Université d'Ottawa | University of Ottawa

Faculty of Science

Annual Research Report 2016-2017

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Featured Discoveries

Zero-knowledge proof systems for QMA

Dr. Anne Broadbent
Department of Mathematics and Statistics

Imagine you know the solution to a complex problem, want to prove to your professor that your solution is valid, but don't want your professor to learn how you discovered the solution.

Such a task is called a "zero-knowledge proof." Together with collaborators, Professor Anne Broadbent has shown that zero knowledge proofs ARE possible, even when the proof is for a hard quantum problem.

This result, which builds on Broadbent's earlier work on quantum cryptography, is surprising and counter-intuitive. However, it could be useful in cryptographic protocols, for example, in electronic voting or online auctions.

Research results appeared in the proceedings of the 2016 *Annual Symposium on Foundations of Computer Science* (FOCS), one of the most prestigious venues in the field of theoretical computer science.

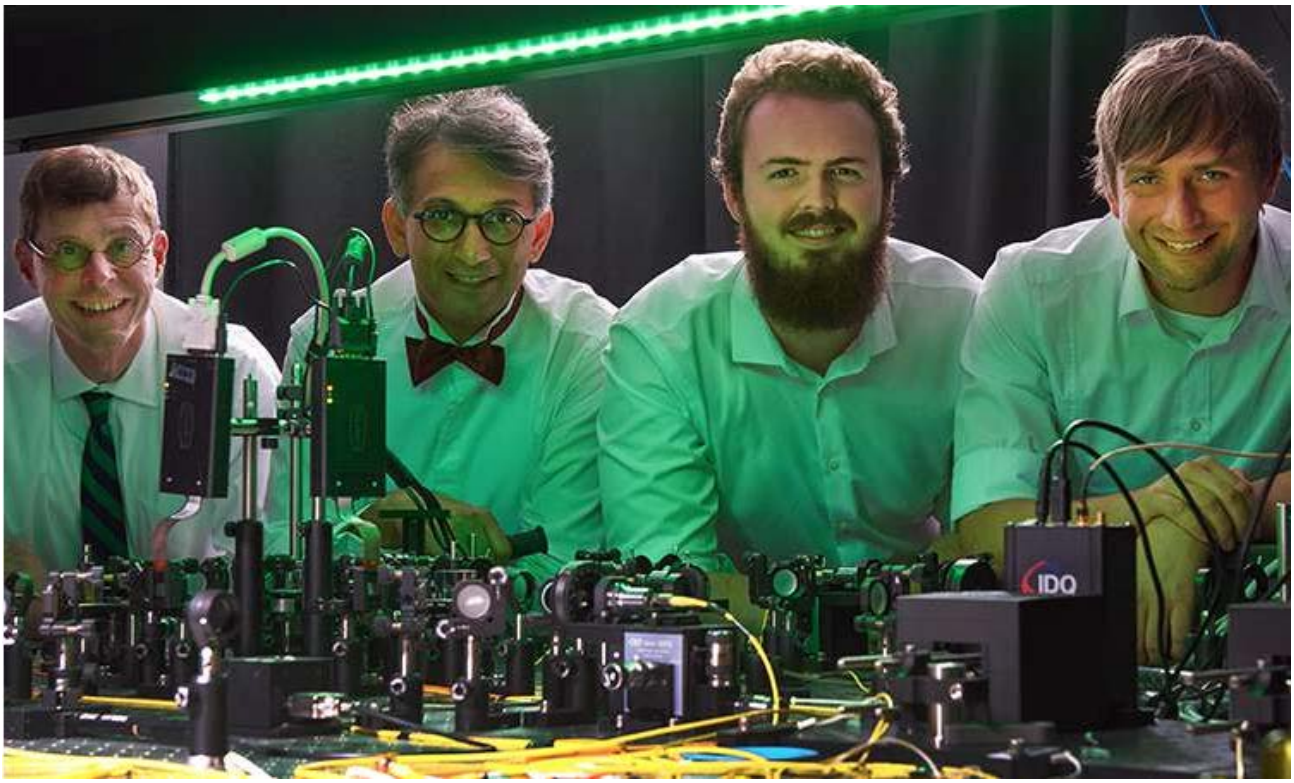
High-dimensional quantum cloning and applications to quantum hacking

Dr. Ebrahim Karimi, Dr. Robert Boyd, postdoctoral fellow Dr. Robert Fickler and PhD student Frédéric Bouchard

Department of Physics

Quantum mechanics, the laws of nature that dictate the behaviour of microscopic objects (e.g., atoms), is arguably one of the most counterintuitive scientific theories.

For instance, one of its strangest features results in a fundamental difference between quantum information and classical information. In everyday life, information may be copied perfectly, for example, using the copy-paste option on a computer, or with a printer or a copy machine. But this does not hold true in the quantum world. According to the no-cloning theorem, there is a limit on the quality of the quantum copies, which depends on the complexity of the original copy. Indeed, attempts at cloning quantum information result in “bad” copies.



In their laboratory, professors Ebrahim Karimi and Robert Boyd, along with postdoctoral fellow Robert Fickler and PhD student Frédéric Bouchard, built the first cloning machine for complex quantum systems, namely, structured photons (the quantum of light). This quantum cloning machine was used to study the effect of a quantum attack on a secure communication link. Their research shows that the security of quantum cryptography increases when more information is stored on a single photon.

Old rocks yield new clues with the discovery of oldest records of life on Earth

Dr. Jonathan O'Neil
Department of Earth and Environmental Sciences

Professor Jonathan O’Neil, joined by an international team of scientists, discovered what is being called the earliest signs of life.

This discovery was made in a commonly ignored substance right beneath our feet, rocks, known as “branded iron formations,” in the Nuvvuagattiuq Greenstone Belt in Northern Quebec. Such a discovery has great potential to help scientists find the missing pieces in understanding early Earth.

According to O’Neil, scientists had previously theorized that early Earth would have been inhospitable. However, research is now suggesting otherwise. Thanks to this 4.3 billion-year-old bedrock, it may be possible to determine when life began to emerge on Earth, and to raise new questions concerning possible life on other planets. O’Neil claims that Mars and Earth were “probably very similar” 4.3 billion years ago. Who knows, maybe there was life on Mars as well!

Is single molecule spectroscopy ready to join the toolkit of organic chemistry and drug discovery?

Dr. Juan Tito Scaiano and research associate Dr. Anabel Lanterna
Department of Chemistry and Biomolecular Sciences

Single molecule spectroscopy (SMS) is a technique that allows the detection of one molecule at a time by following the electromagnetic radiation emitted upon interaction with light.

Professor Juan (Tito) Scaiano and research associate Anabel Lanterna have shown how SMS has matured to the point where it can be used as an instrument to guide organic synthesis and drug discovery.

The researchers found techniques to manipulate one molecule in particular, and to direct its behaviour so it develops desirable chemical changes. Notably, in their experiments, the researchers used “click chemistry” or “click reactions,” a series of high yielding reactions. For example, they found that the reaction between alkynes and azides had improved thanks to the knowledge acquired by using single-molecule fluorescence spectroscopy.

Scaiano hopes that these results will enable major advances in organic synthesis and drug discovery, relying on an intimate understanding of how a molecule reacts and building new large-scale technologies from this knowledge.

How we evolved to have five fingers and toes

Dr. Marie-Andrée Akimenko and PhD candidate Robert Lalonde
Department of Biology

Polydactyly is a medical term for the presence of extra fingers or toes, a condition similar to ancient, extinct animal species. Our earliest terrestrial ancestors, known as tetrapods (meaning “with four limbs”), had polydactylous limbs that had evolved from fish fins in the transition from aquatic to terrestrial life.

PhD candidate Yacine Kherdjemil and Dr. Marie Kmita, Montreal-based collaborators, discovered a small DNA sequence in the mouse genome known as an enhancer, which modulates the activity of a gene named *Hoxa11* involved in limb development in mice. When normal *Hoxa11* activity is disrupted, the mice developed polydactylous limbs, suggesting a role of this enhancer in the evolution of limbs with five fingers and toes. Here at the University of Ottawa, PhD candidate Robert Lalonde and Prof. Marie-Andrée Akimenko went looking for this enhancer sequence in the zebrafish genome but found no evidence of its existence in fish, suggesting that it emerged during the fin-to-limb transition. They also showed that *Hoxa11* activity in zebrafish significantly differs from what is seen in mice, providing further evidence the enhancer element is indeed a tetrapod innovation. Dissecting the mechanisms of limb development is crucial for understanding the causes of congenital limb malformations.

Awards and Honours

How Electric Fish are Helping us Solve the Mystery of the Human Brain

André Longtin & Len Maler

Department of Physics, Faculty of Science / Department of Cellular and Molecular Medicine, Faculty of Medicine

The human brain is often described as the body's greatest unsolved scientific mystery. Like computers, the brain relays information across complex networks of circuits and systems in fractions of a second. What has left neuroscientists puzzled is how the brain is able to function at such capacities.

Professors André Longtin from the Department of Physics and Leonard Maler from the Department of Cellular and Molecular Medicine (both from the University of Ottawa's Brain and Mind Research Institute) have jointly uncovered key features of the neural code that underlie the operation of the brain.

Using electric fish as a model to further understand brain activity, Longtin and Maler traced how signals move during the entire sensory process. They have found neural "signatures" of impending voluntary actions, as well as of attention to objects. The researchers identified specific neural patterns of activity that appear the moment an animal's attention becomes locked onto an object, i.e. the neural signals underlying sensory focusing.

Their research was recently awarded the prestigious Brockhouse Canada Prize for Interdisciplinary Research in Science and Engineering, by the National Sciences and Engineering Research Council (NSERC). Longtin and Maler are now expanding their efforts to unlock another important piece of the neural code: how our senses tap into our memories to gain vital information in order to assist our attention and decision-making.

Using the Common Apple to Grow Human Cells

Andrew Pelling

Department of Physics

Scientist and University of Ottawa professor Andrew Pelling has gained a significant amount of attention over the last year. Considering that his lab has used apple slices carved into the shape of ears to grow human cells, his research has certainly turned some heads. Members of the Pelling Laboratory for Physical Manipulation began by carving apple slices to look like human ears, removed the apple's cells then grew human cells in the remaining cellulose scaffolding.

This innovation came from realizing that cells from animals could grow inside the protein scaffolding of another animal, therefore the attempt was made see if plants could act as the scaffold. His work will also shed light on the normal functioning of cells, which needs a precise balance between biochemistry and mechanical forces to control important processes such as gene regulation, proliferation and movement.

Pelling's ultimate goal is to apply the new knowledge he gains to improve detection and treatments for cancer, muscular dystrophy, heart disease, and other pathoses involving inhibited mechanical properties and behaviours coming from genetic mutations and/or biochemical cues. His work has been in the international media spotlight for many years, with recognition in outlets such as *Wired*, *Huffington Post*, *NPR*, *Scientific American*, *Popular Science*, *BBC*, *Der Spiegel*, *Deutsche Welle* and others, as well as numerous highlights in the Canadian media and Scientific media. He was named TED2016 Fellow and TED2017 Senior Fellow.

Recognizing the Hard Work of a Young Researcher

Pascal Audet

Department of Earth and Environmental Sciences

Pascal Audet is one of the most productive early-career researchers in the Faculty of Science; research accomplishments that were recognized in 2016 with a University Research Chair in Solid Earth Geophysics; the first for the Department of Earth and Environmental Sciences.

Audet is a highly creative and versatile researcher, and a prolific publisher in the world's most influential scientific journals such as *Nature* and *Nature Geoscience*. Some of his most impactful work includes: (1) estimating the strength of the lithosphere (or tectonic plates) and the implications in terms of thermal and mechanical structure of Earth and terrestrial planets; and (2) developing methods to study the propagations of elastic waves through the Earth to better understand its structure, particularly in subduction zones (seismically active regions of the Earth where one tectonic plate slides under another). Fairly recently, he has added a new aspect to his research: Earth deformation due to surface loads related to anthropogenic activity (i.e., resulting from the influence of human beings), which is defining a whole new field of research with deep societal implications.

He has been awarded several major research awards, including the renowned Sloan Research Fellowship and the Early Researcher Award of Ontario. His work and media contributions are also recognized outside of academia: in February 2015 he was named *Personnalité de la Semaine Radio-Canada/Le Droit.* Audet was awarded the 2016 *Excellence in Media Relations Award: Research,* which recognizes outstanding service to the University through sharing of expertise with the wider community through media. Also in 2016, he received the *Young Researcher of Year Award*, which is presented annually to faculty members who have made exceptional contributions to research and the training of students at the University of Ottawa.

Other awards & honours 2016-2017

Recipient	SEC.	Award
Aris-Brosou, Stéphane	BIO	2016-17 Excellence in Education Prize
Arnason, John	BIO	Distinguished University Professor
Audet, Pascal	EES	Excellence in Media Relations Award: Research
Audet, Pascal	EES	uOttawa Young Researcher of the Year Award
Blais, Jules	BIO	Frank Rigler Award from the Society of Canadian Limnologists
Blute, Richard	MAT	(with co-authors) Logic in Computer Science "Test of Time" award
Boyd, Robert	PHY	Fellow of the Institute of Electrical and Electronics Engineers
Broadbent, Anne	MAT	André Aisenstadt Prize
Bui, Tuan	BIO	Ontario Early Researcher Award
Corkum, Paul	PHY	Honorary Doctorate from Aarhus University
Flynn, Alison	CBS	3M National Teaching Fellow
Forrest, Jessica	BIO	Ontario Early Researcher Award
Keillor, Jeffrey	CBS	2017 Bernard Belleau Award, Sponsored by Vertex Pharmaceuticals (Canada) Inc. (CSC Lectureship)
Kerr, Jeremy	BIO	Excellence in Media Relations Award: Research
Kerr, Jeremy	BIO	Discovery Accelerator Supplement
Longtin, André	PHY	NSERC Brockhouse Canada Prize for Interdisciplinary Research in Science and Engineering (with Len Maler, Faculty of Medicine)
Montpetit, Colin	BIO	1st Prize - Innovative Use of Educational Technology Excellence Award in 2016
Murugesu, Muralee	CBS	Royal Society of Canada College of New Scholars, Artists and Scientists
Newman, Stephen	CBS	John Charles Polanyi Prizes from the Council of Ontario Universities
Ogilvie, William	CBS	University of Ottawa Award for Excellence in Teaching
Ogilvie, William	CBS	Faculty of Science Award for Excellence in Teaching
Organ, Michael	CBS	Encyclopedia of Reagents for Organic Synthesis (EROS) Best Reagent Award
Pamenter, Matthew	BIO	Comparative and Evolutionary Physiology Section of the American Physiological Society New Investigator Award
Pelling, Andrew	PHY	TED Senior Fellow
Pezacki, John	CBS	Canadian Society for Chemistry - Teva Canada Limited Biological and Medicinal Chemistry Lectureship Award
Poulain, Alexandre	BIO	Royal Society of Canada College of New Scholars, Artists and Scientists
Roy, Damien	MAT	Faculty of Science Researcher of the Year
Schneider, David	EES	2015-16 Excellence in Education Prize
Spanner, Michael	PHY	Discovery Accelerator Supplement
Stolow, Albert	CBS, PHY	Earle K. Plyler Prize for Molecular Spectroscopy & Dynamics
Villeneuve, David	PHY	Institute of Electrical and Electronic Engineers Quantum Electronics Award

BIO: Department of Biology
CBS: Department of Chemistry and Biomolecular Sciences
EES: Department of Earth and Environmental Sciences
MAT: Department of Mathematics and Statistics
PHY: Department of Physics

Partnerships

From Fibres to Lasers

Xiaoyi Bao

Department of Physics

The Yangtze Optical Fibre and Cable Joint Stock Limited Company (YOFC) is the largest fibre manufacturing company in Asia, and second largest in the world.

The company approached Dr. Xiaoyi Bao and her team to explore new applications using their specialty fibres, and donated four kilometres of polarization maintaining fibre (PMF).

Using this PMF, Bao and her team created a narrow linewidth fibre laser based on Brillouin scattering: the interaction of light and material waves within a medium. They then created a laser with the lowest phase and frequency jitter possible. This low phase noise and frequency laser can be used as the light source for metrology, high precision investigative tools and telecom applications. This collaboration was featured in the *Optics Express* and *Optics Letters* journals.

Defending Tap Water From Cyanobacterial Blooms

Frances Pick

Department of Biology

Algal blooms are a growing problem around the world, including Canada. Toxic cyanobacterial blooms can threaten drinking water supplies and affect human and ecosystem health, with repercussions on regional economies.

The most common freshwater cyanobacterial toxins are hepatotoxic microcystins, small peptides with over 200 variants that differ in their toxicity, persistence and bioaccumulation in the environment.

Frances Pick and her group's project with the Ontario Ministry of the Environment and Climate Change aims to determine the distribution of different microcystin variants in surface waters across the province. The group is particularly interested in one variant that appears to be more persistent than others. It has led to wildlife mortalities in parts of North America but appears less common in Europe for reasons yet to be understood.

Mapping toxin distributions will set the stage for modelling and predicting the presence of these toxins as a function of surface water nutrient concentrations and climate. The study will also incorporate an examination of the history and causes of toxic blooms in selected lakes in Southern and Northern Ontario, by analyzing microbial DNA in lake sediments spanning pre-European settlement to the present.

Atoms in Proteins are Closer than You Think!

David Bryce

Department of Chemistry and Biomolecular Sciences

By preparing protein samples using a type of carbon atom that responds to magnetic fields, known as carbon-13, Professor Bryce and his collaborators developed specialized nuclear magnetic resonance (NMR) experiments to detect extremely small “couplings” between pairs of atoms.

Bryce and his collaborators, which include Dr. Michael Plevin of the University of York, United Kingdom, and Dr. Jerome Boisbouvier of the Centre national de la recherche scientifique in Grenoble, France, have reported on the computational characterization and experimental exploitation of these weak couplings.

Their work shows that these couplings represent a type of communication between the atoms in question, and provides clear-cut evidence that these atoms, while very far apart along the protein backbone, are actually very close in space. The experiments, therefore, provide a unique and novel way to study and understand the structure of proteins. This work, details of which were published in *Angewandte Chemie* (2017), builds on the group’s previous work featured in *Nature Chemistry* (2010).

Uncovering the Impact of Agriculture on Biodiversity and Content of Surface Waters

Ian Clark

Department of Earth and Environmental Sciences

Ian Clark, along with colleagues at the University of Waterloo Department of Earth Sciences and Agriculture and AgriFoods Canada, has begun a five-year research program to explore the impact on carbon cycling and nutrient contamination in watersheds when the natural habitat along riparian buffer strips (tree corridors between fields) is converted to cropping to increase agricultural yields.

This practice, increasingly common in Ontario, is used to increase cropping yields but has a potential impact on biodiversity and nutrient loading of surface waters.

Clark’s research program integrates a range of disciplines, including microbiology, invertebrate biology and hydrology, as well as activities such as contaminant transport and greenhouse gas production. Clark and his undergraduate and graduate students working in the Lalonde AMS Laboratory at the University of Ottawa will use radiocarbon and stable isotopes as innovative tracers to study turnover rates of carbon in the soils and in the exchanges of carbon dioxide and nutrients between the atmosphere, soils, biomass, groundwaters and surface waters.

Developing Limit Theorems to better prepare the future

Rafal Kulik

Department of Mathematics and Statistics

Professor Rafal Kulik, along with French research collaborators Philippe Soulier and Olivier Wintenberger, has been working on a project called “Extremal behaviour of regularly varying time series.”

Most financial, insurance and environmental data are “heavy tailed,” meaning that there is a significant probability of extreme events to occur, like rapid changes in a stock market. Modelling approaches based on a normal distribution are not suitable in these scenarios. Additionally, data has strong dependencies. In other words, past events can easily influence future events.

The collaborators on this project have developed limit theorems and new statistical techniques suitable for such types of data. Limit theorems allow the researchers to analyze the behaviour of different databased models when the sample size grows. Although the project is theoretical in nature, it has potential applications ranging from finance (e.g., risk management) to environmental protection (e.g., flood control).

Remarkable Students

Undergraduate

Yan Steimle

Department of Mathematics and Statistics

Throughout his undergraduate career, Yan received several research scholarships, and he maintained an impressive cumulative grade-point average.

Under the supervision of Professor Mateja Sajna, he undertook a summer project through the Undergraduate Student Research Awards program of the Natural Sciences and Engineering Research council (NSERC) to investigate problems in graph theory, such as the problem of existence of certain Euler tours in hypergraphs. In mathematics, an Euler tour of a (hyper)graph is defined as a closed walk traversing every edge of the (hyper)graph exactly once.

One of Yan’s main motivations in pursuing studies at the University of Ottawa was the many research opportunities made available to students. Undergraduate research opportunities in both theoretical physics and abstract mathematics encouraged him to pursue a career in research. He says that such great research experiences influenced his recent decision to continue in academia. Yan is planning to return to uOttawa for his master’s degree to pursue research in the field of mathematical logic, in the hope of someday completing a PhD.

Anne-Martine Doucet

Department of Earth and Environmental Sciences

With a passion for Earth and environmental sciences, Anne-Martine wears more than one hat, as a student in the CO-OP program and as the captain of the University's Ultimate Frisbee team.

Anne-Martine recently completed a CO-OP placement with Dr. Liam Kieser at the A.E. Lalonde Accelerator Mass Spectrometry Laboratory, where she prepared samples for radiocarbon, tritium and radioiodine analysis. She thanks the CO-OP program for allowing her to gain valuable experience in environmental science working with different research teams.

Throughout her years in university, Anne-Martine has had to learn how to maintain a high level of energy and positivity to excel in her studies and in her athletics. She credits her success to the support she has received from her coaches and professors, who have continuously shown her how she can improve and grow as a student. She looks forward to continuing her education and pursuing graduate studies upon completing her BSc.

Master's

Hayley Tomkins

Department of Mathematics and Statistics

Under the supervision of Professors Monica Nevins and Hadi Salmasian, Hayley's work focuses on cryptographic hash functions, a series of data suitable for use in cryptography.

This specific type of hash function is essential for digital signatures and authentication. As an undergraduate, she wrote three papers, two of which have already been published and are based on her summer research.

Hayley says that one of her biggest hurdles was understanding that her self-worth was not based on her grades. She found that research projects allowed her to overcome it, as she began to feel excited about mathematics outside the world of exams and assignments.

Beyond academia, Hayley has volunteered with the Nova Scotia Math Circles, where she mentored young students. For her, helping young girls gain the confidence they need is crucial, especially in a field where women are still underrepresented.

Neke Ibeh

Department of Biology

After completing a BSc in biomathematics at Queen's University, Neke completed her MSc in two years at uOttawa.

Under the supervision of Professor Stephane Aris-Brosou, she wrote and published a paper on the Ebola virus and its evolution, specifically, how its 2014 variant reached unprecedented transmission and mortality rates. Bioinformatics can help decipher complex biological questions, better equipping those fighting the disease.

Before defending her thesis, Neke had already secured a permanent job as a bioinformatician at the Princess Margaret Cancer Centre in Toronto. In this role, Neke uses many skills she acquired while completing her master's, such as the ability to collaborate across disciplinary boundaries, as well as to objectively analyze her own work. Her career as a bioinformatician challenges her on a daily basis and allows her to apply her skills to tackle the most critical questions in cancer research.

PhD

Giulio Vampa

Department of Physics

On his own initiative, Giulio formed a team of scientists from different institutions to develop a new theory of how high harmonics are formed in solids, and to test it experimentally.

His research, conducted under the supervision of Dr. Paul Corkum, broadens our fundamental understanding of laser-matter interactions with crystals. The theory he developed in collaboration with his partners introduced a new approach to probe the response of materials. Giulio's PhD research led to major papers published in *Nature* and *Physical Review Letters*.

Throughout his PhD studies, Giulio dared to investigate a brand new phenomenon of which very little was known, and was not the initial topic of his thesis. He was focused throughout the process, determined to solve one particular issue without wasting energy on less important matters. Since completing his studies at uOttawa, Giulio has begun a postdoctoral fellowship at Stanford University.

Gwendolyn Bailey

Department of Chemistry and Biomolecular Sciences

During her PhD studies at the University of Ottawa under the supervision of Professor Deryn Fogg, Gwendolyn identified challenges in an important area of synthetic and catalytic chemistry.

Next, she clearly laid out the underlying mechanistic principles and developed practical solutions to them. She was inspired to pursue research in catalyst decomposition mechanisms after recognizing its potential transformative impact on industrial processes.

Gwendolyn has been recognized as a very generous mentor towards her peers and junior trainees, through her stellar leadership role both within Dr. Fogg's group and in the Department of Chemistry and Biomolecular Sciences. Through regular correspondence with her students, encouragement and general advice, she has sparked excitement and enthusiasm among students about their field of study. As proof of her dedication, she has won the University's Teaching Assistant of the Year award two years in a row.

Abdullah Akbar

Department of Chemistry and Biomolecular Sciences

Abdullah's research in Professor Jeffrey Keillor's group has been published in several high-impact journals such as *Nature Chemical Biology* and *Oncogene*.

He was also selected to participate in the prestigious Gordon Research Conference for transglutaminases in Italy. Abdullah's research project aimed to rationally engineer a potent and selective small molecule inhibitor that has therapeutic potential. In collaboration with his colleagues, Abdullah wishes to contribute to a better understanding of human disease and to improve human health.

One area of research that Abdullah has been involved in is the design, synthesis and kinetic evaluation of targeted covalent inhibitors that are selective for human tissue transglutaminase (hTG2). hTG2 has a role in two forms of malignant cancers, and the inactivation of hTG2 in cancer cells decreases cancer stem cell survival rates. Abdullah and his colleagues believe that their inhibitors show promise for targeting hTG2 in anti-cancer stem cell therapy.

Melissa Anderson

Department of Earth and Environmental Sciences

Melissa is an accomplished PhD student, having established an international career as an ocean explorer working extensively with U.S., German and Australian research institutions in her chosen field of volcanology and marine geosciences.

In the last two years, she has represented the University of Ottawa and her supervisor, Dr. Mark Hannington, on three international research cruises, studying active submarine volcanoes in the Canary Islands of the eastern Atlantic, the Mariana Islands of the Western Pacific and eastern New Caledonia and the New Hebrides. Her research, which has now been published or accepted in three peer-reviewed international research journals, spans the fields of volcanology, mineralogy and oceanography.

During her studies, Melissa has found time to mentor several undergraduate and high school students in summer schools and internship programs. At the same time, she gained notice as a science photographer, and several of her images have been published and have won competitions.

Postdoctoral Fellow (PDF)

Robert Fickler

Department of Physics

Robert is very interested in understanding the nature of the physical world.

Broadly speaking, his doctoral work addressed the issue of entanglement in high-dimensional quantum systems. His postdoctoral work, supported by a prestigious Banting fellowship, focuses on the phenomenon of quantum entanglement, where pairs or groups of particles interact in such a way that they can no longer be described independently. It is unlike other physical effects because it tells us that the quantum world is very different from our everyday experience.

Robert chose to pursue his postdoctoral research at the University of Ottawa for several reasons. He was interested in the research performed by the Canada Excellence Research Chair in Quantum Nonlinear Optics, led by Professor Robert Boyd. Furthermore, Robert appreciates the commitment of the University to the field of quantum photonics, as shown by the recent investments in lab space and equipment in the Advanced Research Complex and the potential for building strong research collaborations within the Max Planck-uOttawa Centre for Extreme and Quantum Photonics.

Diane Orihel

Department of Biology

Diane is a freshwater ecologist who investigates the human impact on aquatic ecosystems through large-scale, multidisciplinary field experiments.

Her postdoctoral research, under the supervision of Drs. Jules Blais and Vance Trudeau, focused on topics such as nutrient cycling and algal blooms in eutrophic lakes, mercury contamination of aquatic food webs and the environmental fate of flame retardants. She is now an assistant professor at Queen's University in Kingston, Ontario, where she is studying the effects of oil sands contaminants on amphibians.

At the University of Ottawa, Diane received Banting and Liber Ero postdoctoral fellowships, two of the most prestigious fellowships awarded to postdoctoral researchers in Canada. Her motivation to work in her field comes from her strong connection to water. She is also well known for her determined advocacy work to preserve the internationally unique Experimental Lakes Area research facility.

Strategic Focus

Message from the Vice-Dean, Research, Louis Barriault

Building on last year's momentum, researchers at the Faculty of Science have made significant advances that will benefit Canadians.

For example, they have made progress in research on high-dimensional quantum cryptography to store maximum information in one photon, and on the development of new quantum protocols that could enhance the security of electronic voting or online auctions. Our researchers have also discovered some of the earliest traces of life on Earth by analyzing rocks found in Northern Quebec, providing clues on how life appeared on the planet. Fundamental studies on limb development mechanisms have shed light on the causes of congenital limb malformations. These are just a sample of the spectacular discoveries our colleagues have made. In addition, we have established several strategic partnerships, which will assist our researchers and their teams in transforming their fundamental research into applied science.

All these effervescent progresses have created a unique and stimulating research environment for our postdoctoral fellows, graduate students and undergraduates. Without a doubt, the University of Ottawa's Faculty of Science has positioned itself as one of the best places in North America to conduct research and train the scientific leaders of tomorrow.

Mandate

The Research Office was established to support and promote research at the Faculty of Science. It serves as the main liaison between granting agencies and researchers, as well as with University of Ottawa research services.

The office also assists researchers in preparing grant and scholarship applications, as well as research chair and award nominations.

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.

Key research areas

The six key research areas identified in the Faculty of Science 2016–2021 Strategic Research Plan involve our researchers in some of the great scientific challenges of the 21st century.

Our focus on supporting basic research reinforces interdisciplinary research, research partnerships with industry and emerging research areas.

Fundamental and applied mathematics and statistics

Our faculty is home to internationally-renowned researchers in pure mathematics, and we are on track to rank among the top five departments of our kind in Canada for research intensity. Our mathematics professors are involved in various interdisciplinary collaborations with researchers in other faculties. In the coming years, we will focus our research on 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 explaining and manipulating chemical reactions to better understand, control and alter biological mechanisms. We see this growing tendency towards interdisciplinary research in the Department of Physics, where a cluster of excellent biophysicists is pursuing research at the crossroads of biology, physics and engineering, including the development of new biomaterials. This is a unique opportunity to engineer living systems, open new research fields in biotechnology and create economic opportunity.

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. Major discoveries are also

emerging from our research in the areas of advanced imaging, light-matter interaction, and leading-edge optical materials and nanophotonics, which combine our expertise in physics, chemistry and engineering of photosensitive materials.

Environment and resources

Many Faculty of Science research projects deal with the environmental impact of human activity, such as pollution resulting from natural resource exploitation. Research interests include the impact of natural resource exploitation, ecotoxicology, biodiversity and environmental change, 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 that have greatly contributed to enhancing our quality of life. Catalysis research areas at the Faculty of Science include catalyst development and chemical reactions to fabricate medicinal compounds, CO_2 capture, continuous flow chemistry and fuel-producing biomass.

Quantum information

Quantum information is the interdisciplinary study of the connection between information theory and quantum physics. This discipline, which studies the microscopic laws of nature, can also provide solutions to intractable computational tasks and enhance security of communication. Our researchers are undertaking projects in fields such as quantum information, quantum cryptography and quantum communication.

Faculty of Science Research Committee members in 2016-17

Louis Barriault	**Chair, Vice-Dean, Research**
Antoine Morin	Vice-chair, Vice-Dean, Graduate Studies
Jules Blais	Professor, Department of Biology
Albert Stolow	Professor, Departments of Chemistry and Biomolecular Sciences, and Physics
Pascal Audet	Professor, Department of Earth and Environmental Sciences
Kirill Zaynullin	Professor, Department of Mathematics and Statistics
Andrew Pelling	Professor, Department of Physics
Jasmine Lefebvre	Non-voting member, Research Facilitator
France Malette	Non-voting member, Chief Administrative Officer

Department Chairs

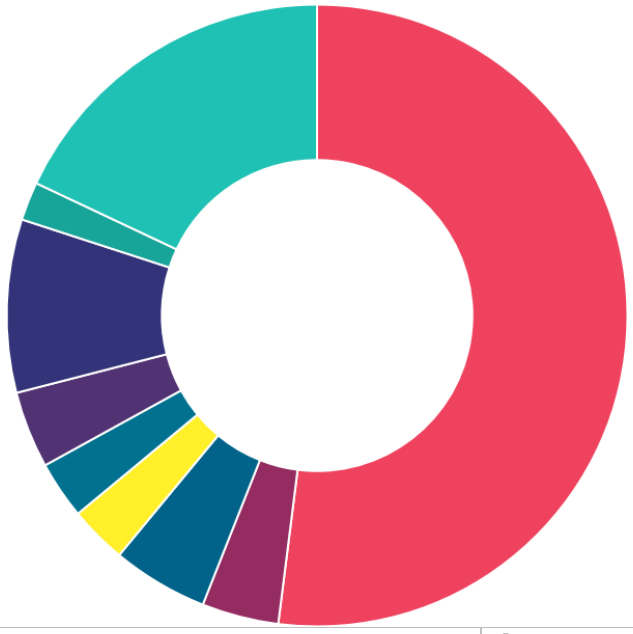
Frances Pick	**Department of Biology**
David Bryce	Department of Chemistry and Biomolecular Sciences
William Arnott	Department of Earth and Environmental Sciences
Rafal Kulik	Department of Mathematics and Statistics
André Longtin	Department of Physics

Research Statistics

Research funding received by the Faculty of Science in 2016-2017

Source	Amount
CFI (MSI + JELF)	$10,029,745
Internal funding	$3,367,232
Contracts – Government	$1,355,075
Contracts - Not-for-Profit Organizations	$971,987
Contracts - International	$700,830
Contracts - Industry	$1,962,698
Other external operating	$3,705,026
Tri-council grants	$9,191,971
Total	**$31,284,564**

Details of funding from the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Canadian Institutes of Health Research (CIHR)



Source	Amount
NSERC - Discovery 2017	$4,775,000
NSERC – Discovery Accelerator Supplement	$360,000
NSERC- RTI	$441,602
NSERC - RTI OMSRE	$300,000
NSERC - Engage	$287,450
NSERC - I2I	$350,000
NSERC - SPG	$794,290
NSERC - CRD	$223,580
CIHR - Project 2017	$1,660,049
Total	**$9,191,971**

CFI: Canada Foundation for Innovation
CIHR: Canadian Institutes of Health Research (CIHR)
CRD: Collaborative Research and Development Grants
DAS: Discovery Accelerator Supplements
DG: Discovery Grants
I2I: Idea to Innovation Grants
JELF: John R. Evans Leaders Fund
MSI: Major Science Initiatives Fund
NSERC: Natural Sciences and Engineering Research Council of Canada
NPO: Not-for-Profit Organizations
OMSRE: Operations and Maintenance Support to Research Equipment
RTI: Research Tools and Instruments
SPG-P: Strategic Partnership Grants for Projects

Our success story by the numbers

- 158 faculty researchers
- 602 graduate students
- 209 undergraduate research scholarship recipients
- 123 postdoctoral fellows
- 5 new researchers (April 2016 - April 2017)
    - Fabien Gagosz, Professor in the Department of Chemistry and Biomolecular Sciences
    - Jan Mennigen, Assistant Professeur in the Department of Biology
    - Antonio Badolato, Associate Professor in the Department of Physics
    - Heather Kharouba, Assistant Professeur in the Department of Biology
    - Delphine Gourdon, Associate Professor in the Department of Physics
- 31 awards to our researchers
- $31,284,564 in grants, of which $6,278,418 was awarded through a CFI – MSI grant to Dr. Ian Clark for the André E. Lalonde Accelerator Mass Spectrometry Facility for Environmental Radionuclides.
- 481 peer reviewed papers published in 2016-17
- 18 invention disclosures
- 11 patent applications filed
- 4 patents issued
- 127 research contracts signed
- 34 research chair holders
- 15 University Research Chairs
- 9 Tier 2 Canada Research Chairs
- 9 Tier 1 Canada Research Chairs
- 1 Endowed research Chair
- 2 new research chairs
    - Pascal Audet, University Research Chair in Solid Earth Geophysics
    - David Bryce, University Research Chair in Nuclear Magnetic Resonance
- 6 research chairs renewed
- Thomas Brabec, Canada Research Chair in Ultrafast Photonics
    - Xiaoyi Bao, Canada Research Chair in Fibre Optics and Photonics
    - David Sankoff, Canada Research Chair in Mathematical Genomics
    - Deryn Fogg, University Research Chair in Homogenous Catalysis
    - André Longtin, University Research Chair in Neurophysics
    - Vance Trudeau, University Research Chair in Evolutionary Developmental Biology
- 2 startups launched
- 50 new research projects in partnership with government
- 21 new industry partnered research projects
- 79% success rate in 2017 NSERC Discovery Grant Competition

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