



Annual Research Report 2015-2016

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By the numbers

155

faculty
researchers

497

graduate
students

\$70,262,063

in grants



Paul Corkum and Juan (Tito) Scaiano were both successful in obtaining Innovation Fund grants from the Canada Foundation for Innovation, and received more than \$32,7 million.

104

postdoctoral
fellows

17

new
researchers

182

Undergraduate
Research Scholarship
recipients

28

awards to our
researchers

20

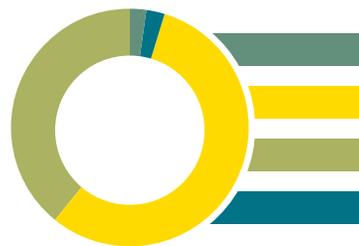
invention
disclosures

11

patents
obtained

39

research chair
holders



1 Canada Excellence Research Chair

22 Canada Research Chairs

15 University Research Chairs

1 Endowed Research Chair

27

new research
projects in
partnership with
government

46

new industry-
partnered research
projects

2

startups
launched

95%

success rate in 2016
NSERC Discovery
Grant competition

Research for tomorrow

Message from the Dean



Steve Perry, Dean

First, I am delighted to welcome you and introduce our inaugural Faculty of Science Annual Research Report. I am so proud to lead a faculty where research is closely tied to the principal mission of our university — education! In our faculty, we educate both undergraduate and graduate students through research and, indeed, we even conduct research on science education.

In these pages you will read about some of the amazing success stories and achievements that have occurred in the Faculty of Science over the past 12 months. I can tell you that it was no easy feat to limit this document to only 20 pages! It has been particularly gratifying for me to witness our faculty's rapid and substantial expansion, which

is now slowing down after three years of frenzied activity. Never could I have imagined hiring 17 professors — some internationally-renowned researchers — over a 12-month period, but that is exactly what we have done.

But with such unprecedented growth also come unprecedented expectations of further enhancement of our research enterprise. Let me assure you that the future has never looked brighter, as our new crop of young professors begin to hit their stride. While this report looks back on the achievements of the past year, we must remain focused on the future and never lose sight of our goal: to excel in research and education.

Enjoy the read!

Department directors

Thomas Brabec

Physics

André Desrochers

Earth and Environmental
Science

Paul Mayer

Chemistry and Biomolecular
Sciences

Antoine Morin

Biology

Monica Nevins

Mathematics and Statistics

Message from the Vice-Dean, Research



Louis Barriault, Vice-Dean,
Research

The 2015-2016 academic year was one of achievement at the Faculty of Science, building on our recent unprecedented growth in researchers and student population.

As a 21st century faculty, we are committed to research leading to new fundamental and applied knowledge that can solve significant challenges for our community. Our research strategy is aligned with the key uOttawa research areas outlined in Destination 2020.

We have made scientific and technological breakthroughs in photonics, cryopreservation, ecology, materials science, fundamental mathematics, geoscience and more.

Of course, this research innovation has been made possible through partnerships

and major funding initiatives. With the constant support of our partners, we have maintained the excellence of our core facilities, which provide state-of-the-art support to our researchers and clients. As well, we have created a new centre for advanced material research, and in partnership with the Max Planck Institute, a joint centre for extreme and quantum photonics that is unique in Canada.

Our growth in recent years has led to an increase in research intensity and productivity. In addition to enjoying new research centres, more than 90% of our researchers receive external funding, which positions the Faculty of Science among the leading faculties of its kind in Canada. And the best is yet to come!

Research Committee members

Pascal Audet

Professor, Department of Earth and Environmental Sciences

Louis Barriault

(chair), Vice-Dean, Research

Richard Blute

(vice-chair), Vice-Dean, Graduate Studies

Laurie Chan

Professor, Department of Biology

Jasmine Lefebvre

(non-voting member), Research Facilitator

France Malette

(non-voting member), Chief Administrative Officer

Muralee Murugesu

Professor, Department of Chemistry and Biomolecular Sciences

Paul-Eugène Parent

Professor, Department of Mathematics and Statistics

Andrew Pelling

Professor, Department of Physics

Joining forces to achieve excellence

Mandate

The Research Office was established to support and promote research conducted at the Faculty of Science. It serves as the main intermediary between granting agencies and researchers, as well as with University of Ottawa research offices. The office also assists researchers in preparing grant and scholarship applications, and award nominations.

Key research areas

The six key research areas identified in the Faculty of Science 2016–2021 Strategic Research Plan will involve our researchers in some of the great scientific challenges of the 21st century. Our focus on supporting basic research will necessarily reinforce interdisciplinary research, research partnerships with industry and our contribution to emerging research areas.

Fundamental and applied mathematics and statistics

Mathematics and statistics are fundamental to all scientific disciplines. The Faculty of Science is home to internationally-renowned researchers in pure mathematics, on track to rank among the top five departments of its kind in Canada for research intensity. Our mathematics professors are involved in various interdisciplinary collaborations with researchers in other faculties. This will lead to major discoveries. In the coming years, we will direct our research towards pure mathematics, data science, financial mathematics, multiscale analysis and scientific computation.

Biomolecular sciences and augmented biology

A growing number of professors are using their expertise in elucidating and manipulating chemical reactions to better understand, control and alter biological mechanisms. This growing tendency towards interdisciplinary research is seen within the Department of Physics, where a cluster of excellent biophysicists pursue research objectives at the crossroads of biology, physics and engineering, including the development of new biomaterials. This is a unique opportunity to engineer living systems, creating new research fields, biotechnologies and economic opportunities.

Advanced materials and photonics

Internationally renowned researchers and state-of-the-art facilities, combined with the synergy between photonics and materials research, are leading to world-class innovation in areas such as plasmonic materials and devices, and molecular magnetic and electronic materials. The symbiosis of physics, chemistry and engineering-related knowledge of photosensitive materials is bound to lead to major discoveries. Highlighted research topics include advanced imaging, light-matter interaction, and leading-edge optical materials and nanophotonics.

Environment and resources

Many Faculty of Science research projects deal with the environmental impact of human activity, such as the environmental pollution resulting from the exploitation of natural resources. Research interests include the impact of natural resource exploitation, ecotoxicology, biodiversity and environmental change, innovations in accelerator mass spectrometry and environmental science big data.

Catalysis and renewable energy

Catalysis is an essential technology for the manufacture of chemical products and materials, therapeutic drugs, and fuel cells and other energy conversion systems, which have greatly contributed to enhancing human life expectancy. Catalysis research at the Faculty of Science includes the development of new catalysts and chemical reactions to fabricate medicinal compounds, CO₂ capture, continuous flow chemistry and the use of biomass to produce fuel.

Quantum information

Quantum information is the interdisciplinary study of the connection between information theory and the microscopic laws of nature, quantum physics. Unlike classical physics, quantum physics allows for the existence of superpositions of two (or more) quantum states. This feature can provide solutions to intractable computational tasks and enhance security of communication. Researchers are undertaking projects in fields such as quantum information, quantum cryptography and quantum communication.



Strategic priorities

The Research Office has adopted the following five strategic priorities:

- Increasing Faculty visibility and improving relations with alumni
- Encouraging partnerships with industry
- Promoting interdisciplinary research
- Spurring international partnerships and funding from international sources
- Seeking out alternative and unconventional funding sources

Our researchers

New professors

Department of Earth and Environmental Sciences

Tom Al – Full Professor

Department of Mathematics and Statistics

Maia Fraser – Assistant Professor
Tanya Schmah – Assistant Professor
Chen Xu – Assistant Professor

Department of Physics

Ebrahim Karimi – Assistant Professor
Adina Luican-Mayer – Assistant Professor
Jean-Michel Ménard – Assistant Professor

Department of Biology

Vincent Careau – Assistant Professor
Matthew Pamerter – Assistant Professor

Department of Chemistry and Biomolecular Sciences

François-Xavier Campbell-Valois – Assistant Professor
Julian Chan – Assistant Professor
Corrie daCosta – Assistant Professor
Alison Flynn – Associate Professor
Eva Hemmer – Assistant Professor
Michael Organ – Full Professor
John Paul Pezacki – Full Professor
Adam Jason Shuhendler – Assistant Professor

HOLDERS OF NEW AND RENEWED CANADA RESEARCH CHAIRS

R. Tom Baker

Canada Research Chair in Catalysis Science for Energy Applications, Tier 1 (renewal)

Vincent Careau

Canada Research Chair in Functional Ecology, Tier 2

Paul Corkum

Canada Research Chair in Attosecond Photonics, Tier 1, in partnership with the National Research Council Canada (renewal)

Ebrahim Karimi

Canada Research Chair in Structured Light, Tier 2

Matthew Pamerter

Canada Research Chair in Comparative Neurophysiology, Tier 2

Adam Shuhendler

Canada Research Chair in Chemical Biology, Tier 2

Opposite page: From left to right: Mona Nemer, Vice-President, Research; Maxim Berezovski; Steve Perry; and Ruby Heap, Associate Vice-President, Research

Awards and recognition

Mayer Alvo

Fellow, Fields Institute for Research in Mathematical Sciences

John T. Arnason

Norman R. Farmsworth Excellence in Botanical Research Award, 2015

Pascal Audet

Sloan Research Fellow, 2015

André Beauchemin

Boehringer Ingelheim Research Excellence Award, 2015

Xiaoyi Bao

Honorary doctorate, University of Lethbridge

Maxim Berezovski

University of Ottawa Young Researcher of the Year Award

Robert Boyd

Optical Society of America Charles Hard Townes Award, 2016

American Physics Society Arthur L. Schawlow Prize in Laser Science, 2016

Vincent Careau

Society for Integrative & Comparative Biology Division of Comparative Physiology and Biochemistry George A. Bartholomew Award, 2016

Paul Corkum

Russian Academy of Sciences Lomonosov Gold Medal, 2015

Thomson Reuters Citation Laureate, 2015

Honorary doctorates, Université de Sherbrooke and Université Laval

Sarah Dare

Geological Association of Canada Mineral Deposits Division William Harvey Gross Award, 2016

Victor LeBlanc

University of Ottawa Excellence in Teaching Award

Thomas Moon

CCUBC Career Achievement Award, 2015

Julie Morand-Ferron, Anne Broadbent and Vincent Tabard-Cossa

Ontario Ministry of Research and Innovation Early Researcher Awards, 2015

Jonathan O'Neil, Pascal Audet and Roberto Chica

Ontario Ministry of Research and Innovation Early Researcher Awards, 2014

Michael Organ

Canadian Society for Chemistry R.U. Lemieux Award, 2016

Andrew Pelling

TED Fellow, 2016

Juan (Tito) Scaiano

American Chemical Society James Flack Norris Award, 2016

Adam Shuhendler

John Charles Polanyi Prize, 2015

Tom Woo

Canadian Society for Chemistry Tom-Ziegler Award

Kirill Zaynullin

Faculty of Science Researcher of the Year Award, 2015–2016



Outstanding discoveries



Biology

Impact of climate change on bumblebees across continents

Relying on over 110 years of North American and European data, Jeremy Kerr carried out a study into whether recent climate change could have caused changes seen in the geographic ranges of more than 67 species of bumblebee, the most important pollinator on the planet. Dr. Kerr's research also includes analysis of similarities between bumblebee species, given that they respond similarly to warming. Bumblebees' relative intolerance to warm conditions may explain why certain species groups suffer considerable losses during climate change. Tackling this conservation challenge will require new strategies, such as assisted migration, to assist species in settling in more northerly zones.

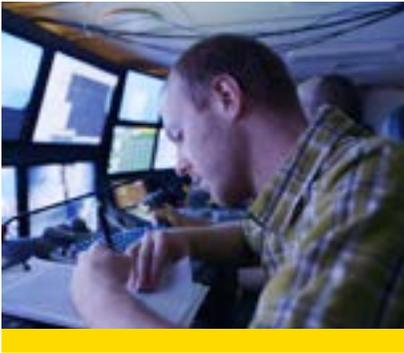


Chemistry and Biomolecular Sciences

Improved cryoprotectants to meet the needs of modern medicine

Robert N. Ben, director of the Biopharmaceutical Sciences program, is a world leader in rational design and synthesis of therapeutic small molecules that prevent damage during cryoconservation. The discovery of these molecules is one of the most important advances in cryobiology in the last 20 years, allowing for the long-term conservation of cells and tissues, such as stem cells.

Results of red blood cell cryoconservation research in Professor Ben's lab show that cell quality and potency is superior to that observed when using conventional cryoconservation protocols. This will improve the effectiveness of many disease treatments and can be easily applied to cryoconservation of engineered tissues and complex molecular systems such as organs.



Earth and Environmental Sciences

Using a Canadian remote controlled vehicle in the Kingdom of Volcanoes

Mark Hannington, Goldcorp Chair in Economic Geology, and John Jamieson, former postdoctoral fellow, are part of the Schmidt Ocean Institute team. Leaders in their research field, they studied the hydrothermal mineral deposits that form at hydrothermal vents. They developed the first virtual reality 3D model of a complete field of hydrothermal vents using a Canadian remote-controlled submersible, ROPOS, covering the largest section of seabed ever imaged in this way.



Mathematics and Statistics

Between real numbers and rational numbers

Damien Roy published a brilliant article in one of the most renowned journals in the world of mathematics, *Annals of Mathematics*. The article proved the optimality of a new approach in diophantine approximation, the study of the approximation of real numbers by rational numbers. The new methods developed by Dr. Roy have already been used to solve a myriad of other problems related to diophantine approximation, a field that interests many mathematicians around the world.

Photo credit: MFO, Archives of the Mathematisches Forschungsinstitut Oberwolfach



Physics

New photonic material with huge nonlinear optical response

Robert Boyd, Canada Excellence Research Chair in Quantum Nonlinear Optics, postdoctoral fellow Israel De Leon and their collaborators recently demonstrated a new approach to developing highly nonlinear materials used in photonics, that is, materials for which the refractive index is not constant, but increases with the intensity of light. Dr. Boyd's team demonstrated this effect in indium tin oxide, a material recognized for its importance in photonics. The nonlinear coefficient measured was 340,000 times greater than that of silica glass and 440 times greater than that of arsenic triselenide glass, the material with the greatest nonlinear coefficient reported until now. Indium tin oxide, with its refractive index, and other materials under development could constitute a game-changer for the field of photonics.

Promising researchers



Bachelor's

Aaron Shifman (biology)

Aaron received an award for the best thesis in the Biomedical Science program. He will soon begin a master's in biology. In the thesis, *The Local and Global Influences of Neuronal Field Effects in Synchronized Networks*, he developed a novel computational modelling framework in order to study a little-understood brain cell communication mechanism, using it to make non-intuitive predictions regarding brain dynamics. Aaron has worked in John Lewis's biology lab as well as with the Université de Montréal's Institut de recherche en immunologie et cancer. He received an NSERC Undergraduate Student Research Award and currently holds an Ontario Graduate Scholarship, in addition to having two publications to his name, in *Scientific Reports* (2015) and *BMC Genomics* (2016).



Master's

Adèle Bourgeois (mathematics)

Soon-to-be PhD candidate Adèle Bourgeois completed her master's with an innovative thesis entitled *Spreading Speeds and Travelling Waves in Integrodifference Equations with Overcompensatory Dynamics*. She is currently preparing two articles based on this thesis, supervised by Victor LeBlanc and Frithjof Lutscher. Adèle's research looks at the mathematical properties of integrodifference equations, models that can be used in biology. She has been invited to speak about these models on numerous occasions, including during the ninth annual Ottawa Math Conference, which she helped organize. For her doctorate, Adèle will study representation theory, thanks in part to another NSERC Alexander Graham Bell Canada Graduate Scholarship as well as a University of Ottawa excellence scholarship.



Master's

Justin Whitaker (Earth Sciences)

An MSc student in Earth Sciences, Justin Whitaker conducted research on bacteria and their use to harden the sandy soil around buildings, to make it more resistant to natural disasters. Co-supervised by Sai Vanapalli and Danielle Fortin, Justin has been recognized on numerous occasions for his work on the topic and has received many scholarships, including the Ontario Graduate Scholarship and the NSERC Alexander Graham Bell Canada Graduate Scholarship. In 2016, he came fourth in the provincial "Three Minute Thesis" competition and 11th in the national competition, organized by the Canadian Association for Graduate Studies.



Doctorate

Frédéric Perras (chemistry)

Frédéric Perras, formerly of David Bryce's lab, has received several prestigious awards, including the 2016 Raymond Andrew Prize from the Ampere Society for his doctoral thesis, *Structural insights from the NMR spectroscopy of quadrupolar nuclei: Exploiting electric field gradient and spin-spin coupling tensors*. The prize, given to young researchers working in the field of magnetic resonance, was for developing a program called QUEST, which simulates exact nuclear magnetic resonance (NMR) spectra. The program, which is used by over 200 researchers worldwide, makes it possible to determine the structure of non-crystalline materials. Frédéric Perras also received a Governor General's Gold Medal for the University of Ottawa in recognition of his academic performance. He has several publications to his name, making him a future leader in his field. Frédéric is now focused on developing an emerging technology known as dynamic nuclear polarization (DNP), which can improve the sensitivity of NMR by 660 times.



Doctorate

Isil Ozfidan (physics)

In materials, electrons occupy certain energy levels, which in turn determine the material's optical properties. Quantum dots are tiny, 0-dimensional materials that confine electrons into a small space. Interactions among electrons are modified due to confinement, changing the separation between energy levels and making it possible to control a material's behaviour with light.

Supervised by Pawel Hawrylak, Isil's research focused on studying the size and shape dependence of electronic properties of graphene quantum dots (GQDs) and how symmetry affects GQDs' coupling to light. In her PhD thesis, *Electron-electron interactions in optical properties of GQDs*, she compares theoretical predictions with experimental results obtained from collaborators and suggest different areas in which GQDs can be used.

Isil received the 2016 PhD Thesis Award from the Canadian Association of Physicists, Division of Condensed Matter and Materials Physics.



Postdoctoral fellow

Claudia El-Nachef (chemistry)

Claudia, a postdoctoral fellow supervised by André Beauchemin, received one of the four prestigious Simons Collaboration on the Origins of Life postdoctoral fellowships in 2016. Her research project, *Simple Aldehydes and Carbohydrates as Probiotic Catalysts*, involves discovering the role of aldehydes as potential catalysts in chemical evolution. Preliminary results have shown that these aldehydes could have acted as "simple enzymes" for many reactions involving water, and that they can also operate as catalysts under dilute aqueous conditions. The project also seeks to focus on the possible mechanisms through which they could have induced homochirality observed in organic molecules.

Research centres and core facilities

The Faculty of Science leads or is involved in a number of research centres, institutes and core facilities. Participating in centres and institutes allows our researchers to exchange and collaborate with other faculties, often leading to multidisciplinary research opportunities.

The Faculty manages the following research centres and laboratories:

André E. Lalonde Accelerator Mass Spectrometry Laboratory

Director: W.E. (Liam) Kieser

Centre for Advanced Materials Research

Director: Juan (Tito) Scaiano

Centre for Catalysis Research and Innovation (CCRI)

Director: Michael Organ

Centre for Neural Dynamics

Directors: André Longtin and Len Maler (Medicine)

Centre for Research in Photonics

Director: Pierre Berini

Core Molecular Biology and Genomics Laboratory

Director: Marc Ekker

G.G. Hatch Stable Isotope Lab

Director: Ian Clark

Geo-chemistry lab

Directors: Tom Al and Jonathan O'Neil

John L. Holmes Mass Spectrometry Facility

Director: Paul M. Mayer

Joint Attosecond Science Laboratory (JASLab)

Director: Paul Corkum

Laboratory for Natural and Synthetic Environmental Toxicants (LANSET)

Director: Jules Blais

Laboratory for Physiology and Genetics of Aquatic Organisms

Director: Marie-Andrée Akimenko

Max Planck-University of Ottawa Centre for Extreme and Quantum Photonics

Lead scientists: Robert Boyd and Gerd Leuchs

Nuclear magnetic resonance (NMR) Facility

Director: David Bryce

Core facilities provide services, analysis and access to instruments, technology and expertise that many researchers require or draw on to carry out their research. We have the following core facilities:

Cellular Imaging and Cytometry Facility

Directors: Michael Jonz and Maxim V. Berezovski

High-Throughput Experimentation and Computational Chemistry Core Facility

Director: Michael Organ

Materials Characterization uOttawa Core Facility

Director: Michael Organ

X-ray Core Facility

Director: Sandro Gambarotta

Faculty of Science researchers are also members of the following external research centres and laboratories:

Centre de recherches mathématiques

Université de Montréal

Fields Institute for Research in Mathematical Sciences

University of Toronto

Institute for Science, Society and Policy

Director: Monica Gattinger

Institute of the Environment

Director: Stewart Elgie

Center for Advanced Computing

Queen's University



Partnerships

International partnerships

Chinese Academy of Sciences

The University of Ottawa signed a memorandum of understanding with the Chinese Academy of Sciences in 2005, establishing a special partnership covering certain key Faculty of Science research areas such as systems biology, photonics and fish biology. In September 2015, on the tenth anniversary of the partnership, uOttawa and CAS signed four new memoranda of understanding, and also inaugurated a joint hydrobiology lab and a joint research centre.

Central China Normal University

The University of Ottawa and Central China Normal University (also known as Huazhong Normal University) have developed a strong partnership in chemistry. A memorandum of understanding signed in 2014 formalized the existing research collaborations in organic chemistry and catalysis. It also established the CCNU–uOttawa Joint Research Centre on Synthesis and Catalysis, to facilitate research into visible light photoredox catalysis and animation reactions.

Centre national de la recherche scientifique

The University of Ottawa, the Centre national de la recherche scientifique (CNRS), the Université de Lyon and the École Normale Supérieure de Lyon formalized the creation of LIA-FUNCAT (fundamental catalysis for green chemistry) on April 17, 2014 in Ottawa. This innovative partnership will encourage sharing of resources and materials.

Max Planck Society

In 2012, the University of Ottawa and the Max Planck Institute for the Science of Light, in Erlangen, Germany, formalized their scientific cooperation through a partnership agreement covering the areas of photonics, nonlinear optics and quantum optics. The Max Planck–University of Ottawa Centre for Extreme and Quantum Photonics, one of only three of its kind in North America, was launched in May 2015, in collaboration with the Max Planck Institute of Quantum Optics in Garching, Germany. In March 2015, the University of Ottawa and Friedrich-Alexander University in Erlangen signed a research and teaching cooperation agreement covering the areas of quantum photonics, nanophotonics and quantum nonlinear optics.



Multidisciplinary partnerships



Institute of the Environment and Scott Findlay (biology)

During the past year, Scott Findlay worked together with experts in environmental law and economists to assist a multilateral group including government, industry and civil society, to strengthen initiatives to protect Canadian species at risk. As an environmentalist, Findlay's role was to assess the impact of strategies to mitigate risk to threatened species.

As authorities in all sectors are concerned both with the socio-economic impact and their legal and civil responsibility, Findlay's research will necessarily be considered in the development of policies and regulations needed to protect species.



Credit: University of Waterloo

Anne Broadbent (mathematics and statistics) and Robert Boyd (physics)

Can the photonics technologies developed by the Faculty of Science lead to more effective secret communication, where secrecy itself is guaranteed by the laws of physics? That's the question that a team led by Robert Boyd and Anne Broadbent answered. Thanks to its many researchers, the team was able to show that high level encoding of information such as the orbital angular momentum of light particles, a technique that Boyd helped to pioneer, can lead to a more efficient quantum key distribution. In this collaboration, the team benefitted from interaction between physicists, with their technical perspective, and mathematicians, with their analytical perspective. They demonstrated the usefulness of high level encoding in ensuring secure communications, even when using less than perfect transmission lines. This work is important, as it ensures personal security while allowing for efficient information transfer.

Opposite page: Announcement of the formal partnership with the Max Planck Society, May 26, 2015

Industry partnerships

Vincent Tabard-Cossa and Michel Godin (physics) — Abbott

Thanks to a major partnership with an international company, Vincent Tabard-Cossa's lab was able to develop a new, highly precise and affordable method of fabricating solid-state nanopores, making it possible for the first time to envisage the commercialization of this nanotechnology. Nanopores are minute channels crossing membranes that can be used to identify individual biomolecules like DNA and proteins in electrical signals for gene sequencing and ultrasensitive, fast and portable screening at the point of need.

With the support of their partners, Professors Vincent Tabard-Cossa and Michel Godin have patented four inventions in this field to date. After refining their technology over the past year with the help of their industrial partner's timely feedback, they have made prototypes available to researchers. This will allow Canada to maintain its position as a global leader in the development of new health and nano- technologies.



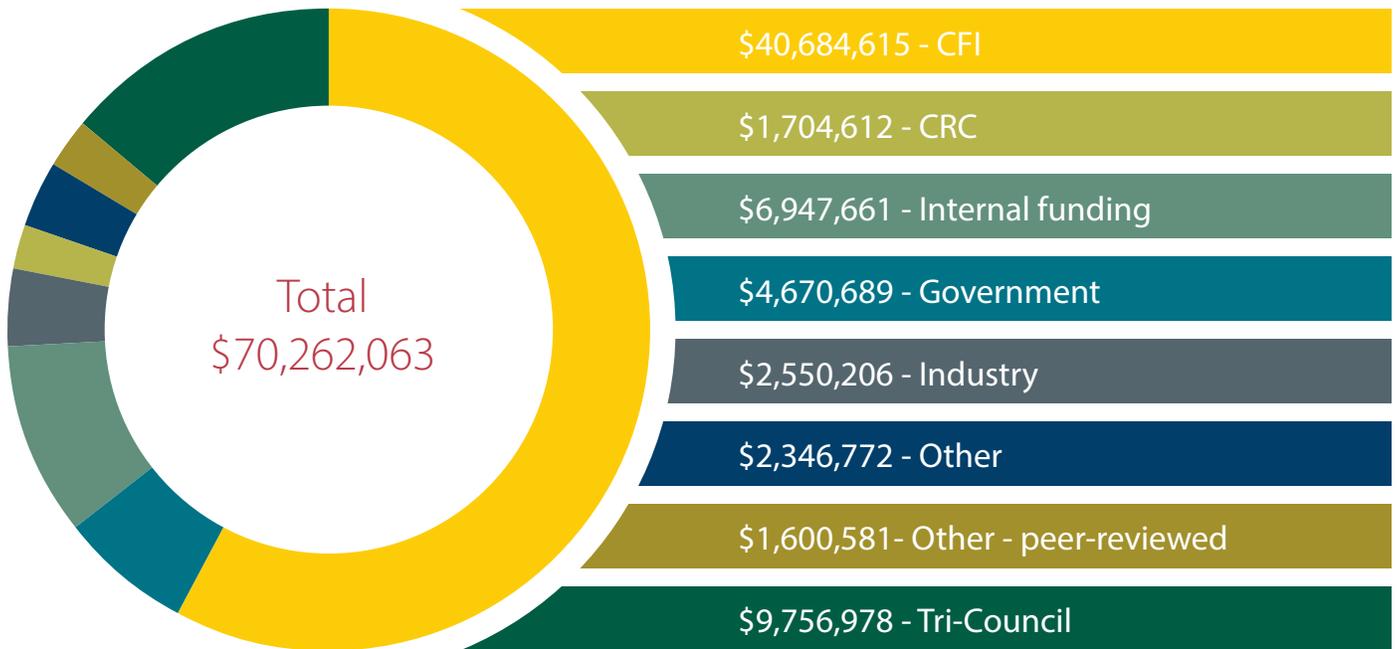
Tom Al and Ian Clark (Earth and environmental sciences) — NWMO

Tom Al and Ian Clark, who received an NSERC Collaborative Research and Development Grant, carried out research in hydrogeochemistry with the support of the Nuclear Waste Management Organization to develop tools to test geological formations where deep geological repository storage might be possible. Their research contributed greatly to the study of the subsurface of the Bruce nuclear site, in order to develop the first low- and intermediate-level radioactive waste storage site in a deep geological repository in Canada. Following an independent review, the Canadian Environmental Assessment Agency submitted a favourable recommendation to the Canadian government. The long-term focus of their research is to identify an appropriate site to handle Canadian nuclear waste.



Research funding

Faculty of Science



NSERC





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