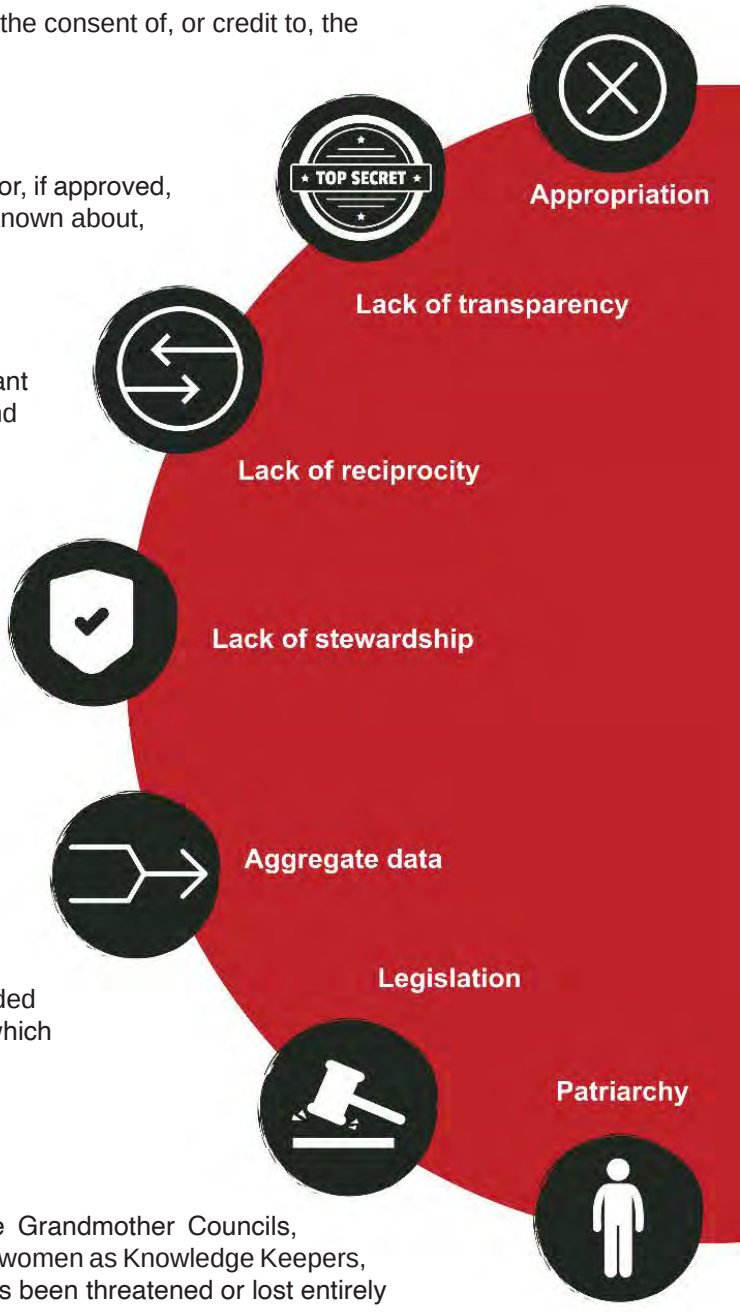
Data that are collected from Indigenous communities are aggregated, making it impossible for them to distinguish and use their relevant information and presenting Indigenous Peoples as homogenous which informs and supports false representations of Indigenous Peoples

LEGISLATION:

Indigenous Knowledges and data collected by publicly-funded programs are the property of the funding government, which subjects it to privacy, access and archival legislation that can expose it to the public

PATRIARCHY:

Patriarchal systems have replaced matriarchal systems, like Grandmother Councils, within many communities, and the traditional role of Indigenous women as Knowledge Keepers, Medicine Women, community leaders and decision makers has been threatened or lost entirely



"A shared common purpose of these Protocols is supporting knowledge and data sovereignty while using this information in a way that prioritizes the needs of, provides a relevant context to, maximizes benefit for and, most importantly, minimizes harm to Indigenous Peoples."

Supporting First Nation, Inuit and Metis communities to solve complex health, social and economic challenges in their community, organizations and institutions must start by encompassing policies and process which are deeply rooted in First Nation, Inuit and Metis Values, Principles and ways of knowing and being so that they can then transform how to collect and use Indigenous Knowledges and data for meaningful impact.

Developing Indigenous Knowledges and data governance Protocols are a must to create a culturally safe framework for how to collect, use and share Indigenous Knowledges and data. In addition, such an initiative will allow for the collection of mutually beneficial data that prioritizes supporting Indigenous-led storytelling and community-level decision making. This revitalization of inquiry and learning processes that have been established and followed by Indigenous Peoples globally since time immemorial will continue to be critical in any efforts towards reconciliation, and to the reclamation of traditional economies and paths to scale.

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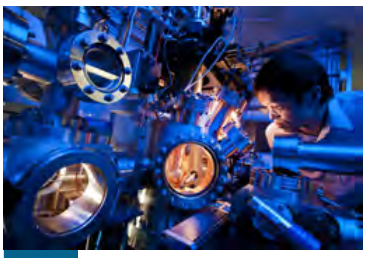


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STRENGTH IN NUMBERS

HOW CANADA'S FEDERAL GRANTING AGENCIES JOINED FORCES IN THE RESPONSE TO COVID-19

Alejandro Adem
President of the Natural Science and Engineering Recearch Council of Canada (NSERC)

Ted Hewitt
President of the Social Sciences and Humanities Research Council of Canada (SSHRC)

Roseann O'Reilly Runte
President and CEO of the Canada Foundation of Inovation (CFI)

Michael Strong
President of the Canadian Institutes of Health Reserch (CIHR)

The COVID-19 pandemic and resultant lockdown have been difficult for Canadians, as these unprecedented events have created significant turmoil and uncertainty across our society. Yet, amidst this upheaval, we have seen some positive stories emerge. One of these stories involves the extraordinary response of Canada's research community as well as the rapid collaboration amongst Canada's research funders in the face of this crisis.

Canada's researchers dedicate their lives to answering critical social and scientific questions and to solving our problems, both big and small. From societal concerns, to health issues, to technological solutions and beyond, researchers are now increasingly called upon to share their knowledge as all sectors look to them for answers and trust them to provide evidence-based solutions. During times of crisis, as we are now seeing throughout the world, citizens also look to their governments for direction, support, and the resources needed to overcome challenges that arise.

Canada's researchers have been exemplary throughout it all. From the moment the World Health Organization declared COVID-19 a pandemic, researchers from across Canada immediately stepped up to assist in our country's response. From vaccine development and personal protective equipment manufacturing, to epidemiological tracking, mental health, and wellness guidance, researchers have been working tirelessly to meet the many challenges arising from the pandemic. This included researchers from other fields who set aside their own work to contribute their expertise. As just one of many examples, Dr. Art McDonald (winner of the 2015 Nobel Prize in Physics) switched from physics to engineering to help create an inexpensive and

easy-to-use ventilator that is now under production in Canada. Such ingenuity and dedication to improving the world are hallmarks of Canada's researchers and we salute them all for their invaluable contributions.

In support of these Canada-wide efforts, the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council, the Social Sciences and Humanities Research Council, and the Canada Foundation for Innovation also leapt to action to develop the programs and deliver the funding that our researchers needed to conduct their vital work. Throughout this process, our organizations worked closely and in unison to integrate the broad perspectives and talents of our diverse research constituencies. These collaborations led to greater harmonization of efforts and the ability to provide vast coverage of research support across multiple disciplines.

"Canada's research community was able to access this funding support in record time. In total, the Government of Canada's rapid research response delivered $275 million to support researchers working on the front lines of the pandemic."

Importantly, Canada's research community was able to access this funding support in record time. In total, the Government of Canada's rapid research response delivered $275 million to support researchers working on the front lines of the pandemic. These research projects covered a broad array of areas and disciplines, ranging from medical research on the prevention, detection, and treatment of COVID-19, to research on the wide-ranging social and economic impacts of the pandemic. Notably, the funding included support for the NSERC

COVID and the Tri-agency Applied Research Rapid Response to COVID-19 grants (worth close to $20 million), as well as the creation of CanCOVID – a network developed to expedite communication and collaboration between the scientific, health care, and policy communities during the COVID-19 crisis. It also launched research projects to study how Canadians are understanding and adapting to the pandemic and how COVID-19 preparedness and response policies are being transmitted to, and implemented in, hospital and family health centres.

As the rapid response projects were initiated, attention was also being focussed on assisting the thousands of researchers who could no longer work due to university and research institution closures. As with many Canadians, the lockdown placed great economic stress on the members of our research communities, and also put at risk many research projects and the years of effort that were invested in them. For some laboratories, this also meant that the health and safety of animals was in jeopardy. The Government of Canada addressed this need by providing $450 million to allow universities and research institutions to retain their staff and maintain essential research-related activities, as well as an additional $291 million to support trainees (including students and post-doctoral fellows) during the crisis.

All of this was done to safeguard the communities we serve and we greatly appreciate the commitment and dedication of our respective teams who worked tirelessly to deliver these critically-needed funding sources. While the past few months have been a strain on our organizations, we believe that these experiences have also brought us closer together and demonstrated the resilience and dedication of Canada's public servants. The pandemic has also demonstrated that there exist great synergies between intramural programs led by the Government of Canada (e.g., in the area of vaccine development) and similar programs that are being led by the academic community (e.g., the COVID-19 Immunity Task Force). Looking to the future, it is important to continue to strengthen these relationships in an effort to maximize research output for the benefit of Canadians.

Of course, as learning organizations, we recognize that there is always room for improvement and we are cognizant of the equity, diversity, and inclusion issues that have been laid bare as a result of COVID-19. As just one example from the research community, we noted that the pandemic disproportionately affected researchers who are also caregivers. Such concerns will be taken into account as we learn from this experience and strive to enhance our country's research capacity and bolster its pandemic preparedness. We will also ensure that we continue to take a multi-disciplinary approach – one that coalesces the disparate expertise of the entire research ecosystem. This is the strength of a multi-agency approach. It ensures the contributions of a diversity of ideas and disciplines and, in doing so, permits the development of more comprehensive strategies to address any emerging challenges that Canada may face in the future.

Canadians can take pride in knowing that their research community is playing a leadership role in the global effort to stop the spread of COVID-19 through the development of a vaccine, and to address its impacts on the economic and social resiliency of our communities. While we continue to deal with this unprecedented crisis, we are also discovering opportunities for Canada's federal granting agencies to more deeply integrate our work with other departments and agencies, as well as with partners throughout academia and other sectors. Our commitment to these collaborations will further strengthen the quality of Canadian research and research talent and help to ensure that we, as a nation, are able to meet any challenges that may lie ahead.

COVID, CONFEDERATION, AND INNOVATION

David Castle
Professor, School of Public Administration and Gustavson School of Business, University of Victoria

Peter Phillips
Distinguished Professor and Founding Director, Centre for the Study of Science and Innovation Policy (CSIP), Johnson Shoyama Graduate School of Public Policy, University of Saskatchewan

Describing and evaluating a country's innovation system is conceptually and empirically challenging work. The two of us have for years been exploring the system, both at the national level and in the context of industrial and technological innovations at the local and regional level. Now we have led a team to explore the middle space – provinces and territories.

Together with our colleague Bruce Doern, we undertook a study of the Canadian innovation system, published in 2016 as Canadian Science, Technology, and Innovation Policy: The Innovation Economy and Society Nexus. Like any study of national innovation systems, we held some institutional and organizational dimensions as constants to allow sharper focus on policy processes and implementation dynamics that were of interest to us. We could see, for example how science for policy was distributed across departments and agencies, growing steadily since the 1970s in terms of impact, but yet rarely a point of discussion in the House of Commons. Regarding policies for science and innovation, we could see the effects of supply-side economics, recapitalization of infrastructure, and experiments in the geography and scale of innovation.

Our approach in our work with Doern was consistent with most of the scholarship about national systems of innovation that creates a portrait of innovation on the canvas of a nation state. To the extent that researching

and writing a book is a sense-making project, this approach generates a coherent account. Yet the national systems of innovation approach may portray more coherence than actually exists. Being interested in testing this idea, and wishing to deepen the state of knowledge about Canadian innovation, we embarked on a study of science, technology and innovation policy in Canada's provinces and territories in 2019, to be published by the University of Toronto Press next year.

Provinces and territories indisputably shape the regional cultural, political and economic context for science, technology and innovation (STI). For example, provinces create municipalities, which are the context for most STI related expenditures and value creation. Provinces and territories also create and significantly fund universities, colleges and technical institutes. Since provinces and territories are responsible for delivering most health services, they also take a keen interest in medical and health related research. They also regulate most firms, sectors and commercial transactions, and they also manage most labour and environmental law.

With these constitutionally-empowered levers, one might think that there would be more overt or at least consistently identifiable sub-national STI policies advanced by provinces and territories, but that is not the case. Instead, provinces and territories define the context for implementing mostly federal STI policies, programs and initiatives – even if they have not contributed much to their design. It is at the sub-national level that we begin to see the coherence of a national innovation systems approach fade away. What we have learned is that the federal government tends to be the policy lead for STI in Canada, but once the tune has been called, provinces and territories rarely join in partnership in the same key or same tempo. Whether working alone or with the federal government, policies, programs and initiatives follow idiosyncratic trajectories in the provinces. Certainly at the level of implementation, provinces and territories follow their own ideas and interests to create or modify institutions and programs. They rarely draw inspiration from other provinces and only

recently have some provinces taken direct interest in how STI policy is developed and implemented in other jurisdictions like Japan, Germany the UK and Israel. Although some form of STI policy making at the sub-national level is increasingly common, the overall balance is tipped toward implicit rather than explicit policies. This gives rise to the aura of STI policy in the provinces and territories as a post-facto rationalization rather than a policy driver, often visible only when a past government's programs is rebranded as those of their successor's. Because STI policy does not play a conspicuous role in program design and delivery, program evaluation is often incapable of finding compelling evidence that STI policy has had a differential impact on innovation.

How much does any of this matter? At the start of 2020 we could have concluded that we have a system coordination problem between levels of government that might continue Canada's downward trajectory in innovation performance and business competitiveness. This is hardly a new concern but we would be able to argue that we had better evidence for it – a small academic victory that might be taken up by the handful of officials interested in STI policy. But that was then and this is now – all of our socio-economic problems are compounded and exacerbated by the COVID-19 pandemic.

As part of the Rebuild Canada series launched by the Public Policy Forum, David Dodge has recently contributed a disturbing analysis of Canada's post-pandemic predicament. We were already amassing considerable foreign debt, but the pandemic is now providing extra stress on the Canadian economy as we amass the largest public debt ever through social spending to relieve Canadians of some of the burden of the pandemic. Dodge argues that we must become more innovative and add value in areas where we have core strengths, including: enhanced digitization in the production of goods and delivery of services; extending the life of an increasingly clean resource sector while rebalancing it toward higher value-added products; maximizing participation in the labour force and improving worker adaptability to new circumstances; and making public services more effective and efficient.

We might add to the list rather than argue with any item on it. But let us accept that Dodge is right that we have to climb the twin mountains of foreign debt and COVID-related public debt and that he has correctly identified areas of core strength where we should focus first. The challenge is that while his message was, to a great extent, meant for decision-makers in Ottawa to develop a plan to tackle ongoing deficit and newly incurred debt, all of the solutions he proposes track back to the provinces and territories holding the levers of control on cities, businesses and employers, higher education, health and the environment.

Setting aside galvanizing rhetoric about 'everyone being in this together,' we know that in good and bad times that federal, provincial and territorial governments do not all pull in the same direction (and indeed, sometimes cities are at odds with their provincial masters). We already know this to be true in the case of the reaction to the Government's September Speech from the Throne in which COVID recovery – 'building back better' – was explicitly linked to policies that would make the recovery 'green.' Already, the top four fossil fuel energy producing provinces, most notably Alberta, have publicly challenged the federal government's approach. We are not making a prediction about solidarity on STI policies, programs and initiatives that will help us exit our current financial predicament, and neither are we suggesting that we need constitutional reforms to get the job done. We are concluding, however, that for the past 30 years in our analysis, provincial and territorial autonomy in STI policy has led to a solid track record of disunity, sometimes leading to missed opportunities but sometimes delivering strong innovation and growth. If we are going to have a strong post-COVID recovery, we might need to change the political rhetoric about how we think about the confederation, working to engage rather than isolate the provincial and territorial governments that are essential to implementing innovation strategies.

NINE MONTHS OF COVID: WHAT LESSONS FOR SCIENCE ADVISING?

Sir Peter Gluckman
Chair International Network for Government Science Advice (INGSA)
President Elect international Science Council (ISC)

We are nine months into the coronavirus pandemic. While it is too soon for the inevitable and important retrospective governmental reviews, it is not too soon to reflect upon what we have learnt about the evidence-policy interface. There are many questions to ask: why were so many countries ill prepared or slow to respond, despite many warnings by experts in recent years about the high likelihood of an impending severe viral pandemic ? Why were such risk assessments ignored? Why were indicators such as those in the Global Health Security Index so misleading? What can this experience tell us about the gap between advice and action? There are many reasons why political and policy communities might defer action on predicted crises, be it about addressing pandemic risk, aging infrastructure or climate change, but when existential risks are at play, we need to understand the obstacles to action and how to cut through.

INGSA has been tracking the use of evidence in over 120 countries' pandemic-related decisions made during the first few months of the evolving pandemic. (see https://www.ingsa.org/covid/tracker-report-1/). COVID has created a classic case of urgent science-informed decisions having to be made in the face of uncertainty. Indeed, there remain many unknowns about the behavior of the SARS-CoV-2 and the pathophysiological and immune responses it triggers. However, it is becoming clear that those countries that made rapid and uncompromising decisions to take the virus seriously and impose severe restrictions on travel and social interactions, have done better in terms of health outcomes. What we now appear to be seeing is that the premature relaxation of such restrictions leads to a resurgence of community spread at well above any societally acceptable threshold.

But how has science really been used in making these decisions? In some countries there has been a plurality of disciplinary inputs from the outset. In others, the advice has tended to be more narrowly constrained. In choosing whether to foreground economic, behavioral, or sociological advice alongside public health and epidemiological advice in their responses, different governments are demonstrating their specific interpretations for the problem and its solution. What impact will such different interpretations and framings have as the global pandemic progresses into a more chronic phase.

"The pandemic has clarified the interpretive and critical appraisal skills required to support 21st Century policy-making."

Both the interpretive and institutional frameworks that countries hold are key in how they structure their responses. In this, the less technical (but no less crucial) skill of evidence brokerage can play an important role. In helping to frame decision-makers interpretation of the problem and its solution(s), having the capacity to bridge the political/science divide is essential, but it has proved very difficult in some contexts and both good communication and diplomatic skills may be necessary.

In some countries pre-existing mechanisms of science advice were used as the basis of the pandemic response. In others, no such mechanisms existed, and ad hoc mechanisms were rapidly developed. Indeed, the INGSA tracker shows that many developing countries rapidly embraced and deeply engaged their own scientific communities. It remains to be seen whether these newly developed mechanisms will trigger the development of institutionalized advice systems post-pandemic.

What has been the relative role of those scientists with formal appointments within the advisory system, whether preexisting or ad hoc, compared to whose advice has been more informal or through the media? How have they each contributed to shaping a particular interpretation or response? In some cases, conflicting advice appeared and scientific debates were soon politicized. There has been much reliance in some countries on formal models - but to what extent has the data used in these models and their interpretation been transparent? What disciplinary expertise helped inform the model? What assumptions were built into the model's algorithms and have they been subjected to formal or informal

peer review? Much scientific information regarding COVID has been only published in non-peer reviewed preprints: expedited peer review is yet to become the norm for many journals.

Has the extent of uncertainty been adequately communicated to the public and governments? Models, numbers and graphs have become the mainstay of communication collateral, but these models, by definition, have enormous assumptions and uncertainties. Are there the right tools to communicate those uncertainties effectively and honestly, when decisions must be made? It is not always commonly understood that models and raw data do not define reality, and that interpretation and judgements have been made at each step along this journey. For instance, the ongoing public debates in some places over the seriousness of COVID is a reflection of the failures of science communication on one hand and the politicization of information on the other.

We have seen how the pandemic itself has been politicized. The early exchanges between China and the USA, for instance, related to the origin of the virus had knock-on effects which have impacted the WHO. But beyond these diplomatic dimensions in several countries we have seen an extraordinary conflation of science, for example over mask-wearing, with partisan politics to the point that science-denial appears to now be a necessary test of political loyalty.

Misinformation and disinformation are exploiting this vulnerability and the longer-term implications of this situation are extraordinarily worrisome for the contract between science and society. Sadly, in some places the science of human health is being pitched as the enemy of business and economic health. Of course, this interpretation is manifestly wrong, but my fear is that its echo will have a long legacy and will fuel political resistance to the use of science in addressing other areas of collective action, from the challenges of climate change and environmental degradation to those of human development.

Regulatory processes and standards could be compromised by politics in the 'race' to be the first country to have a vaccine. Together with the capacity for misinformation to fuel distrust in vaccines, this will also no doubt fuel the anti-vax movement, with the result being a delay in the global retreat from pandemic status. Science advice, including regulatory science and science communication, will face real challenges in this context.

It is too early in the pandemic to reach conclusions on these and other issues, but they do highlight the complexity of the interface between science and public policy, especially in times of crisis. If nothing else, the pandemic has clarified the interpretive and critical appraisal skills required in 21st Century policy-making, all while juggling the impacts on societal values and the trade-offs that also need to be weighed. The question is whether the performance of the science community as advisors has shown the policy community the importance

NEXT GENERATION

CONNECTING AND GALVANIZING THE NEXT GENERATION THROUGH THE CSPC: A VOLUNTEER'S ANECDOTE

Andrew Ruttinger

PhD Candidate, Robert F. Smith School of Chemical and Biomolecular Engineering, Cornell University

I was not always pursuing a career in Canadian science policy. Rather, like many other PhD candidates in STEM fields, I found myself debating the often-posed question: industry or academia? Candidly, it is atypical for someone in engineering to follow a career trajectory in policy, so I was not exposed to the opportunities that go with it. To exacerbate this further, I was also studying in the United States, making me even more disconnected from the Canadian science policy realm. Despite this, my experience and mindset seemed to be passively guiding me in this direction. One of my primary motivations for enrolling in a PhD in engineering was to use my scientific expertise to bring about real change in Canada – to find creative solutions to modern problems. To me, it seemed the easiest route to this objective was to produce sound, novel scientific work. Yet, when I serendipitously became exposed to the idea of science policy through a new department initiative, it was like putting in the last piece of a puzzle, revealing the full picture. Yes, science begins in labs and offices, but scientific innovation flourishes when policy and decision-makers stand behind it. I was compelled by the idea that I could use my engineering background to be the critical link between scientists and decision-makers. At that moment, three thoughts crossed my mind: (1) Wait.. there's a third option for an engineering PhD? (2) Wow, what a great way to use an engineering background to help solve grand challenges! (3) This is perfect for me, how can I get involved?! Fortuitously, I quickly discovered that the answer to the last question was the Canadian Science Policy Centre (CSPC).

I am sure that many people would be able to point to several instances in their career and say, "these events made me grow and pushed my career forward to where I am now." I had those myself - my first research experience set me on a course to my eventual PhD, while working abroad in Germany broadened my perspective in my personal and professional life. However, patterns tend to be more satisfying when they follow the rule of three. Thankfully, I recently experienced my third career defining

"In a time of so much uncertainty, volunteering at the CSPC has provided me a stable foundation to rest on as I develop my career."

event by joining the CSPC. I am currently a first-year volunteer and a one-time attendee, having been a part of CSPC 2019, but the impact the CSPC has had on me cannot be overstated. Attending CSPC 2019 was like a jolt of energy: a refreshing, mentally stimulating, and eye-opening experience. Perhaps being in engineering so long had made me accustomed to the engineering environment, because the CSPC environment made me feel an unbridled wealth of diversity and opinions, led by passionate and focused individuals. I had the immediate sense that the CSPC was a welcoming community, unified by the goal to create a strong community for science policy in Canada. To me, that is the ethos of the CSPC, and that left an impression on me. Despite working in the United States, I felt like I was part of this community back in Canada. Despite coming from an engineering background, my perspective was welcomed as another part of this community's mosaic. Joining the CSPC as a volunteer earlier this year only further solidified that for me.

That was back in February, which for many people probably feels like years ago. In a time of so much uncertainty, volunteering at the CSPC has provided me a stable foundation to rest on as I develop my career. Science, policy, and society has ebbed and flowed more than ever, but the CSPC seems to have taken all this in stride. Coming from a technical background, I had a lot to learn about the policy side of science policy and my volunteering has been a highly rewarding learning experience. Much of this has been through listening – listening to people's experiences, listening to people's opinions. I had the opportunity to review editorials discussing Canada's current challenges and see our current world through the lens of experts across the science policy spectrum. I got the chance to be part of a team that looked at how the perception of science in Parliament has shifted as a result of the ongoing pandemic. With the pandemic in the backdrop, science has been put in the spotlight and volunteering at the CSPC has given me a first-hand account of its interplay with policy. As a professional, I have grown so much in such a short period of time, thanks to the steadiness of the CSPC through this period of turbulence.

If the new decade has shown anything in its first year, it is certainly that our challenges are only getting bigger and more complex. The climate crisis, national health, and equity, diversity, and inclusion are just some of these grand challenges that have been brought to the forefront. For this community though, each new challenge presents a new opportunity and learning experience. For me, I look forward to embracing these opportunities. I believe that science, more than ever, has an important role to play in how Canada comes out of the next decade. 2030 marks an important milestone for Canada's emissions reduction target: a 30% reduction below 2005 levels. It also marks the end of the 2030 Agenda for Sustainable Development. Certainly, there is no silver bullet to meet these objectives, but a science and evidence-based approach should be fundamental in Canada's strategy. The CSPC has positioned itself as a hub for Canadian science policy and based on my experience here, I think it will be instrumental in facilitating action. As someone early in their career, it has provided me the skills and opportunities to hit the ground running. The seeds were planted in the last decade and the CSPC is now educating entire generations of young professionals in Canadian science policy. This will need to be a decade of action and the science policy community is ready for the task. I am both eager and grateful to learn, develop my career, and take action alongside the CSPC and Canada, moving forward to 2030 and beyond.

THE IMPORTANCE OF FINDING YOUR "WHY" AS A YOUNG RESEARCHER

Emily De Sousa
Graduate Researcher and Travel Writer

When I first became involved in seafood and fisheries work, I read every book, journal article, and report that I could find. I wanted to know everything, so that I could use facts and data to back up my arguments.

What I learned however, was that no matter how convincing or reputable the facts were, people don't respond to numbers and statistics.

This is true with anything, but even more so with seafood. If you're not near an ocean, seafood is not usually top of mind. I could scream facts at people until I was blue in the face, but it wouldn't make a difference. Without a personal relationship to seafood, people remained disconnected and uninspired to change.

It wasn't until late into my undergraduate degree that I realized that my approach to changing the seafood policy landscape was all wrong. I was explaining to a colleague what I hoped my graduate research would focus on: restructuring seafood value chains, supporting more transparency in the industry, and getting people to consume more locally-source seafood.

This simple question changed everything about the way I approach research and science policy: "How did you get into that?".

I proceeded to share the story of my upbringing. I was raised by two Azorean parents in a large, Portuguese family that centered gatherings around seafood. I explained the cultural significance of seafood products to my family and the economic significance of seafood

consumption to small fishing communities, like the ones on the islands that we call home.

I noticed a look on this person's face that I'd never seen before when explaining my research goals with data and facts. It was a look of curiosity, interest, and an eagerness to learn more. They had been nodding along politely before, but when I started sharing my personal story, their entire demeanor changed. Their eyes got a little wider and they leaned in closer, as if they were scared to miss a single word.

By sharing my "why", I created a unique connection that can't be cultivated with scientific data. And suddenly, I had their full attention.

This was the lightbulb moment for me. The way to connect with people was not to tell them what I do, it's to tell them why I do it. These personal narratives offer more comprehension, interest and engagement.

So when I submitted my policy proposal for the 2019 CSPC Youth Award of Excellence, I led with my personal narrative. Before I explained the issues of seafood fraud in Canada, I shared why good seafood policy mattered to me. I told stories from my childhood and personal experiences with seafood. I shared that in the Azores it's common practices to pull limpets of volcanic rocks. I told stories of spending Christmas peeling mountains of shrimp with my cousins. And I asserted that every fisherman I'd ever met was the biggest defender of the ocean.

Not everybody is as passionate about seafood as me, but everybody has a family to feed and cultural traditions that they value. Finding this common ground in my own work and the life of a stranger is how I'm able to communicate what I do in a way that resonates with them.

The 2019 CSPC Awards Gala remains one of the most memorable nights of my life. I particularly remember two selection committee members approaching me at different points in the evening to express their appreciation for my personal story in my policy proposal. "I really liked that you talked about your family background and why this was important to you. It made your submission very impactful."
As researchers, we talk a lot about impact and I am a firm believer that if you want to maximize impact, you need to tell stories. Maximum impact results from human connection.

"This was the lightbulb moment for me. The way to connect with people was not to tell them what I do, it's to tell them why I do it."

My experiences at CSPC further validated the role of storytelling in the science policy landscape. Winning the 2019 Youth Excellence Award inspired me to work even harder to promote cross-sector communication in my own work. Since winning the 2019 CSPC Youth Excellence Award, I've been co-hosting a podcast with my advisor Dr. Phillip Loring and colleague Dr. Hannah Harrison. Here, we use the power of storytelling to share experiences of fishermen from around the world. We show our listeners how seafood harvesters are dealing with the impacts of COVID19 on their seafood business.

I've also combined science, policy, and storytelling in my online travel business. Here, I connect with people around the world online to share unique culinary experiences and advocate for change in our global food systems and tourism industry.

In my graduate research, storytelling remains the glue that holds the interviews, data sets, and manuscript drafts together.

It's time that we rethink the way we approach research and science policy. Young researchers should be encouraged and supported in finding their "why" and using it to improve their work in science policy.

The science policy nexus is a critical partnership that CSPC has done an incredible job of nurturing in Canada. I propose that a third facet be added to this collaboration to strengthen the impact of the work of scientists and policy makers in Canada.

Storytelling.

Why does science policy matter? Why does it matter to scientists and policy makers? And why should it matter to the rest of Canadians?

We talk about evidence-based policy, but policy makers are people too. As we've witnessed in responses to climate change and a global pandemic, many people don't act based on science. Science alone isn't enough. Establishing a human connection through storytelling allows us to tap into human values and build a stronger connection with decision makers. This connection is the key to driving policy change in Canada.

A common phrase in the marketing industry is, "people don't buy what you do, they buy why you do it". This same concept can be applied to policy. By combining scientific data with stories that cultivate a personal connection, science policy can move the needle in Canada like never before.

The stories behind the science policy decisions need to be told. I urge young researchers to focus on this right from the beginning. Get to the bottom of why you do what you do.

Everybody has a story and your story is powerful. Start telling it.

THREE'S A CROWD: A CHALLENGING BLEND OF WORKSPACES, SOCIAL MEDIA, AND PERSONAL IDENTITY DURING COVID-19

Fatou Sarr

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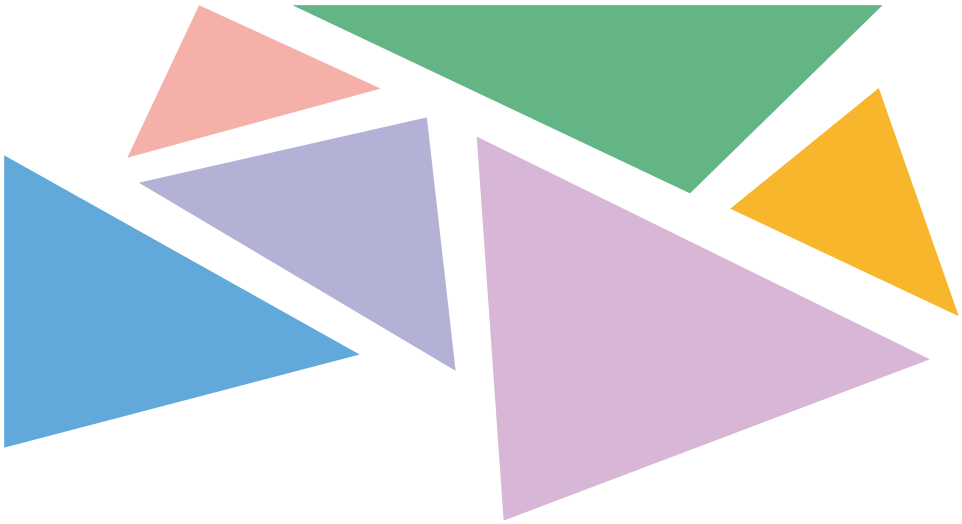
It is quiet. As a PhD student in cognitive psychology, my mornings consist of answering emails and starting work at a medium pace. As I answer work related messages on social media, the quiet continues. Until suddenly, another act of violent racism, murder, and tragedy is filmed, forwarded, and plastered onto my social feed. My reactions are sometimes public comments or expressions, but more often than not, they are taking place internally. As a painful storyline is reactivated, it is accompanied by physical sensations like increased heartbeat with a mixture of sadness, anger, and guilt; sometimes it is also impossible to label those feelings. Usually, avoiding the apathetic comment sections helps get rid of the physical reactions quicker. Once I regain my physical composure, I return to the social media networks, complete my work-related tasks, and then log off. As I return to my inbox, the quiet returns.

This routine is familiar to many graduate students, as COVID-19 prompted swift university closures and the removal of physical gatherings in public spaces. Life saving measures were taken and people were told to remain indoors for months on end, and this process is starting once more. Consequently, universities began relying on Facebook, Instagram, Twitter, and other social platforms, to ensure that contact with students would not completely disintegrate. Alongside the increased reliance on social platforms was the unintended consequence of work interactions on social platforms. Previously, students could manage their exposure to verbal and visual violence against visible minorities (e.g.., Black, Indigenous, and People of Colour (BIPOC)) by not opening these platforms. In fact, it is a well-known recommendation in the BIPOC community to conserve one's mental health



by reducing the amount of trauma exposure via social media. Now, in order to complete work tasks and maintain communication, students must utilize these platforms to avoid falling behind. Exposure to online trauma has already been linked to negative mental health outcomes such as increased fatigue and anxiety. With visible minorities already at a higher risk of experiencing discrimination and violence, these risks are inherently transferred to social platforms via visual and verbal materials students unequivocally encounter. Unfortunately, there was no time during the pandemic to develop safe communication strategies or design alternative platforms.

Managing the intersections of virtual spaces as permanent work spaces is particularly challenging in a post-COVID-19 world. It is worth mentioning that some social platforms have created accessible and transformative spaces that are catalyzing action plans against systemic oppression within work spaces as well. One of those spaces is the Canadian Science Policy Centre (CSPC). When I started volunteering for the 2019 CSPC conference, I was prepared to help contribute to a scientific policy conference, without any expectations as to what science policy work involved. What I was not prepared for was the feeling of surprise experienced by partaking in multiple meeting spaces with numerous visible minorities. This feeling of apparent shock allowed me to reflect upon my own expectations of what diversity in the work space was, as I had become accustomed to expecting to be the only visible minority in a room.

However, as a member of the program committee, it was CSPC's evaluation criteria of the panels that I did not expect. CSPC's evaluation criteria rewards the diversity of panel participants, to ensure that gender, sector, discipline, geography, ethnicity, and age are carefully considered. By doing so, the program committee helps create a conference where the leading science and policy voices reflect the society they service. The value that CSPC places on individuals as a whole is exponentially more rewarding and valuable than the formulaic reduction of a person to just their scientific knowledge. By drawing upon a variety of perspectives, the CSPC conference panels have a higher chance of creating innovative solutions that are applicable to a diversity of challenges. By publicizing the evaluation criteria and incentives for diversity, CSPC's stance on inclusion and equity within their scientific platform is made transparent, and helps alleviate systemic barriers within scientific spaces. During my research career, I have participated in numerous conferences as both an organizer and presenter. CSPC is a unique conference with a system that is actively creating solutions for visible minorities and marginalized groups, on every platform. From this experience, I have a new intrinsic motivation to ensure that all my future research endeavours are embedded with inclusive policies.

To effectively manage systemic barriers within research and work spaces, I believe that one crucial step is to increase the opportunities for collaborations between graduate researchers and policy makers. This strategy is clearly modeled by

the CSPC conference. Early career opportunities for collaboration capitalize on the strengths of graduate researchers, such as program development and strategic analysis. The current experiences of graduate students can foster policies that tackle relevant challenges, such as the negative impacts of repeated exposure to systemic violence online to visible minority students during COVID-19. These unprecedented challenges demand policies that protect the welfare of students; for example, specialized and active mental health systems in all graduate studies (to name a few).

Policies can provide visible declarations against racism and encourage better practices to support vulnerable students by acknowledging the importance of their personal identities within the workplace, both in the creation and production of new knowledge. In this vein, policy work is essential for guaranteeing the success of all graduate students within higher education. For example, granting agencies have begun to create policies that enforce equity, diversity and inclusion (EDI) requirements on review boards. Through policy work, granting agencies can reduce the systemic oppression present during grant application reviews while holding institutions accountable. There are many opportunities to ensure that EDI plans are upheld by institutions, but EDI centered policies are critical to the success of EDI endeavours at every level of the higher education system.

Following my first year with CSPC, the inclination I had towards science policy has now solidified into my personal goal of creating a future career in science policy. Currently, I am working towards my career goals by contributing my research skills to the development of new EDI policies at the University of Ottawa. For example, a small group of students, including myself, are preparing to present an EDI recommendations report to our Faculty. This report focuses on the systemic barriers within the psychology program and solutions, such as admissions policy recommendations. As a returning CSPC volunteer, my experiences with CSPC have solidified the belief that scientific communities cannot grow in isolation. Universities and their linked systems and organizations should not be viewed as separate agents whose role is to only synthesize knowledge and completely abstain from social commentary. Indeed, the higher education system is entirely enmeshed in current events and their success is made relevant by how it “maximizes the greatest amount of good for the greatest number”1. The above-mentioned examples of proactive policies would ensure that students already burdened with systemic racism and oppression are properly supported, while simultaneously creating a more inclusive majority student population. With EDI policy work, higher education systems can start to address and manage the current mental and physical needs of visible minority and marginalized students, so that their identities are no longer separate from their educational success.

FOOTNOTES:
Jeremy Bentham, English philosopher (1748–1832)

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