# SHARPENING OUR COMPETITIVE EDGE: **Positioning Ontario's Research Funding Programs for the Future**



MAY 2018

Ministry of Research, Innovation and Science

# Message from the Panel

Dear Minister:

We are pleased to submit the final report of the Ontario Research Fund Expert Review Panel. Our mandate was to review the design and delivery of Ontario's three competitive research support programs: Early Researcher Awards (ERA), Ontario Research Fund-Research Excellence (ORF-RE), and Ontario Research Fund-Research Infrastructure (ORF-RI). We were also tasked with providing advice on how the programs should adapt to new approaches and opportunities, with a focus on supports for early and mid-career researchers.

Underlying our review was a central assumption that a robust and competitive research environment is vital to the growth and development of Ontario's advanced economy.

Our approach took into consideration our collective experience as a panel of academic researchers, the available data on outcomes and impacts, and the feedback from key stakeholders.

Our main finding, supported by the feedback, is that the three competitive research programs are well designed and continue to have the desired focus and the desired impact. Furthermore, over the past 15 years they have made a strong contribution to the province's research and innovation system.

But what about the next 15 years or longer? That is the kind of timeframe that applies to building capacity in research excellence, growing the talent pool of researchers, and on using the research outcomes to make the most impact for the good of society and the economy. It follows the proverbial Canadian aphorism: we need to skate to where the puck is going, not where it has been.

Ontario can rightfully claim to have a world-class research and innovation system. Our recommendations build on that success, to ensure that the level of investment over the long term is sufficient to maintain Ontario's competitive edge into the future.

We believe that the commitment to research excellence must remain paramount. However, the three competitive research programs can be improved by making them more accessible, more open to all disciplines and better communicated to the research community. We also found a gap in information about the diversity of Ontario's research talent pool. Given the outstanding quality of research in Ontario, it is very important that funding levels keep pace with the rising cost of doing cutting-edge research and federal research investments, while the requirements for obtaining matching support from industry and other sources be relaxed in some cases. We believe that making additional investments will position Ontario to better leverage the new investments by the Government of Canada.

We recommend that the "Ontario First" approach in federal co-funded projects be retained but used as a provincial strategic review process in advance of the federal adjudication where possible.

Finally, we recommend that the Ministry take all the necessary steps to streamline the application and reporting process, thereby reducing the administrative burden on applicants.

We are grateful for the opportunity to provide our advice on the future directions of Ontario's three competitive research programs. We would be pleased to meet with you and to discuss our recommendations further.

#### **Ontario Research Fund Expert Review Panel**

- Dr. Elizabeth Cannon, Co-Chair
- · Prof. Benjamin Geiger, Co-Chair
- Dr. Isabelle Catelas
- Dr. Usha George
- Dr. Amir Khajepour
- Dr. Ted Sargent
- Dr. Steven Rothstein
- Dr. Rui Wang



# Message from the Honourable Reza Moridi

O n behalf of the Ministry of Research, Innovation and Science, I would like to thank the Ontario Research Fund (ORF) Expert Review Panel, as well as Dr. Cannon and Professor Geiger for their leadership in delivering this timely report.

The ORF is an important part of Ontario's scientific and research community. The ORF's streams fund operations and the state-of-the-art facilities our researchers need to advance projects that will help shape Ontario's future economy. I am pleased to learn about the ways we can improve these programs through the insights put forward in this report to ensure we meet the needs of our researchers at every stage of their career.

This report marks the completion of an important part of my ministry's mandate to evaluate the effectiveness of our research programs and inform future research initiatives. Since 2003, ORF projects have leveraged \$4.7 billion in funding and helped create more than 103,000 training opportunities. We welcome the panel's recommendations so we can build on this success and continue to attract the world's best scientists and innovators.

Once again, thank you to the panel for your insights, time and dedication to this report. I look forward to reviewing these recommendations so we can continue to support the next generation of Ontario researchers.

Sincerely,

Reza Moridi Minister

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# **ORF** Review panel members



#### **CO-CHAIR: DR. ELIZABETH CANNON**

President and Vice-Chancellor, University of Calgary

Elizabeth Cannon is President and Vice-Chancellor of the University of Calgary, and a professor in Geomatics Engineering with expertise in GPS and navigation technologies. She is Past Chair of Universities Canada and is a Fellow of the Royal Society of Canada.



### **CO-CHAIR: PROF. BENJAMIN GEIGER**

Professor, Dean of the Faculty of Biology, the Weizmann Institute of Science, Israel

Prof. Geiger served as President of the Israel Cell Biology Organization, the Israel Society for Microscopy, the European Cytoskeletal Forum, and various other scientific initiatives. He chaired the Life Science and Medicine Section of the Israel Science Foundation (ISF), the major funding source for basic research in Israel between 2003 and 2009, and since 2009 he serves as the ISF Chair.



### **DR. ISABELLE CATELAS**

Associate Professor and Canada Research Chair (Tier 2) at the University of Ottawa

Isabelle Catelas is an Associate Professor in the Department of Mechanical Engineering at the University of Ottawa, with cross-appointments to the Department of Surgery and to the Department of Biochemistry, Microbiology and Immunology at the Faculty of Medicine. She holds the Tier 2 Canada Research Chair in Bioengineering in Orthopaedics. She worked for Baxter International Inc. in Research and Development after receiving her Ph.D. in 2002, and joined the University of Ottawa in 2008.

# **ORF** Review panel members



## **DR. USHA GEORGE**

Professor, Faculty of Community Services, Ryerson University Since 2017, Dr. George is the Director of the Ryerson Centre for Immigration and Settlement, after completing terms as the Dean of the Faculty of Community Services and the interim Vice-President, Research and Innovation at Ryerson University. Her area of research and scholarship is Migration Studies.



### **DR. AMIR KHAJEPOUR**

Professor, University of Waterloo

Amir Khajepour is a Professor in the Department of Mechanical and Mechatronics Engineering at the University of Waterloo. He holds the Tier 1 Canada Research Chair in Mechatronic Vehicle Systems, and Senior NSERC/General Motors Industrial Research Chair in Holistic Vehicle Control.



## **DR. STEVEN ROTHSTEIN**

Professor, University Research Chair, University of Guelph

Dr. Steven Rothstein is a Professor in the Department of Molecular and Cellular Biology at the University of Guelph. His main area of study is to use genetics and genomics technologies to develop crop plants having better to tolerance to environmental stresses like drought.

# **ORF** Review panel members



## **DR. TED SARGENT**

Vice-President International, University of Toronto

Ted Sargent holds the rank of University Professor at the University of Toronto and the Tier 1 Canada Research Chair in Nanotechnology and Photonics. His research includes applications in communications and computing, medicine, and energy. He has also founded or co-founded two start-up companies, InVisage Technologies and Xagenic.



#### **DR. RUI WANG**

Vice-President Research, Laurentian University

Dr. Wang has been Vice-President Research of Lakehead University (2004-2014) and Laurentian University (2015-). He is also an international leader in biomedical study of hydrogen sulfide (H2S), holding concurrent research grants from all of the tri-agencies as the principal investigator.

# Acknowledgements

The Expert Review Panel for the Ontario Research Fund (ORF) Review was given a mandate to conduct a strategic review of the Ontario Ministry of Research, Innovation and Science (MRIS) competitive science and research support programs. This review would not have been possible without the full cooperation from participants from across the province representing the spectrum of stakeholders involved in ORF programs. This included researchers, academic and health care system leaders, industry partners as well as key associations such as Ontario Council on University Research (OCUR), Ontario Council on University Research (CAHO) and Colleges Ontario. The Panel is grateful to these stakeholders for their engagement in the consultation process which comprised a critical foundation to the review.

Support from the Ontario Research Fund Advisory Board (ORFAB) was very helpful to the Panel. Dr. Jack Gauldie, Chair, and Dr. Kim Woodhouse, Vice Chair, gave valuable insights to the ORF programs on behalf of ORFAB including areas for consideration by the Panel to increase the programs' impacts for the future. In addition, feedback from Dr. Molly Shoichet, Ontario's Chief Scientist, was appreciated and valued.

Federal partners in the research funding ecosystem are thanked for their contributions to the consultation process. Their participation was important given the federal/provincial co-funding model for several programs and also due to the recent investments made by the Government of Canada in science and research which will shape future co-funding and complementary opportunities. Specifically, the Canada Foundation for Innovation (CFI), the Ministry of Innovation, Science and Economic Development (ISED) and Genome Canada (GC) are acknowledged.

The Panel would like to particularly thank the Secretariat which supported this review with tremendous professionalism and dedication. The work was done under tight timelines which required significant focus and coordination. The thorough analysis and consolidation of the consultation feedback, along with the development of several working papers on issues and opportunities for consideration, allowed the Panel to direct their energies and discussions on the assessment of the information and the development of key recommendations. Members of the Secretariat from the MRIS included Greg Wootton, Assistant Deputy Minister, Katherine Kelly Gatten, Director, Kevin Dilamarter, Manager, Mima Vulovic, Manager, David Garkut, Senior Advisor (Statistics), Stephanie Todorovski, Senior Advisor, and Jenna Oldham, Senior Advisor. Barb Brownlee, Senior Policy Advisor, is specifically acknowledged for her leadership and coordination of the Panel's overall work flow, including agendas, timelines and policy discussions. Finally, Morris Ilyniak, Writer, is thanked for distilling and capturing the Panel's discussions and recommendations into the various drafts for review as well as the final report. The Panel owes a debt of gratitude to the Secretariat for making the process both enjoyable and rewarding.

# Summary of recommendations

**Recommendation 1:** Maintain the Ontario Government's pivotal role in research support for the academic sector

**Recommendation 2:** Increase the funding levels of the three programs to keep pace with the cost of doing research and expanded federal research investments

**Recommendation 3:** Update the Ontario Innovation Agenda, including definitions of primary future focus areas and commitment to supporting early and mid-career researchers

**Recommendation 4:** Continue to leverage federal co-funding of research projects with an "Ontario First" approach under ORF, using a provincial strategic review process in advance of the federal adjudication where possible as a filter to ensure that the best Ontario proposals are put forward to federal co-funding programs

- a. Ensure there is no duplication of federal adjudication processes for Ontario projects eligible under the Canada Foundation for Innovation and other federal programs
- b. Take steps to make the Ontario First commitment for provincial matching of federally-funded research projects more predictable for potential applicants

**Recommendation 5:** Consider some strategic changes to ORF-RE without compromising the program's strong commitment to research excellence

- a. Review the upper limit of ORF-RE funding on a regular basis and raise it as required to keep pace with the increasing cost of research
- b. Communicate to Ontario researchers that ORF-RE is open to all disciplines and types of research that generate societal and economic benefits to Ontario, not just commercial benefits, and that there are options to use matching funding various sources including philanthropy

**Recommendation 6:** While maintaining research excellence as the first priority for funding, make ORF-RE more accessible and inclusive of a broader spectrum of researchers at different career levels, institutions and disciplines by piloting of a new ORF-RE funding stream with a smaller award and fewer matching requirements

**Recommendation 7:** Maintain the current success rate of ERA applications, while broadening eligible expenditures

**Recommendation 8:** Develop and implement a communications plan targeted at raising researchers' knowledge and awareness of Ontario's research funding programs

**Recommendation 9:** Collect information on the diversity of applicants and success rates for statistical purposes only

**Recommendation 10:** Adopt the federal "Tri-Agency Open Access Policy" on research data and publications

**Recommendation 11:** Take steps to further support and strengthen peer review panels by ensuring that the peer review panel members possess the expertise necessary to evaluate proposals **Recommendation 12:** Streamline, clarify and redesign the application and reporting processes to reduce the administrative burden for researchers, while ensuring fairness, transparency, excellence and accountability

- a. Accelerate implementation of an online application process
- b. Simplify and streamline information about program guidelines and requirements
- c. Continue to implement changes to the application process which reduce the amount of time and effort required for researchers and institutions to complete applications
- d. If necessary, collect project information on the funding of basic vs. applied research for statistical purposes only
- e. Work with federal government, provincial partners and philanthropic sector to develop a coordinated approach to measuring outcomes and their attribution to contributed effort and resources



# Chapter 1 INTRODUCTION

# 1.1 Purpose

The Ministry of Research, Innovation and Science has three competitive programs that support world-class academic research at its universities, colleges, and research hospitals: Early Researcher Awards (ERA), Ontario Research Fund – Research Excellence (ORF-RE) and Ontario Research Fund – Research Infrastructure (ORF-RI). Our mandate as the expert review panel is to advise the Minister of Research, Innovation and Science on the current design of these programs, their breadth and effectiveness, as well as gaps and how to address them. More specifically, we have attempted to answer these key questions:

- · Is the program design doing what it intended to achieve?
- · Does it still have the right focus?
- · Is it having the desired impact?
- · Are there programmatic gaps?

In addition, we have been tasked with advising on how the programs should adapt to new approaches and opportunities, with a focus on supports for early and mid-career Ontario researchers. Our mandate was to undertake the review within the current fiscal allocations for the programs.

In this report, we present our findings based on our review of available data collected by the Ministry of Research, Innovation and Science and the feedback received from consultations with stakeholders. We summarize our conclusions with recommendations in the final section.

# 1.2 Methodology

Based on our expertise and international experience as academic researchers and administrators, we reviewed Ontario's programs according to what we considered to be best practices and current trends in research support programs. We asked: what does an effective research program look like? The literature indicates that various approaches to reviewing research programs have been proposed in the past, but that there is not a consensus on any one. Therefore, as a framework for our analysis, we developed a set of key attributes of an effective research support program or suite of programs (see below).

# 1.3 Six key attributes of effective research support programs



#### **EXCELLENCE AND INNOVATION**

While mindful of the societal relevance and value of a particular research project, the program must give equal priority to research selected for its contribution to the breadth and depth of knowledge in a particular field of study. This means that a project is evaluated and selected fairly and objectively by independent experts in a field of study according to its highest and most current standards of research excellence. Nonetheless, inherently risky projects should also be rewarded for being innovative and disruptive of current knowledge.



#### **TALENT AND TEAMS**

The program should create opportunity and access for researchers from diverse backgrounds and stage of career development to advance their career mobility in their chosen field of study, institution and broader labour market. Not only should it foster teams of excellence that support principal investigators, the program also must generate opportunity for entry-level researchers to participate in such teams.



## **CONNECTIONS AND NETWORKS**

The program builds the capacity of institutions, researchers and research teams to establish effective linkages, interactions, networks and collaborations with key innovation actors, including other researchers, institutions, governments, and firms, from the local to the global scale; and, across disciplines. If done effectively, these linkages will open informal and formal channels of knowledge flow between the key innovation actors, including knowledge embedded in technologies and intellectual property.



## **TECHNICAL AND FINANCIAL SUSTAINABILITY**

The program sustains the equipment, facilities and other infrastructure, including databases and computers, which are critical to the success of a research project. Equally important is that the program cover the indirect (overhead) costs of research conducted at an institution. These may include, but not limited to, additional administrative, security, procurement, library, custodial and legal costs created by the research enterprise.



## **OUTREACH AND PUBLIC ENGAGEMENT**

The program communicates the results of the research projects; and, provides opportunities for outreach involving researchers with the broader community, especially youth. The objective of public engagement is to help encourage, create and disseminate a "culture of science".



## ADMINISTRATIVE EFFICIENCY AND ACCOUNTABILITY

Every funding program requires a certain amount of paperwork over the lifecycle of a project: from application through to completion, often to demonstrate accountability for public expenditures. But administrative aspects of a project should not discourage applications or create an unnecessary barrier to project success. The list of attributes was kept to a manageable number of six which underpinned the following question: How well does the design of the three research support programs, taken together or separately, stack up against these six key attributes?<sup>1</sup>

Another aspect of our analysis was to review the outcomes and impacts of the three programs. It is not enough, however, to do a straight count of outputs such as how many papers, patents and startups are generated, although these are important indicators of success.

Because impacts cannot be measured directly, we used our best judgment based on the available information to assess how well the three programs have contributed to strengthening Ontario's innovation system within which the publicly-funded research institutions and their people play a vital role. In other words, how well do these programs support the role that publicly-funded research institutions perform with Ontario's innovation system? Are they relevant to the needs of the institutions or are there gaps in the program design and delivery that need to be addressed?

As part of our analysis, we relied on the ministry's databases for information about project applications, those that were funded and those that were not; and the data generated from annual project reports for each program. We also consulted with, and reviewed the input and experience from, a broad range of academic researchers and administrators in Ontario's universities, colleges, and teaching hospitals; and from different disciplines and different stages in their careers, including those that were unsuccessful at obtaining funding support through the three programs. In summary, our review encompassed an analysis of both quantitative and qualitative evidence.

There are two limitations to our approach. First, it is very difficult to compare Ontario's three research programs to other jurisdictions. Every jurisdiction has a different economic, political, social and cultural profile, and unique challenges that would need to be taken into account. While keeping in mind best practices for research support, it was not possible to make a meaningful comparison of ERA and the two ORF programs with those in other jurisdictions.

<sup>&</sup>lt;sup>1</sup>We realize that not all of the attributes apply equally to all three programs; and, some may not apply at all. For example, the attribute of "talent and teams" has a higher priority for ERA than ORF-RI. That is why in our analysis we look at the programs individually and as a collective.

Second, it would have been constructive to have data from the three programs that could feed into a "logic model" measuring input, output, outcome and socioeconomic impact; and that the model would allow one to benchmark performance and isolate the impacts of the three research programs from other programs and activities, such as R&D conducted by business. The Council of Canadian Academies has developed such a model for government investments within Ontario's innovation ecosystem but did not find sufficient and reliable data to operationalize it.<sup>2</sup> While we agree that the collection and analysis of detailed data is essential for a more robust program evaluation, and worthwhile for the Ministry to consider, it was not a feasible undertaking within the timeframe of our review.

We wish to acknowledge the important contribution to the discussion on government support to science made by Canada's Fundamental Science Review, chaired by Dr. David Naylor, the former President of the University of Toronto. The review panel released its report in April 2017.<sup>3</sup>

In response to the review panel's report, the federal government in its Budget 2018 announced an investment of nearly \$4 billion in Canada's research system to support the work of researchers and to provide them access to the state-of-the-art tools and facilities they need.<sup>4</sup> Ontario will benefit from this investment, by helping to support a new generation of researchers that is larger and more diverse.

Our review also applied some of the recommendations from their report to focus on particular areas for the province to consider for improving its research programs. For example: Do Ontario's programs generate high-risk, high-impact research outcomes? Do they achieve the right balance of support for early and mid-career researchers; between "investigator-led" and "priority-driven" research<sup>5</sup>; and/or basic and applied research<sup>6</sup>? What is the value proposition of industry participation?

- <sup>4</sup> Government of Canada. (2018). *Equality and Growth: A Strong Middle Class* (Budget 2018). Government of Canada, Ottawa.
- <sup>5</sup> Advisory Panel for the Review of Federal Support for Fundamental Science. (2017). *Investing in Canada's Future: Strengthening the Foundations of Canadian Research, Canada's Fundamental Science Review.* Government of Canada, Ottawa. pg. vii.
- <sup>6</sup> This is an issue that the Office of the Auditor General of Ontario recommended the Ministry explore in Office of the Auditor General of Ontario. (2015). *Annual Report 2015*. Chapter 3.14: University Intellectual Property. <u>auditor.on.ca/en/content/annualreports/arreports/en15/3.14en15.pdf</u>. pg. 555.

<sup>&</sup>lt;sup>2</sup> Council of Canadian Academies. (2013). *Innovation Impacts: Measurement and Assessment Ottawa: The Expert Panel on the Socioeconomic Impacts of Innovation Investments,* Council of Canadian Academies.

<sup>&</sup>lt;sup>3</sup> Advisory Panel for the Review of Federal Support for Fundamental Science. (2017). *Investing in Canada's Future: Strengthening the Foundations of Canadian Research, Canada's Fundamental Science Review.* Government of Canada, Ottawa.

# 1.4 On the importance of academic research

Underlying our review is a key assumption that a robust academic research environment is vital to the growth and development of Ontario as an advanced economy. Not only does it open new frontiers of fundamental knowledge and understanding, it contributes to our quality of life by generating ideas for addressing major societal challenges: from climate change to cancer, from homelessness to urban transportation, and much more.

At the same time, we agree with Canada's Fundamental Science Review Panel that the quest for new knowledge must remain free to pursue all channels of inquiry from the theoretical to the applied, as its long-term impacts are difficult to predict:

While the work of full-time researchers in Canada and abroad is sometimes viewed as arcane, it is grounded in traditions of science and inquiry that have transformed our world for the better in recent centuries. These impacts have often been entirely unpredictable, as diverse discoveries were forged into inventions that catalyzed the creation of whole new economic sectors, or startling insights from social research coalesced into broad shifts in the evidence base for public policy.<sup>7</sup>

A sustainable environment for academic research also helps to inspire and cultivate brilliant minds. These are the promising undergraduate students who become graduate students; and who, in turn, must be supported to become researchers and innovators, with many becoming principal investigators in their own right – leading collaborative teams of other researchers and students, sometimes across international borders.

<sup>&</sup>lt;sup>7</sup> Advisory Panel for the Review of Federal Support for Fundamental Science. (2017). Investing in Canada's Future: Strengthening the Foundations of Canadian Research, Canada's Fundamental Science Review. Government of Canada, Ottawa. p. 18.



## **HIGHLY QUALIFIED PERSONNEL**

Highly Qualified Personnel (HQP) is a term used by the Ministry to define the people who are being trained with leading-edge research skills through its programs to create the stock of people that companies, not for profits, post-secondary education institutions and research hospitals are looking to hire. They are mostly students who are completing their Honours Bachelor, College, or Master's degrees, Doctorate degrees, as well as Post-Doctoral Fellows, Research Scientists and other members of the research team such as lab assistants. These individuals comprise the top research talent Ontario is known for.

As research in the 21st Century is increasingly global, the ministry should continue to develop Ontario's capacity for international collaboration between local researchers and their international counterparts. By leveraging its current suite of research funding programs, the province can improve access to top tier global resources, enhance its reputation as a first-rate international research destination and, in doing so, position itself as a key player in the knowledge economy of the future.

This wealth of culturally-diverse research talent leverages public and private investment and brings international recognition to Ontario's publicly funded 21 universities, 23 research hospitals, and 24 colleges. Many researchers go on to fulfilling careers in business, government, and community organizations. Some establish new companies for commercializing innovative technologies. They are also the role models for a future generation of researchers in Ontario. While society places a high value on scientific knowledge and progress, it must be matched with a strong and sustainable commitment to fostering top research talent and excellence in research. In recognition of this commitment, we are heartened by the appointment in November 2017 of Dr. Molly Shoichet as Ontario's first Chief Scientist, to advise the Premier on how to make government smarter and more effective by providing decision-makers with the world's best scientific research and evidence and growing the province's reputation as a global destination for top research talent.

## EARLY AND MID-CAREER RESEARCHERS

What do we mean by researchers in their early and mid-stages of career? How many of these researchers are there in Ontario? What do we know about their age or gender profiles?

Many government-funded research support programs define the stages of a researcher's career by the number of years since they received their doctorate or worked as an independent academic (i.e. someone who is already in the position of independently publishing, supervising, and applying for funding). Under Ontario's Early Researcher Awards program, for example, an early-career researcher is someone who has worked under five years as an independent academic and is within 10 years from completing their doctorate, D.V.M or M.D. This does not reflect a universal standard across jurisdictions, or even among institutions.

# 1.5 Some key considerations

Based on our collective experience and the excellent work undertaken by the federal Fundamental Science Review, we focussed our review on some of the key challenges facing Ontario's research programs – which are not entirely unique to Ontario.

One such challenge is ensuring that Ontario's research programs are effective in building the province's research talent; that it provides the right kind of opportunity and support for academic researchers starting out to grow in their careers based on a reputation of research excellence. The preliminary evidence suggests that the programs are effective at helping researchers in their early and senior-career stages, but may not adequately address the needs of mid-career researchers.

Society loses valuable talent if researchers in the early and middle stages of their academic career become discouraged to the point of abandoning their chosen career path altogether. This also makes it more challenging to encourage undergraduate and graduate students to choose the path of an academic researcher.

YEAR	FULL PROFESSOR	ASSOCIATE PROFESSOR	ASSISTANT PROFESSOR	BELOW ASSISTANT <sup>9</sup>	OTHER	TOTAL
2005-06	4,342 (31.5%)	4,439 (32.2%)	4,131 (30.0%)	N/A	870 (6.0%)	13,782 (100.0%)
2016-17	5,274 (32.9%)	6,309 (39.4%)	3,027 (18.9%)	1,185 (7.4%)	228 (1.4%)	16,023 (100.0%)

 Table 1: A statistical profile of academic faculty in Ontario's universities, according to rank, 2005/06 and 2016/17<sup>8</sup>

Description: Table 1 provides a breakdown of researchers in Ontario universities according to rank (Full Professor, Associate Professor, Assistant Professor and Below Assistant), comparing data from 2005/06 to data in 2016/17.

<sup>&</sup>lt;sup>8</sup> Statistics Canada. (2017). CANSIM 477-0017. Ottawa; Council of Ontario Universities. <u>cou.on.ca/numbers/multi-year-data/faculty/</u> for 2005-06 data.

<sup>&</sup>lt;sup>9</sup> Rank or level below assistant professor includes lecturers, instructors and other teaching staff.

We are also concerned about the diversity of Ontario's research workforce. The available data indicate that Ontario's pool of academic research talent has grown by 16% between 2005-06 and 2016-17. It remains male-dominated, although there has been modest rise in the percentage of female academics since 2005-06 with variability in gender distribution by discipline (see Table 2).

**Table 2:** Percentage of female academic faculty in Ontario's universities, according to rank, 2005/06 and 2016/17<sup>10</sup>

YEAR	FULL PROFESSOR	ASSOCIATE PROFESSOR	ASSISTANT PROFESSOR	BELOW ASSISTANT <sup>11</sup>	OTHER	TOTAL
2005-06	19.8%	35.7%	42.1%	54.9%	62.5%	33.9%
2016-17	27.1%	43.5%	47.4%	49.1%	57.9%	39.4%

Description: Table 2 provides the proportion of female researchers in Ontario universities according to rank (Full Professor, Associate Professor, Assistant Professor and Below Assistant) in 2005/06 and 2016/17.

<sup>&</sup>lt;sup>10</sup> Statistics Canada. (2017). CANSIM 477-0017. Ottawa.

<sup>&</sup>lt;sup>11</sup> Rank or level below assistant professor includes lecturers, instructors and other teaching staff.

Like the rest of Ontario society, it is also aging. The median age of a full professor is 58 years (see Table 3). The percentage of full-time faculty over 65 has increased over 10 years since mandatory retirement was eliminated in Ontario in 2006 from less than 2% to just under 9%. The growing percentage of faculty over 65 is an increasing constraint on faculty renewal;<sup>12</sup> and potentially the career advancement of researchers. In addition, we do not have good information on the cultural backgrounds of our researchers.

**Table 3:** Median age of academic faculty in Ontario's universities, according to rank, 2016/17<sup>13</sup>

YEAR	FULL PROFESSOR	ASSOCIATE PROFESSOR	ASSISTANT PROFESSOR	BELOW ASSISTANT <sup>14</sup>	OTHER
Male	58	49	39	47	52
Female	57	49	39	50	50
Overall	58	49	39	48	51

Description: Table 3 provides the median age of researchers in Ontario universities according to rank (Full Professor, Associate Professor, Assistant Professor and Below Assistant) and gender in 2016/17.

 <sup>&</sup>lt;sup>12</sup> Weingarten, H. P., Jonker, L., Kaufman, A., & Hicks, M. (2018). University Sustainability: Expenditures.
 Higher Education Quality Council of Ontario, Toronto. p. 21.

<sup>&</sup>lt;sup>13</sup> Statistics Canada. (2017). CANSIM 477-0017. Ottawa.

<sup>&</sup>lt;sup>14</sup> Rank or level below assistant professor includes lecturers, instructors and other teaching staff.

Another challenge relates to the importance of generating discoveries and new knowledge from curiosity-driven research, or research that is variously referred to as basic, fundamental or investigator-led research. We accept that all governments are interested in linking the results of science to economic and social benefits – what is often referred to as a "return on investment." Many research support programs thus tend to favour research that is applied, commercializable or "industry-relevant."

We have known for a long time, however, that innovation does not happen in neat linear steps from basic to applied research to commercial product. In fact, it is quite circular and iterative, moving back and forth from theory to practical application in solving multifaceted problems. How should a funding program recognize this "systemic" approach to innovation, while being accountable for generating a return to a public investment in research?

Related to the issue of fundamental science, is whether public research dollars are being invested across a diverse range of disciplines. Should Ontario's research investment be targeted towards "strategic" sectors and disciplines, or should it be more evenly distributed? Should it, for example, strive for more balance between funding research in the life sciences and digital technologies, with funding research in the social sciences, arts and humanities? All disciplines make a contribution to the wealth of knowledge and well-being of society.

We also took into consideration the contribution of researchers in Ontario's community colleges. Are the needs of college researchers being adequately addressed by Ontario's research programs?

The amount of funding allocated to programs, is of course, always a challenge. Costs are rising, while governments face competing demands for public services. Ontario also competes with other provinces to attract federal research dollars; and, in particular, federal co-funding of important research infrastructure. Is Ontario getting its fair share, relative not just to its economic size, but also to its research capacity? Is the federal investment aligned with Ontario's strategic priorities for research and innovation?

The federal government's Budget 2018 included a welcome investment of nearly \$4 billion. But some of that investment will require provincial co-funding, such as for big data, digital research infrastructure and other major science initiatives. While we recognize that co-funding may generate additional fiscal pressure for Ontario in the short term, it is important to bear in mind the long-term benefits that federal and industry investment will make to Ontario's competitive edge as an innovative economy.

Building public support for investment in research, especially the curiosity-driven research which does not yield immediate tangible results, is clearly a big challenge. Typically, academic researchers are focused on their work, leaving little time to engage with the general public in a fulsome manner. But it is necessary. Research programs must take into account the way results of research projects are communicated; and they must provide opportunities for outreach involving researchers with the broader community, especially youth. The objective of public engagement is to help create and disseminate a "culture of science". A unique, and what appears to be a popular, feature of Ontario's research programs is the component of youth outreach where researchers engage some aspect of their work with elementary and secondary school students in the classrooms.

We should not overlook the administrative burden that of is often placed on the researcher and institutions by publicly-funded research programs. The process for selecting projects must be fair, based on strict criteria of excellence, and open to every qualified researcher. The successful researcher must then report back on the milestones of the project and the results – another major hurdle to receive further funding, but a necessary one to ensure accountability.

That said, the administrative aspects of a project should not discourage applicants or create an unnecessary barrier to project success. Researchers should be spending more time doing research, not filling out forms. How can the application and reporting processes for Ontario's research programs be streamlined and redesigned to reduce the administrative burden, while ensuring fairness, excellence and accountability?

We raise many challenges and questions for consideration: many more than we can fully address in this report. A program review never ends when a report is submitted. Rather, we hope that our report sets the stage for an ongoing dialogue with the affected stakeholders – Ontario's research community – and, for further discussion on ways to improve the design and delivery of Ontario's research program.

# Chapter 2 ONTARIO'S COMPETITIVE RESEARCH PROGRAMS



In this section, we provide a short description of three competitive research programs, followed by information on some of their outcomes and impacts. For the reader who would like more detail on the programs and the application and adjudication processes, consult the Ministry website.

# 2.1 Early Researcher Awards (ERA)

Introduced in 2006, the Early Researcher Awards program provides operating funding for leading, early career researchers working at publicly funded Ontario universities, colleges, hospitals and research institutes to help them attract talented people to their research teams.

From 2005 to 2016, the government has awarded \$151 million through ERA to 1,081 researchers, leveraging over \$54 million in additional private and public funds.<sup>15</sup>

ERA provides up to five years of funding to eligible early career researchers working at publicly-funded Ontario research institutions to build their research teams. The program's aim is to improve Ontario's ability to attract and retain the best and brightest research talent. Each award is a maximum of \$100,000, plus up to \$40,000 to cover the indirect costs of research; matched by up to \$50,000 from the researcher's institution and/or partner organization.

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## **DR. NADIA MYKYTZCUK, LAURENTIAN UNIVERSITY**

Environmental microbiologist Dr. Nadia Mykytzuk received an ERA in 2016 and is researching how microbes can be used to recover metals and reduce impacts from mine waste. The Laurentian University Industrial Research Chair is working with industrial partners such as BacTech Environmental, Vale, Denison Environmental Services Inc., and Glencore INO as she and her team develop novel cost-effective ways of preventing the release of contaminants to aquatic systems. She has trained nearly 40 highly qualified personnel and work has been cited by researchers in more than 30 countries. Dr. Mykytzcuk completed her Bachelor of Science at Carleton University, then her Ph.D. at Laurentian University, and a post-doctoral fellowship at McGill University in Montreal.

<sup>&</sup>lt;sup>15</sup> This includes some funding under ERA's predecessor program: Premier's Research Excellence Awards (PREA).

To be eligible for ERA funding support, a researcher must be a full-time faculty member or principal investigator at an eligible research institution; and who was first appointed to the position of an independent academic researcher within the past five years; or has completed their first Doctor of Philosophy, Doctor of Veterinary Medicine degree, Medical Doctor or terminal degree within the past ten years. The funding support is one time only.

The program encourages applications from all disciplines. Eligible applications are reviewed by a discipline-specific peer review panel, including a dedicated panel for arts and humanities. A panel submits recommendations to the Ontario Research Fund (ORF) Advisory Board, which makes a final recommendation for a decision by the Minister.

## DR. ARTHUR CHAN, UNIVERSITY OF TORONTO

A recent recipient of an ERA grant, as a well as participant in the Ontario-China Young Scientist Exchange program, Assistant Professor Arthur Chan is investigating the role of different chemical composition in determining the ability to induce airway hypersensitivity, a hallmark of asthma and chronic obstructive pulmonary disease. As a participant in the OCYSE program Prof. Chan traveled to China in an academic exchange visiting a variety of institutions in China. He moved to Toronto after receiving his Bachelor of Science from University of Pennsylvania and Master's and Ph.D. from California Institute of Technology. ERA applicants are required to undertake annual youth outreach activities and may use up to one per cent (equivalent to \$1,000) of the funding provided by the Ministry to support their efforts.

While ERA grants tend to be small in comparison to some of those in the Ontario Research Fund, they seem to be far more important and known in the academic research community. Many research institutions use them as a key recruitment tool due to their consistent success rates, which have ranged from 32% to 38% of applications on an annual basis.

DR. LORA GIANGREGORIO, UNIVERSITY OF WATERLOO

Dr. Lora Giangregorio, the Schlegel Research Chair in Mobility & Aging, received an ERA grant in March 2011 to grow her team and mentor trainees in the field of bone health and exercise science, with a focus on older adults and individuals at risk of fracture. It was fundamental research that subsequently led to partnerships with other research organizations and funding bodies, resulting in international guidelines and exercises for individuals with osteoporosis. Dr. Giangregorio was awarded a New Investigator award by the Canadian Institutes of Health Research and the Bloomberg Manulife Prize for the promotion of active health. Dr. Giangregorio completed her Ph.D. at McMaster University in Hamilton.

## ERA OUTCOMES AND IMPACTS FOR THE YEARS 2005-06 TO 2016-17

#### **Developing Research Talent and Promoting Research Excellence**

- Nearly 36,000 opportunities made available to highly qualified personnel (HQP) to enhance their knowledge, training or skills
- Of the 5,963 HQP for whom clear career path information is available 61% are pursuing further opportunities at publicly funded research institutions, while 23% moved onto positions in the private sector
- Seven-in-ten of the departing HQP pursued careers within Ontario thus contributing directly to the province's social and economic development
- A total of 588 postdoctoral fellows have completed their training at ERA funded projects while 3,058 graduate and 3,332 undergraduate students have graduated while working as members of ERA research teams
- 14,283 published works which have been cited over 143,000 times in other academic publications

#### Commercialization and technology transfer

- 417 invention disclosures
- 390 patent applications filed, with 97 patents granted and 104 licensing agreements
- 16 spin-off companies formed with 41 employees
- 3,353 instances of collaboration formed with private sector partners

#### Youth Outreach

 8,900 instances of ERA research team members having engaged in outreach activities with almost 245,000 elementary and high school students and over 104,000 other individuals.

# 2.2 Ontario Research Fund – Research Excellence (ORF-RE)

Launched in 2004, the Ontario Research Fund-Research Excellence promotes research excellence of strategic value to Ontario by supporting the direct operating and overhead costs of new, leading-edge, transformative, and internationally significant research in Ontario's universities, colleges and research hospitals.

ORF-RE funding is a critical pillar of the province's innovation system. By funding largescale research operations for leading-edge projects, the program attracts, develops and retains research talent. It is also designed to facilitate collaboration and partnerships; and to foster increased public awareness of science and technology, particularly among educators and youth, and help the next generation of researchers connect to today's research leaders.

The program partly fills a gap created by industry's investment in profit-driven research, promotes mass collaborations and wide dissemination of ideas that benefit the public good. The investments focus on research with demonstrated benefits to Ontario's industry, general economy and broader society.

Since 2004, the Ministry has committed \$879 million towards 242 research projects through the ORF-RE program. These investments have leveraged \$2 billion in private sector and institutional investments. The impact of this investment to the research competitiveness of Ontario's universities and hospitals is significant.

## DR. BARRY SAVILLE, TRENT UNIVERSITY

Dr. Barry Saville received an ORF-RE in 2009 to explore how genomics approaches could be used to mitigate fungal threats to crops. As of 2016 Ontario's farms produce \$6.6 billion<sup>16</sup> from their major crops, which are all susceptible to fungal diseases. Understanding the impact of genetic variation on disease development is greatly improving the chances of developing sustainable means to combat these pathogens and protect Ontario's field and greenhouse crops, and forestry sector.

<sup>&</sup>lt;sup>16</sup> omafra.gov.on.ca/english/stats/finance/receipts.htm

ORF-RE contributes towards the eligible operating costs of an approved research project up to a maximum of 1/3 of the total project costs, with 1/3 of the remainder coming from the applicant institution(s) and 1/3 from the private sector and other partners. The minimum support provided by ORF-RE award is \$1 million and the maximum support is \$4 million. For projects in the social sciences, arts and humanities streams the minimum is \$200,000; the maximum is \$1 million.

## DR. BETH PARKER, UNIVERSITY OF GUELPH

Director of University of Guelph's G360 Centre for Applied Groundwater Research, Dr. Beth Parker, received an ORF-RE award in 2009. The funding supported research conducted by a 13-member multidisciplinary team from three Ontario universities (Guelph, Waterloo and McMaster), in collaboration with Quebec, German and US organizations, that is improving the scientific basis for expanding bedrock aquifer use, designing aquifer protection and clean-up of abandoned industrial/commercial lands to achieve secure and sustainable municipal drinking water supplies. The project trained more than 100 highly qualified personnel and published almost 120 journal articles over the life of the project. Through a number of youth outreach events across the three university campuses, more than 2,000 elementary and high school students learned about how hydrogeology plays an integral role in maintaining Ontario's safe water supplies. ORF-RE funds projects through competitive rounds generally open to all disciplines. In some rounds, however, priority may be given to a strategic area of interest to the Province. For example, in the 2017/18 round, applications were encouraged from the clean technologies and the social sciences, arts and humanities, in addition to a general call for proposals from all research disciplines.

The initial step in the application process is for an institution to submit a "Notice of Intent" to submit a proposal. The practice was adopted to encourage collaboration across similar or related proposals from different institutions. After it is submitted, a research proposal goes through a rigorous multi-stage adjudication process involving external, independent expert reviewers.

Each proposal is evaluated according to five main criteria: research excellence, impact and an impact implementation plan, recruitment and training, as well as a management plan with measurable milestones and deliverables. It is the impact component of the application that is sometimes misunderstood by stakeholders to focus only on commercialization, when, indeed it includes a much broader consideration of benefits to society and the economy.

## DR. EMIL PETRIU, UNIVERSITY OF OTTAWA

Dr. Emil Petriu received an ORF-RE award in 2007 to develop a multimodal surveillance system using environmental surveillance sensors. Through the project, Dr. Petriu trained 58 highly qualified personnel and created three spin off companies. The team also participated in youth outreach activities that reached nearly 100 elementary and high school students. In 2016, Dr. Petriu received the Natural Sciences and Engineering Council's Category 1 Synergy Award for Innovation with private sector partner Larus Technologies for the Total::Insight<sup>™</sup> decision support system. Total::Insight<sup>™</sup> uses computational intelligence and advanced learning techniques to analyze large volumes of data to enhance the situational awareness of decision-makers. The technology has been applied to defence, security, health care and infrastructure protection, with local and international recognition and application.<sup>17</sup>

<sup>&</sup>lt;sup>17</sup> <u>nserc-crsng.gc.ca/Prizes-Prix/Synergy-Synergie/Profiles-Profils/Petriu-Petriu\_eng.asp</u>

## ORF-RE OUTCOMES AND IMPACTS FOR THE YEARS 2005-06 TO 2016-17

#### **Research Excellence**

• Nearly 16,500 published works produced, receiving over 132,500 citations in other academic studies.

#### **Developing Research Talent**

- Over 14,300 highly qualified personnel provided with nearly 40,000 opportunities to enhanced their knowledge, training or skills through the program;
- Of the 5,076 HQP who have left ORF-RE funded projects, over one-third pursued careers in the private sector. Of those pursuing private sector careers, 73% did so within Ontario; and
- A total of 4,332 doctoral, master's and undergraduate students working on ORF-RE funded projects have graduated since the inception of the program.

#### Commercialization

- 730 patent applications have been filed and 250 patents granted;
- 149 new licensing agreements have been issued;
- 97 spin-off firms have been formed employing a total of 769 individuals;
- · 980 invention disclosures have been reported; and
- 1,398 new private sector and 2,996 new academic collaborations have been established.

#### Alignment with Key Priority Sectors

• 89% of all ORF-RE committed funds went into projects aligned with the priority sectors outlined in Ontario's Innovation Agenda.

#### Youth Outreach

• Just over 2,500 research team members have participated in outreach activities that have engaged more than 378,000 youth. There were just over 4,300 outreach activities specifically aimed at engaging high school aged students.

# 2.3 Ontario Research Fund – Research Infrastructure (ORF-RI)

Research infrastructure is defined as equipment, laboratories, databases, specimens, scientific collections, computer hardware and software, communications linkages and buildings necessary to conduct leading-edge research.

The Ontario Research Fund - Research Infrastructure (ORF-RI) program ensures that Ontario's publicly funded research institutions continue to have competitive, state-of-theart infrastructure to engage in world-leading research and technology development.

Since its inception in 2004, ORF-RI has committed \$1.2 billion towards 2,588 research infrastructure projects leveraging over \$2.6 billion from federal, private, and institutional sources.

ORF-RI is designed to co-fund infrastructure projects with the federal government through programs operated by the Canada Foundation for Innovation (CFI).

# CANADA FOUNDATION FOR INNOVATION

CFI is a federal agency that makes financial investments for research infrastructure in Canada's universities, colleges, research hospitals and nonprofit research organizations. CFI manages several funds and runs various competitive rounds for funding of research infrastructure. Only research institutions may apply, not researchers or private industry.

CFI will cover up to 40% of the eligible costs of a research infrastructure project. Only eligible institutions – not individual researchers – may submit a project proposal. While the federal program does not explicitly require provincial co-funding, in practical terms there are few viable alternative operating funding sources available. Thus, ORF-RI was set-up to co-fund up to 40% of the eligible cost of a research infrastructure project approved by CFI. The institution is responsible for the 20% balance, including from its own, private and non-profit sources.
ORF-RI has three main funding streams:

 Small Infrastructure Fund (SIF) provides Ontario awards ranging in size from approximately \$10,000 to up to \$800,000, through three funding rounds a year against an institutional allocation. Awards are designed to attract and retain top international research talent.<sup>18</sup>

#### FACILITY FOR APPLIED SOCIAL WELFARE RESEARCH, UNIVERSITY OF WINDSOR

Led by social worker Dr. Jill Grant, the facility was established to generate, disseminate and transfer knowledge that informs policies, programs and practices that foster and promote the welfare of our communities in four main areas: homelessness/housing, immigration, inclusive education and international collaborations on gender equity in developing countries.

- Large Infrastructure Fund (LIF) provides Ontario award amounts that can be up to \$10 million, through rounds that fall every 18 months to two years. Awards are to support research in areas where Ontario is or can be internationally competitive.<sup>19</sup>
- College-Industry Innovation Fund (CIIF) provides Ontario award amounts up to \$1 million annually to Ontario's Colleges. These are designed to build capacity to support innovation through regional business partnerships.<sup>20</sup>

<sup>&</sup>lt;sup>18</sup> The Small Infrastructure Fund co-funds the CFI's John R. Evans Leaders Fund.

<sup>&</sup>lt;sup>19</sup> The Large Infrastructure Fund co-funds the CFI's Innovation Fund.

<sup>&</sup>lt;sup>20</sup> Both ORF and CFI refer to this program as College-Industry Innovation Fund.

#### CENTRE FOR INDUSTRIAL MATERIAL DEVELOPMENT (CIMD), LAMBTON COLLEGE

The CIMD is a regional and provincial hub for industrial material and biomaterial development projects, ranging from developing recyclable materials to helping companies optimize their instrumentation to improve productivity and reduce energy consumption. Recently CIMD researcher Kevin Ryan and three students from Lambton's Instrumentation Control Engineering Technology program worked in collaboration with the team from Sarnia microbrewery, the Refined Fool, to implement the new technology in their facility. The project gave the brewers the ability to monitor their tanks remotely using smart devices and automating the keg washing system which was previously done by hand. Led by Dr. Mehdi Sheikhzadeh, the CIMD received funding through the College Industry Innovation Fund of the ORF-RI to expand its operations so it can assist even more businesses across the province.

In addition, ORF-RI makes specialized infrastructure investments in partnership with the federal government and institutions in cyberinfrastructure or Advanced Research Computing.<sup>21</sup>

<sup>&</sup>lt;sup>21</sup> ORF co-funds the CFI's Cyberinfrastructure Initiative, Challenge 2.

#### **ORF-RI OUTCOMES AND IMPACTS**

### Promoting the attraction, retention and development of highly qualified personnel

- Since 2005-06 ORF-RI funded infrastructure has played an important role in the decision of 3,356 researchers to join Ontario academic institutions
- Just over half (53%) of the new principal investigators recruited to head ORF-RI funded projects since 2012-13 came from outside of Canada; and over two-thirds of already established project leaders indicated that ORF-RI funded infrastructure played a very important role in their decision to remain at their host institution
- Since 2011-12 there have been 52,103 reported instances of postdoctoral fellows, graduate and undergraduate students having used ORF-RI infrastructure
- A total of 4,435 technical personnel have been trained to use and operate project infrastructure since 2011-12

#### Social and economic benefits for Ontario

- 248 patents granted since 2008-09 with 180 of these being granted between 2011-12 and 2015-16
- 144 spin-off companies formed since the start of the program employing 788 individuals
- · 266 licensing agreements established since the start of the program
- Just over 7,400 public and private sector jobs have been created since the start of the program
- Since 2007-08 a total of 2,630 trainees have moved on to positions in the Canadian private sector

#### Research activities, infrastructure and collaborations

- 26,578 peer-reviewed publications and 33,333 presentations have been generated since 2011-12
- Almost 38,000 instances of researchers having used ORF-RI funded infrastructure to advance their research since 2011-12
- Over two-thirds of project leaders in all five reporting years indicated that they had engaged in at least one academic collaboration
- Between 2011-12 and 2015-16 a total of 4,219 formal research agreements were struck.
- Between 80% and 90% of project leaders each year indicated that their highly specialized research equipment was state of the art



## Chapter 3 MAKING CO-FUNDING DECISIONS WITH THE FEDERAL GOVERNMENT

The challenge for Ontario, and other provinces, is that the federal government controls timing and content of funding rounds with little consultation beforehand. In 2009, the Ministry adopted an "Ontario First" policy, for the ORF-RI Large Infrastructure Fund to maximize federal co-investments in research infrastructure while ensuring that the funding was going to projects aligned with Ontario's strategic goals and funding constraints.

In practice, Ontario First works like this: CFI launches a competitive funding round which triggers applications from institutions for funding of their research infrastructure. The Ministry provides prior feedback to CFI so that its funding decisions can be made with consideration of Ontario's priorities. A "notice of intent" requirement for institutions was later added to strengthen and align their proposals with provincial priorities and funding capabilities.<sup>22</sup>

Ontario defers to CFI's expert review process to establish the scientific excellence of projects. CFI has a rigorous, competitive and independent merit-review process that rewards excellence, is well established, and follows best practices. The Ministry only funds proposals which pass CFI scientific review.

In addition to co-funding CFI infrastructure, the "Ontario First" approach is now also being used to co-fund federal operating programs at CFI and Genome Canada, including:

• Major Sciences Initiatives (ORF-MSI) to help support the operating and maintenance costs of national research facilities (CFI).

### GENOME CANADA

Genome Canada is a not-for-profit organization, funded by the Government of Canada. Genome Canada acts as a catalyst for developing and applying genomics and genomic-based technologies to create economic and social benefits for Canadians. Genome Canada makes investments together with regional Genome Centres, such as Ontario Genomics. These are independent entities that receive operational support from Genome Canada, provincial governments, and others.

<sup>&</sup>lt;sup>22</sup> The exception are projects under CFI's Small Infrastructure Fund (SIF). ORF-RI accepts CFI's evaluations and conducts a due diligence review of applications. Institutions utilize the SIF stream primarily to attract and retain research talent and this is a benefit that serves Ontario's need in that area.

- Large-Scale Applied Research Projects (LSARP) that contributed to a more evidencebased approach to health, agri-food and agriculture, and natural resources and the environment (Genome Canada);
- downstream research and development projects that address real world opportunities and challenges identified by industry, government, not-for-profits and other receptors of genomics knowledge and technologies (Genome Canada); and
- disruptive innovation in the field of genomics, which is defined as a new genomicsbased technology or the application of an existing technology from another field, applied to the field of genomics, that is truly transformative in that it has the potential to either displace an existing technology, disrupt an existing market or create a new market (Genome Canada).

#### ➡ RECENT FUNDING SUPPORT FOR MAJOR SCIENCE INITIATIVES IN ONTARIO

ORF-MSI is providing five year operating funding of \$34 million to Ontario's Advanced Computing facilities and \$28.8 million to the SNOLAB facility that can be used by institutions to match their recent CFI-MSI awards.

Ontario's Advanced Computing facilities help Ontario's leading researchers solve real world problems using sophisticated computers with massive data storage capabilities and computing power. This is part of the national Compute Canada MSI.

SNOLAB is a world-class science facility located two kilometers underground near Sudbury Ontario. The combination of great depth and cleanliness that SNOLAB affords allows researchers to study extremely rare interactions and weak processes in the fields of sub-atomic physics, largely neutrinos and dark matter physics.

The level of pre-launch consultation with provinces has improved, but the situation is not ideal. Ontario has little opportunity to shape the programs before launch, such as who is eligible and what costs are eligible. This includes a trend of increasing operating funding through CFI. Ontario's goal is to maximize federal investments in Ontario with limited available funding. Some type of review is required that assists Ontario to select the best research infrastructure projects, while also avoiding duplication of federal review efforts and causing undue delays in funding decisions; as well as allowing the federal government to make its decisions with an understanding of provincial priorities.



## Chapter 4 CONSULTATION AND FEEDBACK

## 4.1 Consultation methodology

The stakeholder consultation methodology for this review was divided into three phases.

In phase I, we reached out mainly to the vice-presidents of research at Ontario's universities, colleges and hospitals. We also reached out to the Ontario Council on University Research (OCUR), Council of Academic Hospitals of Ontario (CAHO), and Colleges Ontario.

Using a questionnaire format, we requested feedback in four key areas:

- · Are the program designs doing what they intended and having the desired impact?
- · Do the programs still have the right focus?
- · Are there programmatic gaps?
- · Are there opportunities to streamline?

We expanded our consultation in phase II to include private sector partners, specific Ontario research institutes, such as the Perimeter Institute, and selected federal government organizations such as Innovation, Science and Economic Development Canada, and Canada Foundation for Innovation (CFI). Outreach to these stakeholders was done through a variety of methods, including focus groups, surveys and teleconference meetings.

In addition, Ministry staff helped create focus groups and/or conducted surveys of former ORF and ERA Peer Review Panel Chairs/Panel Members, multiple award recipients (ORF and/or ERA), and unsuccessful award recipients.

As part of Phase III, we returned to some of the leading representative research organizations to test and validate our recommendations. This included meeting with the Ontario Research Fund Advisory Board, whom we engaged from the start of the consultation process; and, with Ontario's Chief Scientist, Dr. Molly Shoichet.

A complete listing of our contacts with stakeholders in the course of this review may be found in Appendix A.

## 4.2 Stakeholder feedback summary

The majority of stakeholder feedback was directed at ORF-RE, although some of it was expressed in broader terms about "ORF" collectively to include ERA, ORF-RE and ORF-RI.

Overall, many stakeholders confirmed that the three competitive programs are an important tool for attracting and retaining top research talent. "The ORF is a primary driver of discovery and innovation; and is a bright light for researchers in this province."

The importance of ERA, in particular, as one stakeholder pointed out, goes beyond financial assistance. "They help establish greater recognition for the recipient; and increase the likelihood of success in other funding programs." But the feedback on ERA also pointed to various areas for improvement, with a focus on administrative efficiency, funding allocations, performance metrics. Some institutions also suggested that an increased emphasis on mid-career researchers would be of benefit.

There was also strong stakeholder support for the design of the two ORF programs, with some small, but important, changes.

With respect to ORF-RE, stakeholders appreciated the flexibility to use the funds for operational purposes, including hiring post-doctoral fellows and support staff (technicians, administrators, research assistants, etc.). They were also pleased with the 40% top up of project costs dedicated to overhead, a proportion that is aligned with true costs when compared to research funding programs in other jurisdictions.

As well, they noted that the program has become more inclusive of research disciplines beyond the natural and life sciences, especially in the social sciences, humanities and the arts. However, some suggested that greater emphasis should be placed on multidisciplinary research projects, which may involve collaborators across many disciplines working on a common problem.

Some institutions expressed some concerns about the ORF-RE program and how it affects their ability to do world class research and to attract exceptional talent.

The perception is that all three competitive research programs (ORF-RE in particular) are oriented towards "industry-relevant" research targeted towards a commercial application or outcome, even though the application form covers benefits and impacts that are much broader in scope. Nevertheless, many stakeholders indicated that the application process places fundamental or basic research, where potential end-users are further downstream on the innovation pathway, at a disadvantage.

Some institutions, especially colleges, the smaller ones or those without significant medical research capacity, find it very difficult and time-consuming to raise private sector contributions. They say that the high level of required partnered funding associated with the ORF-RE program limits the pool of researchers who are able to apply; and that it disadvantages those who conduct basic research, as well as those in the social sciences and humanities.

Stakeholders expressed a general frustration with the administrative and other application aspects of the three programs. Applications are quite lengthy and complex. Budgets are also especially complex and require the institution to devote significant administrative resources, which colleges and smaller institutions do not necessarily have. They suggest that the Ministry implement an effective electronic submission process for applications, including all aspects of the submission such as letters of reference.



# Chapter 5 **ANALYSIS**

In the Introduction we proposed a framework of analysis based on what we refer to as the six attributes of an effective research support programs:

- Excellence and innovation
- Talent and teams
- · Connections and networks
- · Technical and financial sustainability
- · Outreach and public engagement
- · Administrative efficiency and accountability

The framework was developed as a systematic means of organizing and analyzing the large amount of information that we encountered in the course of reviewing Ontario's three competitive research programs. We suggested that it could be applied to individual programs as well as a suite of programs; realizing, however, that depending on the objectives and design of a program, not every attribute applies equally or sometimes not at all.

Below, we have attempted to synthesize our analysis across the three programs, with a focus mostly on ERA and ORF-RE which is where we received the most stakeholder feedback. Overall, we find that the programs individually and together make a strong contribution to Ontario's research and innovation system by providing sustainable and flexible funding support to academic research, leveraged by private funding. It is important to maintain the pivotal role that these funding programs play in creating opportunities for research talent, enhancing the research competitiveness of Ontario's publicly-funded institutions, and for attracting investment to Ontario's economy.

## 5.1 Excellence and innovation

We are impressed by the high quality of research that is being funded by the ERA program. We encountered many examples of where research funded through ERA that have contributed to scientific knowledge and enhanced understanding of social problems. It has opened doors to innovative and more complex research projects.

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#### DR. JASON FISH, UNIVERSITY HEALTH NETWORK – TORONTO GENERAL HOSPITAL RESEARCH INSTITUTE

Since receiving an ERA grant in 2012, Dr. Jason Fish has rapidly established himself as an emerging world leader in understanding how inflammation leads to heart disease. The award attracted external funding, helped train research talent and generated several highly influential publications. Dr. Fish has received many prestigious awards, including a Tier 2 Canada Research Chair and a Young Investigator Award from the Canadian Cardiovascular Society. Dr. Fish completed his Ph.D. at the University of Toronto and did a post-doctoral fellowship at the Gladstone Institute of Cardiovascular Disease and the University of California, San Francisco.

We are also impressed with the high quality of research that is being funded through ORF-RE and ORF-RI. The peer review process is working. Without this support, Ontario would surely lag other jurisdictions in research output; and, Ontario's institutions would be less able to compete for world class talent and R&D investment.

Nevertheless, there is a perception that ORF-RE, in particular, is tied to industrial collaboration, which, as expected, tends to favour projects with more commercial and industrial relevance.

ORF-RE application guidelines do not explicitly distinguish fundamental research projects with a theoretical or experimental bent from those with a more practical purpose. In our view, it should not do this as the two types of research orientations cannot be meaningfully separated at the scale of a research funding program.

The Ministry should also not support clinical trials as Ontario has been supporting them through other means such as the Ontario Institute for Cancer Research and the Ontario Brain Institute. A significant portion of the ORF-RE funding already supports life sciences projects.

Research excellence means that a project has to demonstrate a potential contribution to the world stock of scientific knowledge, which is both fundamental and applied; and only then to the areas of strategic relevance for Ontario's economy, which are not even clearly defined or current as the Ontario Innovation Agenda has not been updated for nearly a decade.

## 5.2 Talent and teams

We heard from stakeholders, including many researchers, that ERA has played an important role in launching the careers of many researchers who have gone on to become principal investigators in other research funding programs. It has also played a key role in the development of research teams.

We heard from both institutions and researchers that ORF-RE is effective in attracting, recruiting and retaining excellent research talent. We have less information, however, on how effective it has been to help individual researchers advance their career path from early stage to mid-stage and beyond. We have some anecdotal evidence that the requirements for preparing an application and securing partners are a major hurdle for many younger researchers. It is a very large step from applying for an ERA to an ORF-RE, which may hinder career progression.

We also understand that researchers in smaller institutions and colleges may be at a disadvantage because they have less access to administrative resources for support. Finally, we lack a comprehensive picture of how well ORF-RE promotes inclusivity and diversity of research talent.

## 5.3 Connections and networks

ORF-RE is designed to promote collaboration and linkages across research institutions and with community and business partners. Building such connections, however, seems to be more apparent for researchers in some disciplines than in others; for example, the health sciences vs. social sciences.

Although this was not an objective of the ERA program, some institutional stakeholders and researchers who participated in the consultation process noted that it had some impact on helping them to establish connections with other researchers in academia and the private sector. There is evidence that the number of ERA-funded research collaborations has been on the rise.

#### YOUNG SCIENTIST EXCHANGE PROGRAM (YSEP)

The Young Scientist Exchange Program (with a small budget of \$50,000/ per year) enables Ontario's ERA recipients to join a 3-week exchange program in China and Ontario's researchers to host incoming Chinese early researchers to develop joint research partnerships. Once they established research partnerships, they are able to apply for the ORF-RE or the Ontario China Research and Innovation Fund to conduct joint research projects which are mutually benefit for Ontario and China. To date, the Ministry has launched two YSEP rounds in 2016 and 2017. A total of 19 early researchers from Ontario and China participated the exchange and 11 Ontario Universities and 19 Chinese Universities hosted the YSEP recipients.

## 5.4 Technical and financial sustainability

One of the key features of the ERA program is that it provides an appropriate amount of funding to cover the indirect costs of a research project. Similarly, with respect to ORF-RE, most stakeholders were very appreciative of the 40% funding support for indirect costs.

We note, however, some concern about the extent to which industry contribution is calculated based on cash or as "in-kind" value equivalent for equipment, databases, and potentially personnel. There appears to be some confusion over which is preferred by the Ministry – or if there is even a preference. The "mix" of industry support, whether it is tilted to cash or to in-kind, matters only in how well it supports research excellence and the infrastructure that is created and becomes a building block for future research projects.

But we also would like to highlight that industry or non-profit partner contribution is more than about money and other resources. Perhaps even more important of industry partnership is the contribution that is made in terms of expertise, data, and market knowledge that can leverage the impact of the research for the good of society.

## 5.5 Outreach and public engagement

Encouraging youth to explore and potentially pursue careers in science and engineering is one of the unique elements of the ERA and ORF-RE program. Youth outreach is not a requirement for other research support programs anywhere in Canada.

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#### DR. KULLERVO HYNYNEN, SUNNYBROOK RESEARCH INSTITUTE

Dr. Kuellervo Hynynen was recruited from Harvard Medical School in 2006 for his expertise in MRI-guided high-intensity focused ultrasound (HIFU). Using a Small Infrastructure Fund ORF-RI investment to build his lab, Dr. Hynynen has gone on to win another two ORF-RI and two ORF-RE awards, among other awards such as a Tier 1 Canada Research Chair. With these investments, his lab has developed a way to use HIFU so that some surgeries no longer require people to be cut open: the HIFU can heat and destroy cancerous tumors or misfiring neurons without harming surrounding healthy tissue. This scalpel-free surgical technique has been used to remove cancer, eradicate tremors and open the blood-brain barrier so that patients with Alzheimer and Parkinson's disease can receive better drug treatments and potentially clear the brain of toxic plaque.

In recognition of the development of this disruptive technology, Dr. Hynynen was recently named a Fellow of the IEEE (Institute of Electrical and Electronics Engineers), an international distinction that is bestowed to very few in his field. During these projects, Dr. Hynynen has trained more than 100 highly qualified personnel and reached 225 high school students through youth outreach events. Of these high school students, Dr. Hynynen invited a handful into his lab to complete a research project and supported them in continuing on to attend top universities in Ontario and around the world.

Other countries have initiatives to engage youth in science, but not directly as part of a funded research project. ERA and ORF-RE allow for the allocation of up to 1% of the project budget towards outreach. A detailed youth outreach plan in the application is required. Proposals must outline a plan and include (where funds are allocated) the spending in the proposed budget.

The number of young Ontarians exposed to the work and methods of researchers through the ERA and ORF-RE programs is substantial and unique when compared to research programs in other jurisdictions. The number of researchers willing to do numerous and varied outreach activities over the life of their projects in both programs is encouraging. The Ministry should also publicly report on the progress made through the funded projects, including youth outreach activities.

## 5.6 Administrative efficiency and accountability

The time and resources invested in preparing and submitting an application to an ORF program is significant, and perhaps daunting enough that it discourages applications from early-stage researchers, colleges and smaller institutions.

Much the same can be said of the post-award reporting requirements for meeting project milestones and demonstrating outcomes and impacts or what economists refer to as a social return on investment.

This comes back to the question of what gets counted as a "return": knowledge, talent, technology or other tangible and sometimes intangible outcomes per dollar spent that are difficult to quantify but are required to demonstrate accountability. It is important to understand that there is not a one-to-one relationship between science and innovation; and that all kinds of scientific endeavor contribute to our well-being, from the curiosity-driven, fundamental science that generates new insights about the physical and human world, to the science that is more directly linked to evidence-based decisions about policy and investment.

There is much that the Ministry can do to streamline and ease the administrative burden on researchers, who should be spending more time on their research projects rather than on filling out forms. It would also help if competitive rounds are held on a more predictable schedule. A related point that perhaps also touches upon the excellence and talent attributes of an effective program, is that more effort should be placed on providing meaningful and timely feedback to the successful applicants – and to the unsuccessful ones so that they are encouraged to apply the next round.



## Chapter 6 CONCLUSION AND RECOMMENDATIONS

Our review of the suite of three Ontario competitive research programs – Early Researcher Awards (ERA), Ontario Research Fund-Research Excellence (ORF-RE), and Ontario Research Fund-Research Infrastructure (ORF-RI) – was mandated to answer the following key questions:

- · Is the program design doing what it intended to achieve?
- · Does it still have the right focus?
- · Is it having the desired impact?
- Are there programmatic gaps?

We were also tasked with advising the Ministry on how the programs should adapt to new approaches and opportunities, with a focus on supports for early and mid-career researchers.

As described in the *Introduction*, our approach took into consideration our collective experience as a panel of academic scientists, the available data on outcomes and impacts, and the feedback from the key stakeholders. We took this information and applied it against a six-part framework of analysis of the three research support programs: How well does the design of the programs stack up against the six key attributes of an effective research support program? Our unequivocal response to this question is in the affirmative.

Next, we used the available information to assess how well the three programs have contributed to strengthening Ontario's innovation system. We find that over the nearly 15 years of their existence, the Ontario's suite of research programs has made an immense contribution to the province's innovation system. But what about the next 15 years or longer? That is the kind of timeframe that applies to building capacity in research excellence, growing the talent pool of researchers, and on using the research outcomes to make the most impact for the good of society and the economy. It follows the proverbial Canadian aphorism: we need to skate to where the puck is going, not where it has been.

Overall the stakeholder feedback was that Ontario's research community is pleased with the ERA, ORF-RI and ORF-RE programs and the supports they provide. Recommendations made in this report focus on fine-tuning the programs as the panel agrees there is no need for a major overhaul. The ORF and ERA program designs continue to have the desired focus and achieve the desired impact, using research excellence as the evaluation standard that drives funding decisions. Thus, the recommendations presented here are intended to highlight some programmatic gaps the panel suggests the Ministry address.

## Recommendation 1: maintain the ontario government's pivotal role in research support for the academic sector

Ontario has more than 14,000 researchers in its universities<sup>23</sup> alone, not including those who work in the province's colleges, research hospitals and research institutes. These researchers train the province's next generation of highly skilled workers on the building blocks of the world's leading innovations.

The Government of Ontario's support for academic research is therefore essential so that the facilities and training keep pace with those in other jurisdictions; and, in turn cements the province's ability to attract and retain top research talent. To continue this success, the Ministry must ensure that research funding remain predictable and reliable. Previous instances where the Ministry's research funding programs have been suspended such as in 2012, have a long-lasting negative impact on researchers' abilities to secure funding from other sources since Ontario's support is often used to match federal and other funds.

## Recommendation 2: Increase the funding levels of the three programs to keep pace with the cost of doing research and expanded federal research investments

On average, the funding levels of the ORF and ERA programs have not increased for almost 15 years, despite the inflation rate increasing more than 20% over the same period. The Ministry should periodically adjust research funding according to inflation.

With the recent investment in science and research in the 2018 federal budget of nearly \$4 billion, the Ministry should also strive to increase funding for its programs to ensure that investments not only keep pace with the current cost of research, but also enable the province to optimally leverage all available federal dollars.

<sup>&</sup>lt;sup>23</sup> Statistics Canada. (2017). CANSIM 477-0017. Ottawa.

#### Recommendation 3: Update the Ontario Innovation Agenda, including definitions of primary future focus areas and commitment to supporting early and mid-career researchers

The Ontario Innovation Agenda (OIA) was released over a decade ago and seems dated in comparison to those in other leading jurisdictions. Ontario needs a new mid- to long-term innovation strategy, turning a keen eye to supports for early- and mid-career researchers. An OIA update should take into consideration the ORF programs in the context of all programs that support Ontario's entire innovation system.

The ORF and ERA programs have evolved to support all kinds of research, not just those described as the focus areas of the OIA. The focus areas of the OIA also need to be updated. Until Ontario's new innovation strategy is released, we recommend that all references to the OIA be removed from program guidelines.

Recommendation 4: Continue to leverage federal co-funding of research projects with an "Ontario First" approach under ORF, using a provincial strategic review process as a filter in advance of the federal adjudication where possible to ensure that the best Ontario proposals are put forward to federal co-funding programs.

The Ontario Innovation Agenda (OIA) directed the Ministry to "extract more value from all provincial investments"<sup>24</sup> noting, however, that, at the same time, Ontario should not leave federal research dollars on the table.

The ORF program is a cornerstone of Ontario's research and innovation system; and is effectively linked to competitions run by federal co-funding programs such as those by the Canada Foundation for Innovation (CFI) and Genome Canada. We heard from stakeholders that "ORF-RI is essential to ensuring researchers can develop world-leading facilities and is absolutely critical for co-funding projects approved by CFI." Research excellence means that a project is approved for co-funding by federal partners. Projects not approved by federal partners will not be considered for co-funding by Ontario. Federal approved projects, however, still need to align with Ontario's strategic priorities to be eligible for funding under ORF.

<sup>&</sup>lt;sup>24</sup> Government of Ontario. <u>ontario.ca/page/seizing-global-opportunities-ontarios-innovation-agenda</u>.

In 2009, ORF-RI adopted an "Ontario First" approach in response to the Government's desire to ensure that the funding was going to projects that were of a benefit to Ontario. Occasionally, however, there has been a misalignment of the Ontario First approach with the goal of leveraging Ontario's share of federal research funds, raising serious concerns by Ontario's research institution applicants. We received feedback from stakeholders about their frustrations when situations arise where the federal government provides support where Ontario cannot provide co-funding (e.g., CFI and Genome Canada). To address these concerns, we recommend the following:

#### a. Ensure there is no duplication of federal adjudication processes for Ontario projects eligible under the Canada Foundation for Innovation and other federal programs

The panel recommends that the Ministry focus on ensuring there is no duplication of federal scientific review processes and look to streamline the provincial strategic review process to ease these frustrations and maximize federal dollars coming to Ontario.

#### b. Take steps to make the Ontario First commitment for provincial co-funding of federallyfunded research projects more predictable for potential applicants

The Province needs to keep pace with federal research investments. The recent funding announcement in the 2018 federal budget will hopefully provide some ability for the Ministry to predict when federal co-funding will be required. Whenever possible, the Ministry should build sustainability into its budgets so that situations where Ontario is unable to match federal research funding no longer arise.

The Ministry should also make sure that any provincial selection process happens well before federal competitions begin their adjudication. Should an applicant not meet the Ontario First criteria, the applicant may still apply to the federal program, and obtain co-funding from other sources.

As well, the Ministry should use a provincial strategic review process as a filter to ensure that the best Ontario proposals are put forward to federal co-funding programs; in turn, ensuring that the potential for any federal dollar match is maximized.

#### Recommendation 5: Consider some strategic changes to ORF-RE without compromising the program's strong commitment to research excellence

We strongly believe that ORF-RE must maintain research excellence as the prime criteria for funding a research project. It is the world class excellence of the research funded by ORF-RE that makes a meaningful contribution to Ontario's research and innovation system. However, we recommend some of the following changes will help strengthen this contribution even further:

### a. Review the upper limit of ORF-RE funding on a regular basis and raise it as required to keep pace with the increasing cost of research

One of the main benefits of the ORF-RE was to initiate large and longer-term funding for world-class research. We heard from stakeholders that to ensure that internationally significant platforms continue to be created and supported, the upper limit of the ORF-RE award should be increased to \$6 million and every 4-5 years the limit be adjusted to reflect the increase in the cost of research.

#### b. Communicate to Ontario researchers that ORF-RE is open to all disciplines and types of research that generate societal and economic benefits to Ontario, not just commercial benefits, and that there are options to use matching funding from various sources including philanthropy

Although the ORF-RE program began as a program that focused on commercializable research, it has evolved over time to recognize a broader definition of impact to Ontario, affording room for applications from basic research and the social sciences, arts and humanities (SSAH) to be successful.

We applaud the Ministry's creation of a dedicated SSAH stream of the ORF-RE in 2017; and, recommend that it continue to be a feature of the program. Nevertheless, the number of applications to the program from these areas could improve.

However, better communication is required so that fundamental/basic science and social sciences, arts and humanities researchers see themselves in the program and understand that they are eligible to apply; and, that commercialization is only one of the potential benefits to Ontario's society and economy, such as improvements to health and well-being, better public policy, and sustainable use of natural resources. The Ministry should also increase awareness of the options available when seeking matching funding options for operations (i.e. in-kind vs. cash contributions) for the larger awards.

Recommendation 6: While maintaining research excellence as the first priority for funding, make ORF-RE more accessible and inclusive of a broader spectrum of researchers at different career levels, institutions and disciplines by piloting of a new ORF-RE funding stream with a smaller award and fewer matching requirements

We understand that there is a significant jump between the ERA and ORF-RE programs, which may not necessarily support typical career progressions. We also heard concerns from stakeholders that the private or philanthropic sector partner and institutional matching requirements are difficult for some institutions, particularly those in some geographic locations and research disciplines. While maintaining research excellence as the standard of evaluation, the Ministry may consider piloting a smaller award of \$250,000 - \$1 million that has fewer matching requirements that is complementary to existing federal and provincial programs. This program could potentially accommodate a wider range of applications, including those from mid-career researchers, smaller institutions and researchers in disciplines where finding matching funding is difficult.

However, we caution that ORF-RE not be used to solve every operating funding challenge the Ministry encounters. It should not be partitioned into too many individual programs, nor should its funding be used to offset federal co-funding expectations. Should the pilot of this smaller award program be successful, it should be expanded with separate, dedicated investment and not compromise the overall success rates of the general ORF-RE program.

## Recommendation 7: Maintain the current success rate of ERA applications, while broadening some of the eligible expenditures

ERA is very effective in helping early-career researchers gain momentum and success in their research endeavors before they are ready to apply to for larger grants. The program influences how long early-career researchers are able to carry out research before getting a major grant. We recommend that the Ministry maintain the success rates of 32% to 38% seen in past rounds for the ERA program.

The panel also recommends increasing the flexibility of eligible expenditures in ERA to include operating costs such as consumables (e.g., reagents, pipettes, test tubes, etc.) or costs related to publishing or intellectual property, but not faculty release time.

# Recommendation 8: Develop and implement a communications plan targeted at raising researchers' knowledge and awareness of Ontario's research funding programs

The panel heard from stakeholders that in some cases, researchers do not readily see themselves as eligible applicants. The Ministry should make efforts to meaningfully engage with all eligible applicants, specifically those from the social sciences, arts and humanities, college researchers and from smaller institutions so that they understand they are welcome to apply to the ORF and ERA programs.

In many cases researchers do not have a clear understanding of eligible mixing of institutional matching for operations and where a mix of cash and in-kind contributions can be used for matching from philanthropic and private sector partners in the ORF-RE program. The Ministry should clarify the various methods available to applicants they can use to fulfil the matching requirements for the program and any linkages between types of matching support to potential success of applications.

A good number of researchers do not seem to recognize the significant co-funding that the Ministry provides for federal and other partner programs. The Ministry should develop a communications plan that highlights the strong provincial presence in research investments, particularly in infrastructure. Further, funded researchers should properly attribute funds received from the Province on all publications and presentations. Though many funding recipients have adopted this practice, it has not been consistent.

## Recommendation 9: Collect information on the diversity of applicants and success rates for statistical purposes only

As the federal Fundamental Science Review noted, there is a need to develop "policies to achieve better equity and diversity outcomes in the allocation of research funding while sustaining excellence as the key decision-making criterion."<sup>25</sup> We found that there is a dearth of diversity data available both at the Ministry and at the research institutions. As a first step towards understanding the equity and diversity of applicants and success rates for the Ministry's programs, we recommend that the Ministry follow the federal standard of collecting information on gender, visible minorities, Indigenous peoples, and people with disabilities for statistical purposes only.

<sup>&</sup>lt;sup>25</sup> Advisory Panel for the Review of Federal Support for Fundamental Science. (2017). Investing in Canada's Future: Strengthening the Foundations of Canadian Research, Canada's Fundamental Science Review. Government of Canada, Ottawa. p. 161

The Ministry should ensure that the peer reviewers do not have access to this information during the adjudication of the applications. It should also assure applicants that this information will only be publicly reported in aggregate form.

#### Recommendation 10: Adopt the federal "Tri-Agency Open Access Policy" on research data and publications

Other jurisdictions are leading the way in developing policies that will help researchers share their publications and data with the world. As Canada moves toward this goal, we recommend that the Ministry adopt the federal open-access policy developed by the three main federal research funding agencies: the Canadian Institutes of Health Research (CIHR), the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Social Sciences and Humanities Research Council of Canada (SSHRC).<sup>26</sup>

The goal of the "Tri-Agency Open Access Policy" is to promote the availability of findings that result from publicly-funded research, including research publications and data, to the widest possible audience, and at the earliest possible opportunity.

#### Recommendation 11: Take steps to further support and strengthen peer review panels by ensuring that the peer review panel members possess the expertise necessary to evaluate proposals

The peer review process, while not perfect, remains the gold standard process<sup>27</sup> through which excellent, relevant research is selected. It is critical for determining which projects receive government support and the Ministry should continue to ensure that the peer review panel members possess the expertise necessary to evaluate proposals. The Ministry may also consider working with research institutions and their representative associations to provide a roster of potential reviewers to which the Ministry can refer when building their peer review panels.

We also note a trend in other jurisdictions where honoraria are being offered to peer reviewers. The Ministry should continue to monitor these trends and refer to policies adopted by the Tri-Agencies on this matter.

<sup>&</sup>lt;sup>26</sup>Government of Canada. (2016). <u>science.gc.ca/eic/site/063.nsf/eng/h\_F6765465.html</u>

<sup>&</sup>lt;sup>27</sup> ncbi.nlm.nih.gov/pmc/articles/PMC4093306/ Mayden, K.D. (2012)

Recommendation 12: Streamline, clarify and redesign the application and reporting processes to reduce the administrative burden for researchers, while ensuring fairness, transparency, excellence and accountability

#### a. Accelerate implementation of an online application process

Ontario's research programs require that applicants submit paper copies of their proposals. Stakeholders have expressed frustration with this requirement and the need to provide electronic copies as well. We understand that the Ministry will soon be implementing an online application portal, which will hopefully address these concerns. The Ministry should also accept electronic letters of reference, as is the practice in other Canadian research funding programs.

#### b. Simplify and streamline information about program guidelines and requirements

We heard from numerous stakeholders about the need for more clarity on guidelines and communications during the Ministry's cross-province "road shows". The Ministry should review how their guidelines are presented online and seek ways to simplify and streamline the information so that applicants do not have to repeatedly contact Ministry staff for clarifications.

### c. Continue to implement changes to the application process which reduce the amount of time and effort required for researchers and institutions to complete applications

We understand from both personal experience and stakeholder consultations that the ORF-RE application process is onerous and requires many hours of effort to complete. While the Ministry has reduced the size of the proposals over the years with feedback from the peer review panels, we encourage it to continue to look for ways to minimize the amount of preparation time necessary to put together the applications. In a similar vein, the budget proposal and reporting forms for the ORF-RE programs should be streamlined.

### d. If necessary, collect project information on the funding of basic vs. applied research for statistical purposes only

The Ontario Auditor General recommended in 2015 that the Ministry track the amount of basic and applied research being funded. The Ministry has previously not collected this information on the principle that the ORF and ERA programs are open to both kinds of research.

A recent survey of previous ORF and ERA recipients conducted by the Ministry revealed that 52% of the research funded is in basic science and the remaining 48% is applied, as reported by the principal investigators. If this information must be collected, we recommend that the Ministry collect this information via approved projects' final reporting forms for statistical purposes only and not at the time of application.

#### e. Work with federal government, provincial partners and philanthropic sector to develop a coordinated approach to measuring outcomes and their attribution to contributed effort and resources

The Ontario Auditor General recommended in 2015 that the Ministry develop "outcome and potentially socio-economic measures to use in assessing the impact of the Ministry's investments in university research and commercialization."<sup>28</sup> Given that attribution for any given outcome in science and research is difficult since it is a collective effort supported by many funders, we suggest instead that the Ministry dedicate funding and resources so that it can work with its funding partners in the federal government, provincial partners and philanthropic sector to leverage existing and future outcome measurement exercises.

We also note that the changes to the Ontario.ca website resulted in the loss of many of the success stories and content that celebrates the province's innovation strengths. We strongly encourage the Ministry to publicly report the outcomes of its investments in science and research.

<sup>&</sup>lt;sup>28</sup> Office of the Auditor General of Ontario. (2015). Annual Report 2015. Chapter 3.14: University Intellectual Property. <u>auditor.on.ca/en/content/annualreports/arreports/en15/3.14en15.pdf</u>. pg. 545.

## **APPENDICES**

## Appendix A: Acronyms

ACRONYM	DEFINITION
САНО	Council of Academic Hospitals of Ontario
CANSIM	Canadian Socio-Economic Information Management System
CFI	Canada Foundation for Innovation
CIHR	Canadian Institutes of Health Research
CIIF	College-Industry Innovation Fund
CIMD	Centre for Industrial Material Development
D.V.M.	Doctor of Veterinary Medicine
ERA	Early Researcher Award
HIFU	high-intensity focused ultrasound
HQP	highly qualified personnel
IEEE	Institute of Electrical and Electronics Engineers
ISF	Israel Science Foundation
LIF	Large Infrastructure Fund
LSARP	Large-Scale Applied Research Projects
M.D.	Medical Doctor
MSI	Major Sciences Initiatives
NSERC	Natural Sciences and Engineering Research Council of Canada
OCUR	Ontario Council on University Research
OIA	Ontario Innovation Agenda
ORF	Ontario Research Fund
ORFAB	Ontario Research Fund Advisory Board
ORF-RE	Ontario Research Fund-Research Excellence
ORF-RI	Ontario Research Fund-Research Infrastructure

Ph.D.	Doctor of Philosophy
PREA	Premier's Research Excellence Awards
R&D	research and development
SIF	Small Infrastructure Fund
SNOLAB	Sudbury Neutrino Observatory Laboratory
SSAH	social sciences, arts and humanities
SSHRC	Social Sciences and Humanities Research Council of Canada
YSEP	Young Scientist Exchange Program

## Appendix B: Submissions and meetings with stakeholders

This appendix provides a summary of the consultations undertaken by the Expert Review Panel and secretariat with a number of key stakeholders, both within and outside of Ontario. Submissions and meetings with stakeholders with members of the science and innovation ecosystem were imperative in providing feedback to the Panel. We are pleased with the responses received as they provided a vital contribution in helping inform and shape the recommendations of this report. Please note that where individual responses were provided, names are not listed or identified by name in this report.

#### METHODOLOGY

Consultations with external stakeholders were conducted in three Phases, with a variety of methods implemented, and discussions taking place via in-person meetings, phone calls, e-mails, teleconferences, and formal electronic written submissions. In each case, a series of open-ended questions tailored to each stakeholder was provided.

#### PHASE I: INSTITUTIONS AND ASSOCIATIONS

A number of Ontario's key institutions and associations were contacted via formal e-mails and encouraged to engage in the ORF Review consultations, and submit electronic written responses. Phase I of the consultations process was facilitated through CAHO, OCUR and Colleges Ontario. A number of key institutions and associations from across the province were contacted, with 21 institutions providing submissions.

A comprehensive list of the institutions and associations that provided submissions are listed below:

- Colleges Ontario
- The Council of Academic Hospitals of Ontario (CAHO)
- The Centre for Addiction and Mental Health (CAMH)
- Hamilton Health Sciences
- · Health Sciences North Research Institute
- Holland Bloorview Research Institute
- Ontario Council on University Research (OCUR)
- Queen's University
- Ryerson University
- Sheridan College Institute of Technology and Advanced Learning
- Sick Kids Research Institute
- St. Michael's Hospital
- Sunnybrook Research Institute
- Toronto Academic Health Science Network
- University Health Network
- University of Guelph
- · University of Ontario Institute of Technology (UOIT)
- University of Ottawa
- University of Toronto
- · University of Windsor
- Women's College Hospital

## PHASE II:

During Phase II of the consultations process, a series of open-ended questions tailored to each stakeholder was shared through e-mails by Ministry staff from the Research Division. Participants were asked to provide input on several aspects of the ORF and ERA programs including strengths of the programs, potential gaps, advice for improvement in policies, guidelines or procedures as well as any challenges that they may have experienced. Please find below a comprehensive listed of participant groups as part of Phase II of the ORF Review consultations:

- Federal Government (via teleconference):
  - Canada Foundation for Innovation (CFI)
  - Genome Canada
  - Innovation, Science and Economic Development Canada (ISED)
- Research Institutes (via email submission):
  - Ontario Brain Institute (OBI)
  - Ontario Institute for Cancer Research (OICR)
  - Ontario Institute for Regenerative Medicine (OIRM)
  - Ontario Genomics (OG)
  - Perimeter Institute for Theoretical Physics
- Private Sector Partners (invited via email):
  - ARISE Technologies\*
  - Bell Canada
  - GE Healthcare
  - Hewlett Packard
  - ► IBM
  - Rimon Therapeutics Inc.\*
  - Siemens

\*Please note: Organizations that may no longer be active are indicated with an asterisk.

The secretariat exercised its best efforts in contacting individuals who were private sector partners on specific projects with researchers funded by ORF-RE; however only three private sector partners responded to the request to participate.

## • ORF-RE and ERA (via email submission):

- Panel Chairs and Members
- Multiple Award Recipients
- ORF and ERA Previous Applicants

## PHASE III:

The Secretariat shared the key recommendations prior to the report's release with Ontario's Chief Scientist, ORFAB, CAHO, OCUR and Colleges Ontario.

# **CONSULTATION QUESTIONS BY PHASE**

## **PHASE I QUESTIONS**

**Please answer the following questions.** You may answer them individually or address them as a whole.

- I. Are the program designs doing what they intended and having the desired impact?
  - a. The <u>Early Researcher Awards</u> provide funding to new researchers working at publicly funded Ontario research institutions to build a research team. How has the program played a role in your institution's recruitment and retention of new talent?
  - b. How valuable has the <u>Ontario Research Fund Research Excellence</u> program been in supporting researchers conducting leading-edge, transformative, and internationally significant research at your institution?
  - c. In what ways does the <u>Ontario Research Fund Research Infrastructure</u> program provide research institutions with funding to help support infrastructure needs, such as modern facilities and equipment?
  - d. What could the programs do to further support the recruitment, training and retention of top research talent in the province?
  - e. Are there ways to more efficiently or more accurately assess the outputs, impacts and contexts of research in order to allocate Ontario's research funding?

### II. Do the programs still have the right focus?

- a. When looking at your researchers and their career transitions, what supports are most needed at your institution?
- b. The Research Excellence program currently funds projects between \$1 million and \$4 million for the general and clean technology streams and between \$200,000 and \$1 million for the social sciences, arts and humanities stream. Are the minimum and maximum amounts set for the applications appropriate? How do these limits impact your application?
- c. Are there any concerns regarding the required partner funding associated with ORF awards? If so, what are some suggested improvements?

### III. Are there programmatic gaps?

- a. Do researchers feel that the appropriate measures are in place to effectively promote and support all disciplines through Ontario's competitive research programs?
- b. How can the Ministry best address the perception of a lack of continuity in the funding opportunities for the researchers at different levels in their career? Is there a need for a dedicated program supporting excellence for mid-career researchers?
- c. Are there any perceived barriers regarding the ability to receive support for investigator-led research? Do researchers feel that the Ministry's programs support their ability to do independent research?
- d. What are some suggestions for areas of improvement?

#### IV. Are there opportunities to streamline?

a. Are there changes to the existing application, peer review and reporting processes for funding that could be improved?

# **PHASE II QUESTIONS**

The following questions were asked to all Phase II consultation stakeholders:

- I. Are the program designs doing what they intended and having the desired impact?
  - a. The Early Researcher Awards provide funding to new researchers working at publicly funded Ontario research institutions to build a research team. In your view, how has the program played a role in the recruitment and retention of new talent?
  - b. What could the programs do to further support the recruitment, training and retention of top research talent in the province?
  - c. How valuable has the Ontario Research Fund Research Excellence program been in supporting researchers conducting leading-edge, transformative, and internationally significant research?
  - d. In what ways does the Ontario Research Fund Research Infrastructure program provide researchers with funding to help support infrastructure needs, such as modern facilities and equipment?
  - e. What do you believe to be the main strengths of the Ontario Research Fund and Early Researcher Awards programs?
  - f. Do you believe there to be any gaps in the Ministry's current research funding mechanisms? Yes or no? Please explain.
  - g. Are there ways to more efficiently or more accurately assess the outputs, impacts and contexts of research in order to allocate Ontario's research funding?

## II. Do the programs still have the right focus?

- a. When looking at your researchers and their career transitions, what supports do you believe are most needed?
- b. The Research Excellence program currently funds projects between \$1 million and \$4 million for the general and clean technology streams and between \$200,000 and \$1 million for the social sciences, arts and humanities stream. Are the minimum and maximum amounts set for the applications appropriate? How might these limits impact an application?
- c. Are there any concerns regarding the required partner funding associated with Ontario Research Fund awards? If so, what are some suggested improvements?

### III. Are there programmatic gaps?

- a. Do researchers feel that the appropriate measures are in place to effectively promote and support all disciplines through Ontario's competitive research programs?
- b. How can the Ministry best address the perception of a lack of continuity in the funding opportunities for the researchers at different levels in their career? Is there a need for a dedicated program supporting excellence for mid-career researchers?
- c. Are there any perceived barriers regarding the ability to receive support for investigator-led research? Do researchers feel that the Ministry's programs support their ability to do independent research?
- d. What are some suggestions for areas of improvement?
- e. Are there opportunities to streamline?
- **IV.** Are there any other issues or questions that you would like to raise and address?

In addition, the following questions were asked to the Ministry's Federal Government counterparts and the Canada Foundation for Innovation (CFI):

- a. Are there opportunities to better streamline processes between CFI and the Ministry with respect to the administration of programs?
- b. Do you have suggestions for how the federal and provincial government can better coordinate its efforts in supporting projects requiring co-funding?
- c. Are there any gaps in the processes, policies, guidelines or procedures? What improvements would you suggests?
- d. In general, what are the major issues faced by researchers regarding infrastructure funding?
- e. In cases where there projects do not receive a consensus by both funding bodies (CFI and the Ministry), what are some alternative options for researchers in seeking out additional research funding? Should researchers be advised to develop a strategy surrounding this potential issue prior to applying?
- f. Does the Ministry have an appropriate level of emphasis on the commercial potential of research? Is there too much or too little emphasis? Please explain.
- g. Are there opportunities for the federal and provincial research funding bodies to partner further on projects with socioeconomic impacts?

### The following questions were posed to Genome Canada:

- a. What would you say are the main strengths of the Ministry's research funding programs? What works well in the programs?
- b. Are there any gaps in the processes, policies, guidelines or procedures? What improvements would you suggests?
- c. Are there opportunities to better streamline processes between Genome Canada and the Ministry with regards to the administration of the GAPP, LSARP, and DIG programs?
- d. In your view, are there more efficient ways to streamline processes between the federal funding agencies and Ontario?
- e. Do you have suggestions for how the federal and provincial government can better coordinate its efforts in supporting projects requiring co-funding?
- f. What are the main issues or challenges you experienced?
- g. Are there opportunities for the federal and provincial research funding bodies to partner further on projects with socioeconomic impacts?

# The following questions were also asked to Innovation, Science and Economic Development Canada (ISED):

- a. How is the federal government working to address and implement the recommendations from the recent Naylor Report?
- b. What is the federal government doing to support early and mid-career researchers?
- c. Do you have suggestions for how the federal and provincial government can better coordinate its efforts in supporting projects requiring co-funding?
- d. In your view, are there more efficient ways to streamline processes between the federal funding agencies and Ontario?
- e. Is the Ministry's research funding programs sufficient in meeting the needs of the researchers within Ontario? Why or why not? Please explain.
- f. Are there opportunities for the federal and provincial research funding bodies to partner further on projects with socioeconomic impacts?

### The following additional questions were asked to Panel Chairs and Members:

As a Chair or Panel Member of the Ontario Research Fund – Research Excellence (ORF – RE) program,

- a. What do you believe are the main strengths of the ORF RE program? What works well in the program?
- b. Are there any gaps in the program's current policies or procedures? If so, what improvements do you suggest?
- c. Are the Ministry's guidelines clear in establishing its criteria for researchers applying to ORF RE?
- d. From your perspective, what were the main challenges you experienced?
- e. Overall, what improvements could you suggest to the Ministry's ORF RE program?
- f. Are there any other questions or issues you would like to address?

### The following additional questions were asked to Multiple Award Recipients:

As a recipient of multiple awards from the Ministry,

- a. What do you believe are the main strengths of the programs? Are there any programmatic gaps?
- b. Are the Ministry's guidelines clear in establishing its criteria for researchers applying to our programs?
- c. How have the Ministry's programs and research funding helped you in your career as a researcher?
- d. In your opinion, what were the critical factors for establishing independence early on in your research career?
- e. Do you believe you received the appropriate level of advice and feedback from program peer review panels? Why or why not?
- f. Overall, what improvements could you suggest to the Ministry's programs?
- g. Are there any other questions or issues you would like to address?

### The following additional questions were asked to Previous Applicants:

As a researcher who has previously applied to the Ministry's ORF and/or ERA programs,

- a. Do you feel the Ministry's programs are well-structured to support research excellence in terms of:
  - Areas of focus?
  - Size of grant available? (i.e. too small or too large)
- b. Was the process for proposal preparation clear and reasonable? Do you have any recommendations to clarify or strengthen the process?
- c. Were the criteria for proposal evaluation clear and reasonable? Do you have any recommendations that could be enhanced or improved?
- d. Did you receive valuable and sufficient feedback on your proposal to understand where you could make adjustments and enable you to successfully reapply to a future competition?
- e. From your perspective, what challenges did you experience in securing funding from the Ministry? Please explain.
- f. Overall, what improvements could you suggest to the Ministry's programs?
- g. Are there any other issues you would like to address?

### The following questions were asked to Private Sector Partners:

- a. Why did you choose to partner on this project with the research institution through the ORF program? What were you hoping the partnership would bring to your company? What value did this partnership add or bring as a result?
- b. What outcomes did your company achieve as a result of the partnership? (i.e. licenses, HQP, etc.)
- c. Did your company experience any issues or challenges associated with the Ministry's programs? If yes, please explain.
- d. Were there any issues or challenges establishing and/or maintaining a relationship with the research institution?
- e. Do you have any suggestions or recommendations for improving the Ministry's programs?

- f. Do you believe greater flexibility should be given for research institutions seeking matching funds? (i.e. partnership eligibility, matching criteria, timing of partner contributions, how matching funds are obtained).
- g. Do you believe that the Ontario Research Fund should maintain its current level of required matching funds from private sector partners? If no, why not? And, what level would you suggest?
- h. Does the Ministry have an appropriate level of emphasis on the commercial potential of research? Is there too much or too little emphasis? Please explain.
- i. Based on your response, how may this impact the researcher's success in applying for funding?

# Appendix C: Ontario's research and innovation system – emerging technological fields

This appendix examines the impact Ontario researchers are having in five emerging technological fields – artificial intelligence, fuel cells, quantum computing, quantum science (broadly defined) and regenerative medicine. It looks at Ontario's research efforts in national and global perspective by examining outputs of scholarly publications, the impact these outputs are having on the larger academic community as measured by citations, citations per publication and the share of publications which are among the most highly cited as well as the extent to which Ontario researchers are engaged in international collaborations in these areas.

# **METHODOLOGY**

A series of keywords were defined for each of the five research areas (the specific terms used are outlined at the end of this appendix). These keywords were then inputted into SciVal, an online bibliometric tool that is integrated with the Scopus database.<sup>29</sup>

A series of metrics regarding scholarly output, citations and international collaborations were utilized for the analysis:

*Publications:* This metric covers all articles, review papers and conference papers produced by researchers in the five emerging fields. It should be noted that the number of publications can vary by discipline so comparisons across research areas is not recommended.

*Citations:* This represents the total number of times an article is cited by other researchers and can serve as a broad indicator of the influence that researchers in a specific field from a particular jurisdiction are having on the wider academic research efforts in a given field. To be conservative self-citations were excluded from the results presented in this appendix.

*Citations per publication:* This measures the total number of citations divided by the total number of publications produced in a given field. It can serve as a broad indicator of research impact that controls for the volume of publications produced.

<sup>&</sup>lt;sup>29</sup> Both Scopus and SciVal are products produced by Elsevier publishing. Detailed information regarding the data coverage of SciVal/Scopus can be found here: <u>elsevier.com/\_\_data/assets/pdf\_file/0020/53327/scival-metrics-guidebook-v1\_01-february2014.pdf</u>.

*Top cited publications:* This metric reports upon the number of publications from a particular jurisdiction which are among the most cited (top 10%) of publications in a specific area of research. This measure can serve to highlight the most highly regarded papers being produced in a jurisdiction. The results for this metric are field-weighted to take into account differences in publication rates.

*International collaborations:* This metric reports upon the percentage of publications involving a Canadian or Ontario researcher which also involved an international co-author. This can serve as an indicator of both the level of importance attached to Ontario-based research by international researchers and the ability of Ontario researchers to tap into global academic networks.

The Canadian and Ontario results reported in the Findings section were constructed as follows. After running the search terms against the list of all publications available through SciVal a two stage filtering process was carried out. First the results were filtered to look for any papers featuring a Canadian author. This generated lists of publications which included not only Canadian institutions but also foreign institutions since many papers involved international co-authors. Thus a second institutional filter was introduced which only selected Canadian institutions or Ontario institutions as the case need be to try to eliminate the double counting caused by the presence of the foreign institutions. An element of double-counting will still be present, however, due to potential collaborations between Canadian based researchers.

The results presented below should be treated as a quick, initial cut at a more fulsome bibliometric analysis. A more comprehensive approach would move beyond the use of keywords to the use of some of the pre-defined subject area categories available through SciVal.

# **FINDINGS**

Table Appendix C1 provides an overview of where Ontario stands, both nationally and globally, in terms of the quantity and quality of research being conducted within the province in five emerging fields – artificial intelligence, fuel cells, quantum computing, quantum science and regenerative medicine.

**Table Appendix C1:** Ontario research performance in select emerging technology fields, 2011 to 2017<sup>30,31</sup>

FIELD	JURISDICTION	PUBLICATIONS	CITATIONS	CITATIONS PER PUBLICATION	TOP CITED PUBLICATIONS	INTERNATIONAL COLLABORATIONS
ARTIFICIAL INTELLIGENCE	WORLD	57,370	371,919	6.5	9,450	21%
ARTIFICIAL INTELLIGENCE	CANADA	2,213	23,430	10.6	482	44%
ARTIFICIAL INTELLIGENCE	ONTARIO	868	11,808	13.6	212	44%
FUEL CELLS	WORLD	47,035	578,713	12.3	7,677	21%
FUEL CELLS	CANADA	1,800	30,925	17.2	375	44%
FUEL CELLS	ONTARIO	960	19,065	19.9	220	48%
QUANTUM COMPUTING	WORLD	15,016	145,840	9.7	2,024	30%
QUANTUM COMPUTING	CANADA	841	13,310	15.8	184	69%
QUANTUM COMPUTING	ONTARIO	442	7,254	16.4	91	68%

<sup>30</sup> SciVal database. Data extracted between March 15 and March 26, 2018.

<sup>31</sup> Notes:

- 1. In this analysis a publication refers to articles, reviews and conference papers. This definition holds for all the metrics examined.
- 2. For all the citation metrics, self-citations are excluded from the analysis.
- 3. Figures for the top cited publications metric are field weighted.
- 4. Because of data processing issues the global total for quantum science refers only to the top 10 countries in this field.

FIELD	JURISDICTION	PUBLICATIONS	CITATIONS	CITATIONS PER PUBLICATION	TOP CITED PUBLICATIONS	INTERNATIONAL COLLABORATIONS
QUANTUM SCIENCE	WORLD	46,137	549,931	11.9	7,073	31%
QUANTUM SCIENCE	CANADA	2,390	43,251	18.1	565	63%
QUANTUM SCIENCE	ONTARIO	976	21,518	16.4	252	63%
REGENERATIVE MEDICINE	WORLD	54,644	742,874	13.5	7,694	21%
REGENERATIVE MEDICINE	CANADA	1,650	26,406	16.0	281	46%
REGENERATIVE MEDICINE	ONTARIO	768	14,201	18.5	156	46%

Description: Table Appendix C1 provides a breakout of research generated by Ontario researchers in five emerging fields, artificial intelligence, fuel cells, quantum computing, quantum science and regenerative medicine. Ontario's results are compared against the Canadian national and global totals in terms of publications, citations, citation per publication, top cited publications and international collaborations.

On a national basis Ontario researchers were involved in producing approximately half of all Canadian publications in the areas of fuel cells, quantum computing and regenerative medicine showing Ontario's particular strength in these areas. Ontario researchers involvement in the national production of articles in artificial intelligence (39%) and quantum science (41%) is on par with the provinces overall share of the nation's population and economy.

Metrics on citation rates also suggests the research being conducted in these emerging fields within the province is regarded highly by other scholars. In terms of citations per publication Ontario scores higher than the global average across all fields and leads nationally in four of the five areas examined. Additionally when one examines the share of all Ontario publications which rank among the top 10% of most cited papers one finds that Ontario surpasses the global equivalent measure in all of these fields and outperforms the national scores in four of the five areas.

Ontario researchers also demonstrate a strong willingness to engage in international collaborations in these emerging fields. Researchers in the areas of quantum computing and quantum science particularly stand out with 68% of researchers in quantum computing and 63% engaged in quantum science having produced publications in collaboration with international partners

# **KEYWORD SEARCHES**

The following keyword text searchers were used to generate the publications total in SciVal. As noted above this is an initial bibliometric analysis and could be followed up with a more comprehensive analysis.

- Artificial Intelligence: Text search "machine learning" OR "artificial intelligen\*" OR "neural net\*"
- Fuel cells: Text search "Fuel cell\*"
- Quantum computing: Text search "quantum comput\*" OR "qubit"
- Quantum Science: Text search "quantum comput\*" OR "qubit" OR "quantum crypt\*" OR "quantum informat\*" OR "quantum communic\*" OR "quantum key" OR "quantum security" OR "quantum dot\*" OR "quantum photo\*" OR "quantum entangle\*" OR "photon entangle\*" OR "quantum superposit\*" OR "quantum teleport\*" OR "quantum metro\*" OR "quantum squeez\*" OR "quantum control" OR "quantum device" OR "quantum measure\*"
- Regenerative Medicine: Text search "regenerative medicine" OR "tissue engineering" OR "cell therapy"

# Photo References:

- Chapter 1 SNOLAB, Queen's University
- Chapter 2 WindEEE Research Institute, Western University
- Chapter 3 Flickr Ontario Innovation, The Hospital for Sick Children (SickKids)
- Chapter 4 Flickr Ontario Innovation, University of Toronto
- Chapter 5 Cabinet Office Photo Library, Carleton University
- Chapter 6 iDAPT, Toronto Rehabilitation Institute UHN, University of Toronto

# **ONTARIO RESEARCH FUND REVIEW**

MAY 2018