



UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

Report on

BioZone

Centre for Applied Bioscience and Bioengineering

2016 - 2018

Report on BioZone

February 2019

Reporting Period September 2016 - August 2018

An electronic copy of this report is available through www.biozone.utoronto.ca.

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BioZone

Centre for Applied Biosciences and Bioengineering

2018 | HIGHLIGHTS



9 Core Principle Investigators

6 Associate Members
2 Adjunct Faculty Members



27 Research Staff

13 Research Associates
5 Technicians
9 Staff



94 Trainees

10 Postdoctoral Fellow
76 Graduate Students
8 Undergraduate Students



\$7 Million Cash Funding

Leading 48 Projects



2000 m² Shared Space

3 Research Facilities



53 publications

2 new start-ups

Director's Message

**Welcome to BioZone,
a Centre for
Applied Bioscience
and Bioengineering
at the University of
Toronto.**



Elizabeth Edwards
Professor and Director, BioZone

BioZone traces its origins back to 2007, when the first phase of renovations began to consolidate bioengineering research space in the Wallberg building. Infrastructure support from CFI, the province of Ontario, and from the University of Toronto enabled the construction of new or renovated space that has now grown to 2000 m² along with resources dedicated to cooperative multi-disciplinary research in applied bioscience. This shared physical space has been key to BioZone's continued success, enabling formal and informal discussions and catalyzing lasting friendships. While BioZone's official status as an "extra-departmental unit" was not conferred until 2010, research was well underway in a dynamic environment soon after the completion of the first renovations in 2008; consequently, BioZone is in fact celebrating over 10 years of rewarding successful research projects and partnerships.

Now at the end of 2018, we are winding down a 5 year/ \$5M NSERC Industrial Biocatalysis Network, while many new, large-scale, industry-supported projects, co-funded through Federal and Provincial grants, are fully underway. These initiatives address environmental liabilities in the metal mining and petroleum production sectors, green energy production, food fortification, renewable plastics and biochemicals, wastewater treatment, and anaerobic digestion of municipal and industrial solid wastes.

BioZone's core facilities give access to expertise and equipment in: (i) biomass production using bioreactors up to 80L, (ii) medium throughput heterologous protein production and characterization, and (iii) mass spectrometry and metabolomics. A growing number of new initiatives and collaborations are emerging, such as projects on the gut microbiome and on food and nutrition. If you have a need for such facilities, please reach out to us. We wish to help if we can.

BioZone's collaborative network has expanded geographically over the past 2 years, thanks to new opportunities and the twists and turns of research projects. Alexei Savchenko

is now an associate professor at the University of Calgary, and recently, Alexander Yakunin secured a permanent position at the University of Bangor in Wales, UK. These two professorships recognize Alexei and Sasha's outstanding research, while expanding BioZone's connections to the West of Canada and to the UK. Congratulations Alexei and Sasha! Both professors maintain their core facilities and personnel around protein and enzyme characterization in Toronto while opening their new labs.

In BioZone, trainees have the opportunity to develop skills in both experimental and computational bioscience research. This combination is extremely effective, particularly for translating research data to actionable results and broad meaning. Iterating between powerful genome-enabled computational analyses and enzyme- or culture-based screening assays has led to the discovery of new microbe-microbe interactions, new enzyme activities and gene annotations, and novel synthetic biochemical pathways. These fundamental discoveries are enabling much more accurate predictions of biological processes used in natural and engineered systems. The computational expertise of Prof. Krishna Mahadevan and his team, and the excellent support from Dean Robson, Camilla Nesbo and Sean Caffrey and many others are helping to build a strong computational knowledge base in BioZone that all can draw upon.

I am personally grateful to everyone who has dedicated time and effort in the spirit of sharing knowledge and ideas freely. It is rewarding to see many dreams from 10 years ago now coming to fruition. We welcome any questions, feedback, and dreams for the next 10 years.

A handwritten signature in black ink that reads "Elizabeth A. Edwards".

Elizabeth Edwards, Director

Executive Director's Message

Realizing BioZone's Vision

BioZone is a research and training centre that brings together engineers, biologists, environmental and health scientists at the University of Toronto to share equipment, expertise, and support staff. It has become a place where students can access all kinds of state-of-the-art equipment, hear different perspectives, learn to listen and share ideas, make mistakes, and witness the value of open science and teamwork. Our goal is to create a place where new thinking and skills can be learned and vetted in a supportive dynamic environment. Our previous report (2015-2016) focused on the renewal of BioZone through our success in acquiring large multidisciplinary grants. Over the last two years our focus has shifted to determining how to meet BioZone's vision (page 3) and accelerate the rate at which the knowledge generated at BioZone is disseminated.

BioZone is built on the principles of open collaboration, teamwork, and research excellence. To realize these principles, we aim to create a sense of community where all BioZone professors, researchers, students, and staff feel a sense of purpose and shared a vision. Community building is accomplished, in large part, by the social and research related events organized by the student-led BioZone Council. We further attempt to increase opportunities for collaboration by writing large-scale grants that involve multiple BioZone research groups, co-supervise students, and maintain shared research spaces, equipment, and facilities for students to train and access. We have established a new portal to help facilitate equipment access and moving forward we are planning to implement improved methods of data storage, analysis, processing, and sharing.

The research conducted at BioZone is dedicated to improving the sustainability of industrial operations in the sectors of manufacturing, forestry, mining, energy production, groundwater remediation, and improving health outcomes. To meet urgent societal needs this research must be translated. Impacts from this research can directly improve the environment, economy, and society and demonstrate that environmental and economic sustainability are not mutually exclusive. BioZone is currently leading projects to design more efficient industrial waste treatment processes for the forestry and mining industry, reduce the environmental footprint of the chemical and manufacturing industries by replacing petrochemical feedstocks with renewable biomass derived from agricultural

and forestry waste, remediate groundwater contaminated by industrial pollution, and fortify foods with micronutrient and iron to treat anemia in developing countries. Although each of these projects has interesting challenges, from coordinating diverse teams to funding constraints, the research is clearly important and therefore, it is necessary that BioZone effectively translates this knowledge to industry and public sector stakeholders. To help facilitate technology transfer we are increasingly providing BioZone Highly Qualified Personnel (HQP) with opportunities to learn professional, entrepreneurship, and business skills. Another measure to facilitate knowledge mobilization is establishing an industry hub in BioZone. To this end, we have relevant fee-for-service facilities open to the private sector. This includes the fully operational Mass Spectrometry Facility that is attracting industrial users and emerging facilities such as our Biomanufacturing (fermentation) facilities. The goal isn't to make these facilities self-sufficient but to make connections to new industry partners with relevant problems to solve and the capacity to translate impactful BioZone research. Finally, we are finding new approaches, such as open and immediate data and resource sharing, to accelerate the pace at which the knowledge we generate is translated to industry and other researchers.

The past two years were marked by many successes described in this report including new grants, numerous publications and awards, and the deployment of BioZone technologies through existing and new companies. I am sure the next years will be just as successful.



Sean Caffrey, Executive Director, BioZone

Vision & Mission

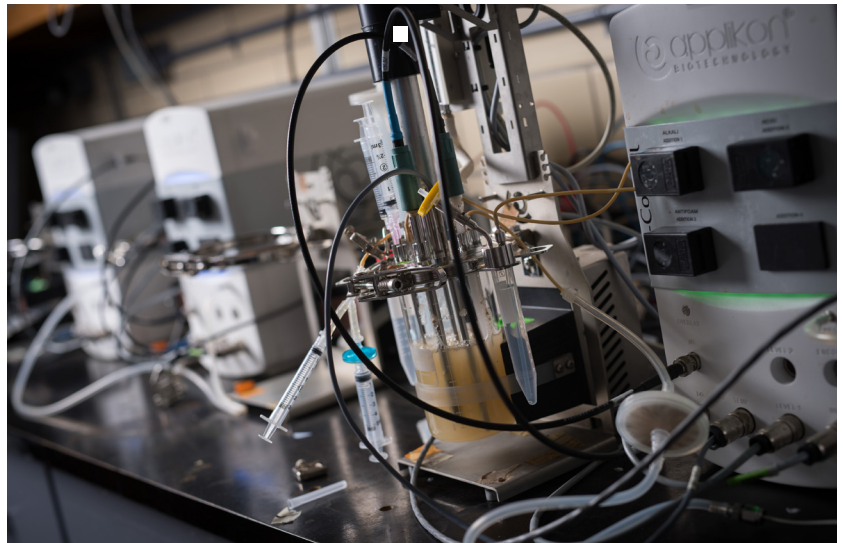
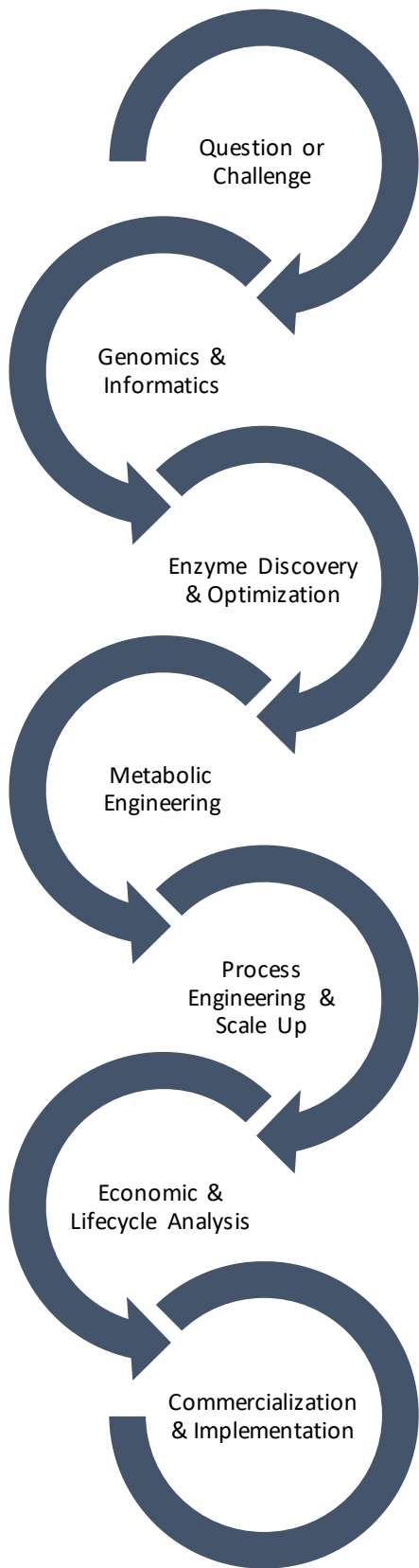
BioZone's vision is to be a multidisciplinary and internationally recognized centre for bioengineering research, technology transfer, outreach and training focused on urgent societal needs in sustainable energy, the environment and human health. A particular strength will be our ability to effectively translate the most appropriate and up to date molecular and cellular discoveries and tools into industrial practice.



BioZone's mission is to:

- attract the best and brightest minds from a diverse range of fields, including chemical and process engineering, microbiology, genomics, biochemistry, medicine, computer science, economics and public policy
- create a focal point for collaborative applied and environmental bioengineering research leading to the development of innovative new technologies that address urgent challenges and foster the long-term sustainability of our planet and its inhabitants
- provide state-of-the-art facilities and exciting opportunities for research
- provide students with the knowledge and ability to debate public policies and influence political decisions that affect the environment and health, based on sound scientific principles
- foster innovation, creativity, and imagination
- encourage leadership and excellence, humility and collegiality
- have a lasting and positive impact on our environment and society
- have fun

What is BioZone?



BioZone is a centre for applied bioscience and bioengineering research at the University of Toronto with a track record of developing sustainable technologies that reduce resource-use and help to clean up the environment. With the resident expertise to address relevant technical, economic, and public policy constraints, BioZone's researchers have the ability and the passion to transform ideas from the laboratory to commercial application with the assistance of a large number of domestic and international collaborators. BioZone's expertise includes: bioinformatics, genomics, metagenomics, proteomics, metabolomics, enzymology, structural biology, microbiology, cellular biology, chemistry, biophysics, catalysis, tissue culture, process engineering, mathematical modeling, computer simulation, and technoeconomic and lifecycle analysis.

BioZone connects engineering know-how with the power of genomics to address urgent challenges in energy, the environment and health

BioZone Members

Full Members



D. Grant Allen

Environmental
bioprocess engineering



Krishna Mahadevan

Metabolic systems
engineering



Alexei Savchenko

Enzyme crystallography



Levente Diosady

Food engineering



Emma Master

Enzymes for plant
bioproducts



Bradley Saville

Bioprocess technology
& economic analysis



Elizabeth Edwards

Bioremediation and
anaerobic digestion



Alison McGuigan

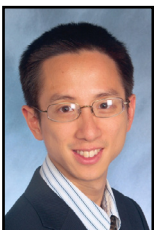
Tissue engineering



Alexander Yakunin

Enzyme genomics

Associate Members from the University of Toronto Faculty community



Arthur Chan

Atmospheric chemistry,
air pollution, and
health impacts



Elodie Passeport

Removal of
contaminants from
natural environments



Brent Sleep

Biological and
geochemical processes
in soils



Frank Gu

Nanotechnology
engineering



Barbara Sherwood Lollar

Deep subsurface
geochemistry and
microbialdegradation



Vlad Papangelakis

Aqueous and
environmental process
engineering

Adjunct Faculty Members



Nigel Guilford

*Guilford and Associates,
Toronto*

Anaerobic Digestion



Savia Gavazza

*Associate Professor, Civil
Engineering, Federal University
of Pernambuco, Brazil*

Bioremediation

Executive Summary

BioZone researchers are continuing to develop biotechnologies that improve the sustainability of industrial processes, remediate environmental contamination, and improve societal wellbeing. The research at BioZone builds on advancements in genomics and computational biology and deploys biological solutions at multiple scales, including enzymes, cells, microbial communities, and tissues. More importantly, BioZone continues to be a dynamic space filled with exciting ideas, enthusiastic students, and meaningful collaborations.

This report provides a summary of the research, training, and impact that BioZone has undertaken over the past two years, September 2016 to August 2018.

Research Projects: BioZone is leading several projects that aim to replace the petrochemical process used to produce chemicals and materials with bioprocesses that use residual agricultural or forestry feedstocks. In this reporting period, two new projects were funded. These include a Genome Canada GAPP application that will engineer yeast strains to convert sugars into adipic acid for bio-nylon production and an NSERC CRD that aims to reduce the carbon footprint of Canada's oil production through the development of biodiluent produced from renewable feedstocks. Work continues on the Genome Canada LSARP and the Ontario Research Fund – Research Excellence grants funded in 2016. These grants use enzymes or microbes to convert waste forestry feedstocks into value-added materials.

Over the past two years, BioZone researchers also expanded their portfolio of projects designed to reduce the environmental impact of Canada's industries. One of these applications is an NSERC CRD that will help Pulp and Paper Mills improve the dewatering of biosludge; thereby facilitating improved water recycling in their operations and reducing the amount of material sent to landfill. The other NSERC CRD will develop conceptual site models for environments contaminated with industrial pollutants that incorporate information about the microbial communities present at the site and model how these communities can accelerate the remediation process. This project builds on an ongoing Genome Canada GAPP project scaling-up benzene degrading microbial communities for field trials. Additionally,



work is continuing on the Ontario Research Fund – Research Excellence project developing biotechnologies to reduce the tremendous environmental liability of Ontario's mining tailings ponds.

Other important grants include the NSERC Industrial Biocatalysis Network, the NIH Center for Structural Genomics of Infectious Diseases, US AID Saving Lives at Birth Consortium - Quadruple Fortification of Salt, and the International Development Research Grant Enhancing Productivity and Cognitive Ability of 10 Million Rural Agricultural People in Uttar Pradesh in India via Scale-Up and consumption of Double Fortified Salt.

Impact: BioZone is supporting the growth of two startup companies spun out of BioZone (Ardr Inc. and Phycus Biotechnologies) working to develop sustainable chemicals produced from non-petroleum renewable feedstocks. BioZone researchers are testing and optimizing a new anaerobic digestion technology that will be deployed at demo scale in a municipal waste treatment facility to reduce landfilling and capture greenhouse gases. BioZone is working with industry partners to test the effectiveness of a benzene degrading microbial community at contaminated field sites. Finally, double fortified salt formulated by BioZone researchers is helping millions of individuals in India to fight anemia. During this period BioZone graduated 34 highly qualified personnel, with many being hired by innovative companies around the world. In addition to these applied impacts, BioZone researchers published 90 publications in many high impact journals during this reporting period.

Awards: BioZone faculty and staff were recipients of several prestigious awards including Royal Society of Canada's College of New Scholars, Artists and Scientists, Engineers Canada Gold Medal, and Faculty of Engineering Quality of Student Experience Award.

Moving Forward: BioZone is continuing to evolve, expand, and look for new ways to increase its impact. For example, we are planning to improve how we store, process, and analyze data sets, incorporate machine learning into our research and training programs, and develop a training structure that includes a greater focus on professional, entrepreneurship, and social science skills. Finally, we are finding ways to accelerate the pace at which the knowledge we generate is translated to industry and other researchers.

Overall, during the 2016-2018 reporting year, BioZone received over \$12.6M in cash funding, as well as valuable and generous in-kind contributions from many industrial partners. BioZone was home to 128 students, PhDs, research assistants, technicians, and staff. These and other metrics are provided in more detail in the following pages. We look forward to coming years full of promise!

Research Impact

This report highlights our achievements during the **September 2016 - August 2018** reporting period, unless otherwise indicated.

The impact of BioZone's research goes beyond publications and includes company creation, improved industrial and environmental outcomes, and healthier societies. The following section highlights some of direct impact from BioZone researchers over the 2016-2018 period.



Chemicals From Renewable Feedstocks – *Ardra Inc*

Ardra is a synthetic biology start-up focused on producing natural ingredients for cosmetics, flavour and fragrance industries. Spun out of Krishna Mahadevan's lab, Ardra has developed patent-pending biocatalysts for production of natural ingredients at low production cost and consistent supply. Ardra's first two products are: 1) leaf-aldehyde, an ingredient used in perfumery and fruit flavouring such as green apple; and 2) butylene glycol, an ingredient used in cosmetic formulations such as a moisturizing agents. The technology to produce leaf-aldehyde is currently being scaled-up at pilot-scale, and the product has received significant interest from customers and potential industry partners. Ardra was incubated at the prestigious San Francisco-based Indie Bio-Accelerator and has raised over \$800,000 in private and government funding. Ardra currently operates from JLABS at the MaRS Centre in Toronto.



Life Cycle and Technoeconomic Assessment – *Savant Technical Consulting*

BioZone researchers operate *Savant*, a research-driven consulting company that provides world-leading expertise in the fields of microbiology and biotechnology, process and bioprocess design, financial modeling, and life-cycle assessment (LCA) for the renewable energy, environmental remediation, biofuels, and waste management industries.



Sustainable manufacturing - *Phycus Biotechnologies*

Phycus Biotechnologies is another company started by graduates of the Mahadevan Lab. Phycus Biotechnologies is closing the gap between the development of new, sustainable products and their availability on store shelves. Their goal is to help consumer and industrial product companies adopt products that are actually good for the environment.

Phycus Biotechnologies has developed a novel biocatalyst platform that facilitates the production of chemicals and chemical products. Their engineered microorganisms do not use sugar for growth. By not using sugar Phycus can: (1) significantly reduce the lead time for producing new chemicals, and (2) increase product yields which are often notoriously bad on glucose. Today, their product pipeline includes a variety of different molecules with different end markets such as formaldehyde free bioGlycolic Acid. To date, Phycus has secured almost \$500,000 in private and government funding.



Micronutrient Food Supplements - *Tata Trusts / The Bill and Melinda Gates Foundation*

BioZone researchers have developed a cost effective system for adding iron to salt without modifying its taste or appearance. To help combat the extremely high prevalence of anemia in developing countries, the iron-fortified salt developed in BioZone is being distributed to more than 24 million people in India, curing over 1 million children.



Remediation of Contaminated Sites - *DuPont and SiREM*

Microbial-based technology developed at BioZone and commercialized by SiREM is being used to remediate sites around the world contaminated with toxic chlorinated compounds. We are currently starting field trials that will assess the ability of microbial communities to remediate sites contaminated with benzene and other toxic petroleum-based compounds.

Work is underway evaluating the potential for bioremediation and natural attenuation at numerous sites around the world contaminated by a complex suite of chemicals, including the pesticides lindane and diuron. Remarkably, microbes can detoxify many of these chemicals. The goal of these projects is to understand rate-limiting steps to then devise ways to accelerate remediation.

Processing Solid Organic Waste – *Miller Waste Systems Inc.*

BioZone researchers have developed and are testing new anaerobic digester designs that reduce the quantity of solid waste sent to landfills, produce renewable energy, lower the amount of greenhouse gases released into the environment, and generate a compost by-product suitable for land application. The benefits are considerable; a reduction in organic waste to landfills by up to 80%, a reduction in greenhouse gas emissions of 1.25 tonnes of CO₂ for every tonne of waste processed, and the production of commercial quantities of electricity or renewable natural gas.

This reactor design will be tested at demonstration scale, and then full scale, at a new integrated waste management facility to be constructed in Ottawa by Taggart Miller, a joint venture of The Miller Group and The Taggart Group.

Innovations

Some of the recent innovations from BioZone projects and researchers include:

- Machine learning-based biochemical pathway prediction tool for synthetic biology applications
- Microbes engineered for 1,3-butanediol production, adipic acid, ethylene glycol, and other chemicals
- Novel enzymes for recycling of plastics made from polylactic acid
- Characterization of novel antimicrobial resistance mechanisms from the environmental microbiome
- Discovery of novel pathogenic enzymes from *Legionella pneumophila*
- Engineering *in vitro* regenerative microenvironments to functionally assess stem cell mediated tissue regeneration
- Robust manufacturing of tissue biocomposites for generating reproducible 3D TRACER culture
- A method to spatially and chemically resolve lignin from polysaccharides in woody samples
- Processes for fortifying salt with iron and iodine (double-fortified salt)
- Novel anaerobic digester designs for municipal waste reduction
- Enhanced digestion of waste fibers through co-digestion with food waste
- Purification of a novel co-factor (prenylated FMN) that enables aromatic carboxylation and decarboxylation reactions
- Novel co-factors that enhance dechlorination
- Triple, quadruple and multiple fortified salt, Morenga-based bouillon cubes
- Device for rapid visualization of cell invasion in a horizontal plane
- Novel enzyme system for carbohydrate amination
- Benzene-degrading cultures for bioremediation
- Three-dimensional tissue modeling technology
- Wave guides for enhanced microalgae production

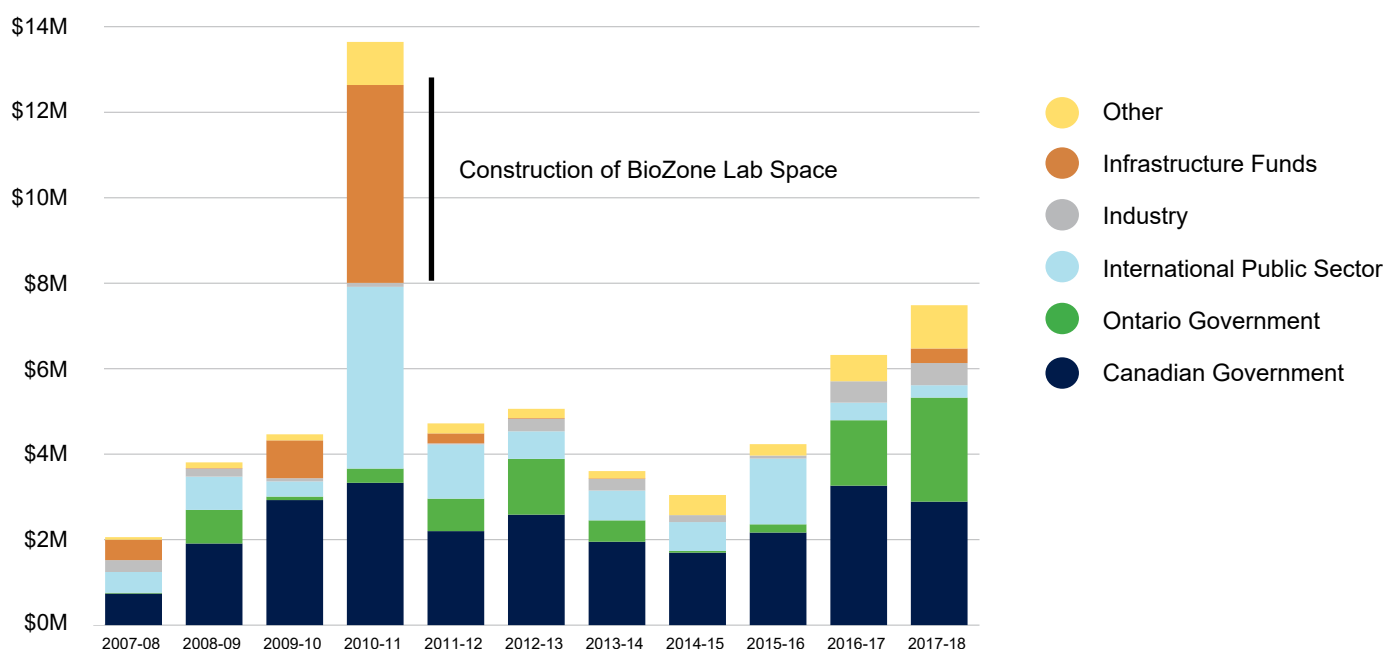


Research Funding

BioZone researchers led 48 funded research projects from September 2016 to August 2018. Many of the grants involved collaborations between multiple research groups, both domestic and international. Figure 1 shows the total research cash funding to the core BioZone principal investigators (PIs) since BioZone's inception. These totals do not include in-kind funding or project funds flowing to non-BioZone researchers from the awarded grants.

Cash funding for BioZone research in 2012-2018 came from a mix of domestic and international sources (Fig. 2). International research grants provided between 12-35% of total cash funding to BioZone from 2012-2018. The majority of funding for BioZone included funding from the federal government. This includes a seven-year Canada Research Chair in Anaerobic Biotechnology awarded to Dr. Elizabeth Edwards in 2014.

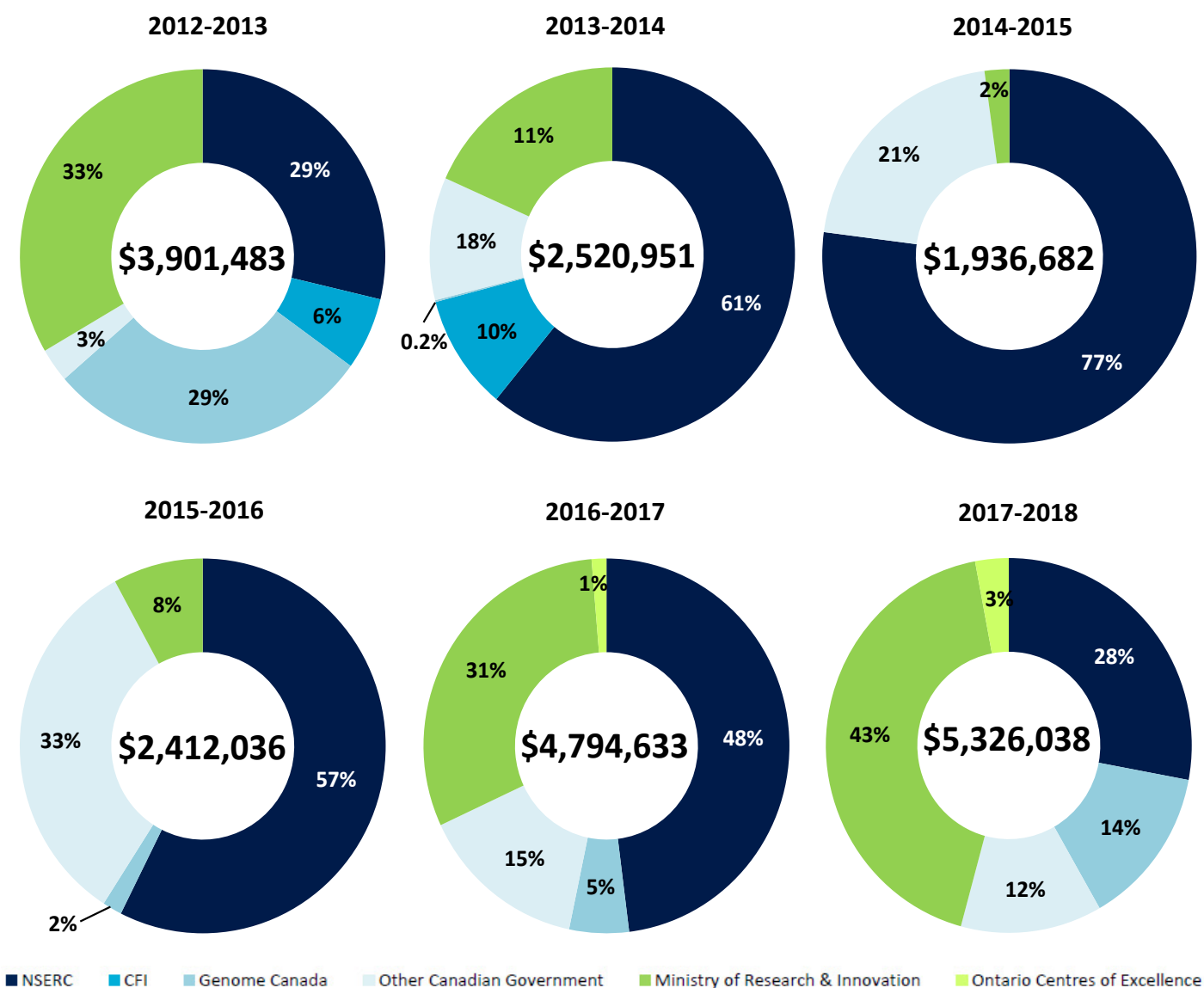
Figure 1 (and associated table below). BioZone cash funding received per year (September 1 to August 31). Includes operating, capital, and equipment grants, overhead, and amounts sub-awarded to other University of Toronto professors when a BioZone PI leads the project. Does not include in-kind contributions, amounts sub-awarded to other universities, or other leveraged funds.



	Canadian Government	Ontario Government	International Public Sector	Industry	Infrastructure	Other	Total
2007 / 2008	\$737,813	\$20,000	\$486,799	\$275,899	\$480,179	\$57,065	\$2,057,754
2008 / 2009	\$1,911,799	\$784,218	\$778,088	\$190,568	\$9,500	\$135,512	\$3,809,685
2009 / 2010	\$2,925,232	\$81,988	\$354,655	\$75,000	\$887,828	\$140,715	\$4,465,418
2010 / 2011	\$3,330,119	\$334,065	\$4,251,247	\$93,155	\$4,628,118	\$1,009,180	\$13,645,884
2011 / 2012	\$2,198,925	\$760,775	\$1,267,228	\$25,000	\$234,748	\$495,571	\$4,982,247
2012 / 2013	\$2,584,531	\$1,303,452	\$647,492	\$296,204	\$13,500	\$477,584	\$5,322,763
2013 / 2014	\$1,950,982	\$501,763	\$695,648	\$270,420	\$13,496	\$436,774	\$3,869,082
2014 / 2015	\$1,693,656	\$41,300	\$677,411	\$160,993	\$0	\$734,246	\$3,307,607
2015 / 2016	\$2,167,201	\$191,898	\$1,536,707	\$72,500	\$0	\$478,322	\$4,446,628
2016 / 2017	\$3,262,835	\$1,531,798	\$411,580	\$498,311	\$0	\$616,432	\$6,320,955
2017 / 2018	\$2,887,933	\$2,438,105	\$285,669	\$520,420	\$339,784	\$1,011,689	\$7,483,600

Figure 2. Sources of cash funding to BioZone professors from the Canadian Federal Government and the Ontario Provincial Government between September 1 to August 31 for the fiscal years between 2012 and 2018. Infrastructure funding not included, other inclusions and exclusions are listed in the caption for Fig. 1.

Source		2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018
Canadian Government	NSERC	\$1,119,289	\$1,536,275	\$1,492,606	\$1,384,129	\$2,302,157	\$1,488,690
Canadian Government	CFI	\$244,618	\$251,564	\$0	\$0	\$0	\$0
Canadian Government	Genome Canada	\$1,119,123	\$4,000	\$0	\$41,553	\$252,538	\$734,052
Canadian Government	Other Canadian Government	\$115,000	\$267,349	\$402,776	\$794,456	\$708,140	\$665,191
Ontario Provincial Government	Ontario Ministry of Research and Innovation	\$1,303,452	\$461,763	\$41,300	\$191,898	\$1,469,298	\$2,280,605
Ontario Provincial Government	Ontario Centre of Excellences	-	-	-	-	\$62,500	\$157,500



Existing and New Major Research Programs

Major research initiatives in BioZone typically involve collaborations between multiple BioZone PIs, researchers at other institutions in Canada and abroad, and private sector partners. Thus, total project values for major research initiatives are often significantly higher than the cash awards as they include leveraged contributions from other institutions and private sector partners. Major awards held in September 2016 to August 2018 are listed below.



NSERC Strategic Network: Industrial Biocatalysis Network (2014-2019)

Website: <http://www.ibnet.ca/>

Member(s): Edwards (co-lead), Savchenko (co-lead) Mahadevan, Master, Yakunin and 4 other collaborators

Total project size: \$5,915,000

Contributions:

NSERC: \$5,000,000

Universities (Toronto, UBC, & Concordia): \$420,000

Industry Partners (BP, CanSyn, DuPont, Elanco, Lallemand, BP & Suncor): \$495,000

Through the *Industrial Biocatalysis Network*, university researchers and industry partners are using the latest genomics tools to identify and characterize enzymes that can convert renewable resources, such as agricultural or forestry waste, into new materials and chemicals. The goal of the project is to use these enzymes to develop sustainable bioprocesses that reduce energy consumption and carbon emissions compared to traditional petrochemical processes.



NIH/NIAID Contract: Center for Structural Genomics of Infectious Diseases (CSGID) (2012-2017)

Website: <http://www.csgid.org>

Member(s): Savchenko (lead), Stogios

Contributions:

National Institute of Allergy and Infectious Diseases, National Institutes of Health: \$2,750,000

The *Center for Structural Genomics (CSGID)* is a multi-site collaborative initiative to determine the 3D crystal structures of bacterial proteins implicated in infectious disease. The goal of the project is to disseminate molecular information into the public domain (Protein Databank) to facilitate molecular biology research into the molecular mechanisms of infectious diseases and to accelerate targeted drug discovery efforts to treat such infections. The BioZone Protein Production and Crystallization Facility's role in the CSGID is to conduct high-throughput protein purification, crystallization, structure determination and interpretation/analysis. To date, the BioZone Protein Production and Crystallization Facility contributions to the CSGID include 2,300 cloned genes, 1,100 purified proteins, 405 protein crystals and 250 3D structures.

Saving Lives at Birth Consortium - Quadruple Fortification of Salt (2016-2018)

Website: <https://www.savinglivesatbirth.net/>

Member(s): Diosady (lead) and 1 other collaborator

Total Project Size: \$331,710

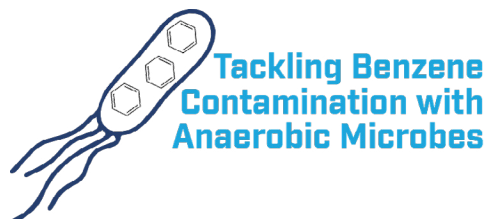
Contributions:

United States Agency for International Development (US AID), Norwegian Ministry of Foreign Affairs

The Bill & Melinda Gates Foundation, Grand Challenges Canada, The Department of International Development United Kingdom, Kingdom of Great Britain and Northern Ireland (DFID), Korea International Cooperation Agency (KOICA)

This funding is administered by Grand Challenges Canada. Salt is universally consumed at a constant level independently of socio-economic status. We propose to fortify salt with iron, iodine, vitamin B12 and folic acid. Quadruple-fortified salt (QFS) will provide these at levels that will result in a substantial improvement in the micronutrient status of women and children, leading to large decreases in maternal, neonatal and infant mortality.





Tackling Benzene Contamination with Anaerobic Microbes

Genome Canada Genomics Applied Partnership Program: Tackling Anaerobic Benzene Contamination with Anaerobic Microbes (2016-2019)

Website: <http://anaerobicbenzene.ca/>

Member(s): Edwards (lead), Sandra Dworatzek (SiRem)

Total project size: \$997,397

Cash Contributions:

Genome Canada: \$317,422

Ontario Ministry of Research and Innovation: \$317,422

In-kind & Cash Contributions:

SiREM: \$217,540

Federated Cooperative Limited: \$100,000

Mitacs: \$45,000

This project is optimizing and scaling-up microbial cultures and monitoring tools that will drive *in situ* remediation of benzene and BTEX compounds. Outcomes include:

- significantly decreasing the time to clean up sites
- reducing the cost to meet regulatory requirements
- avoid disrupting on-going site activities
- reducing the costs of site monitoring



Genome Canada Genomics Applied Partnership Program: Genomics Driven Engineering of Hosts for Bio-Nylon (2017-2020)

Member(s): Mahadevan (lead), Alexander Yakunin

Total project size: \$5,700,000

Cash Contributions:

Genome Canada: \$1,900,000

Ontario Ministry of Research and Innovation: \$1,900,000

In-kind & Cash Contributions:

BioAmber: \$1,900,000

A genomics-driven bioengineering approach has been developed by the University of Toronto's team at BioZone led by Dr. Radhakrishnan Mahadevan to convert sugars into value-added industrial chemicals such as adipic acid. Adipic acid alone has a market of 2.2 million tonnes; chemicals that can be derived from it have similarly large markets.

The results of its work will benefit Canada's economy by growing the biorefining industry and creating new manufacturing jobs, while protecting the environment through reduced greenhouse gas emissions and pollution.



Ontario Research Fund - Research Excellence: Biochemicals from Cellulosic Biomass (BioCeB) (2017-2021)

Member(s): Mahadevan (co-lead), Yakunin, Savchenko, and 5 other collaborators

Total project size: \$ 11,816,407

Cash Contributions:

Ontario Ministry of Research and Innovation: \$3,929,469

Institutional Leveraging: \$2,926,249

In-kind & Cash Contributions:

Industry Partners (BioAmber and Bioindustrial Innovation Canada): \$2,550,000

The *BioCeB* project will design bacterial and yeast strains capable of efficiently converting glucose derived from renewable agricultural and forestry feedstocks into value-added chemicals such as adipic acid for bio-nylon production. The goal of the *BioCeB* project is to develop microbial manufacturing systems that reduce society's reliance on petrochemicals, reduce the use of toxic compounds, and lower greenhouse gas emissions.



Functional genomics and techno-economic models for advanced biopolymer synthesis

**Genome Canada Large Scale Applied Research Project:
SYNBIOMICS: Functional genomics and techno-economic
models for advanced biopolymer synthesis (2017-2020)**

Website: <http://www.synbiomics.ca/>

Member(s): Master (lead), Edwards, and 4 other collaborators

Total project size: \$9,989,427

Cash Contributions:

Genome Canada: \$2,830,871

Genome Quebec: \$791,438

Genome BC: \$181,879

European Research Council: \$2,298,124

Ontario Ministry of Research and Innovation: \$479,318

Canadian Foundation for Innovation: \$181,879

In-kind & Cash Contributions:

University of Toronto: \$695,606

Queen's University: \$60,000

Industry Partners (Canfor, DuPont, EcoSynthetix, IGPC, Innotech, Millar Western, Tembec, West Fraser): \$635,000

The *SYNBIOMICS* project is developing biocatalysts that upgrade the three wood fractions produced by pulp mills: cellulose, hemicellulose, and lignin.

By upgrading, rather than degrading, these renewable biopolymers, this project overcomes major challenges of biotechnologies developed to breakdown lignocellulose structures and builds on the unique qualities of Canada's forest resource. The optimized biocatalysts developed through the *SYNBIOMICS* project will upgrade renewable forest biomass to create high-value bio-based polymers for targeted applications, including resins, coatings, bioplastics, and adhesives for lightweight biocomposites.

SYNBIOMICS will provide the following environmental, social, and economic benefits:

- environmental benefits by facilitating healthy forestry practices and promoting the transition from petrochemical to lower carbon renewable feedstocks
- social benefits by revitalizing the forestry sector by increasing the sustainable forest harvest and establishing SME-mill clusters that drive economic activity and job growth in rural communities
- economic benefits by creating new forestry-derived products such as biopolymers for use in adhesives, dispersants, coatings, and bio-resins to meet global demand for green bio-based products



**Ontario Research Fund - Research Excellence:
Elements of Bio-mining (2017-2021)**

Website: www.biomining.ca

Member(s): Papangelakis (lead), Edwards (co-lead), Mahadevan, Yakunin, Saville, Savchenko, and 7 other collaborators

Total project size: \$12,000,000

Cash Contributions:

Ontario Ministry of Research and Innovation: \$4,000,000

NSERC: \$1,257,792

Genome BC: \$204,975

In-kind & Cash Contributions:

University of Toronto: \$1,283,812

Laurentian University: \$292,073

University of British Columbia: \$349,481

CSIRO: \$363,614 (Australia)

INMARE: \$500,000 (UK)

Industry Partners (Barrick, CEMI, Denison Environmental, Glencore, Hatch, MetagenomBio, Imperial, Teck, Tetrat-ech, & Vale): \$2,274,094

Issue: During base metal recovery, iron sulfides are rejected as waste tailings. When exposed to air, water, and microbes, these sulfide-laden waste tailings are oxidized to sulfuric acid, thereby producing acid mine drainage. The cost to clean up acid mine drainage at Canadian mine sites is estimated to be in the range of \$2-5 billion. However, the value of the nickel stored in existing tailings in Sudbury, Ontario is estimated to be \$7 billion. Thus, there is financial and environmental incentive to improve mine waste management. Selenium (Se) is an analog of sulfur (S) and a minor but more toxic component of sulfide minerals. Metal and coal mines in Canada released ~20 tonnes of Se into water in 2012.

Solution: With the tremendous advances in molecular biology tools, sequencing technology, and the ensuing "omics" revolution, bioprocesses are no longer "black boxes." Acid mine drainage ecology has now been characterized and provides us with a broad understanding of the dominant microorganisms in these communities. This information provides us with a toolkit to engineer improved mining processes by manipulating individual microbes or entire communities. This project will develop microbial-driven processes to stabilize S and Se in their neutral elemental forms with simultaneous base metal recovery. Conventional approaches stabilize S and Se in their most reduced state. Our approach has technical and economic advantages, and also challenges. While microbial processes contribute significantly to the oxidation and reduction of S and Se, arresting these reactions at elemental S and Se while liberating metals of commercial value requires a better understanding of rate-controlling reactions and the microbes involved in these conversion processes.

**NSERC Collaborative Research and Development Grant
Enhancing Dewatering, Drying, Combustion and Utiliza-
tion of Pulp and Paper Mill Biosludge
(2017-2021)**

Member(s): Allen (lead), Edwards and other collaborators

Total project size: \$1,424,200

Cash Contributions:

NSERC: \$722,100

In-kind and Cash Contributions:

University of Toronto: \$220,000

Industry partners (Andritz, AV Nackawic, Clyde-Bergemann Power Group, Domtar Inc., ERCO Worldwide, Valmet Ltd., WestRock Corporation): \$482,100

Canadian pulp and paper mills generate more than 20 million cubic metres of raw biosludge per year during biological wastewater treatment and consists. Energy intensive dewatering can decrease the water content to 60 - 80% before the sludge is either being landfilled, incinerated in biomass boilers, or land-applied. Regardless of the disposal option selected, the processing, chemical and energy costs are substantial as are the opportunities to reduce their environmental footprint. In order to remain competitive on the global market and to meet increasingly stringent environmental regulations, Canadian mills need to be provided with methods and strategies for a more cost and energy effective management of biosludge.

The results from this program will provide pulp and paper mills with methods and guidelines to significantly decrease the costs for sludge handling, and thereby diminishing the mills' environmental footprint.

**NSERC Collaborative Research and Development Grant
Decreasing Dependence on US Pentane using Canadian
Produced Biodilutents (2018-2022)**

Member(s): Mahadevan (lead), Yakunin

Total project size: \$741,428

Cash Contributions:

NSERC: \$294,001

OCE: \$150,000

In-kind and Cash Contributions:

Industry Partners (Suncor): \$295,713

Due to mounting public pressure and government policy, energy companies are looking for methods to reduce their carbon footprints. One approach is to use drop in biobased chemicals as fuel additives or biodilutents. The ultimate goal of this project is to develop biotechnologies that can convert CO₂ to drop in biodilutents and fuels. In particular this project will focus on the development of a biocatalyst that can convert ethylene glycol, which can be produced electrochemically from CO₂ and renewable energy, to biodilutents.

**NSERC Collaborative Research and Development Grant
Integrating microbial characterization tools into conceptual
site models (CSMs) at complex contaminated sites
(2018-2020)**

Member(s): Edwards (lead), Passeport, and other collaborators

Total project size: \$426,825

Cash Contributions:

NSERC: \$151,190

In-kind and Cash Contributions:

Industry partners (DuPont, Geosyntec): \$275,635

The goal of this project is to develop better approaches to remediate sites with a complex mix of contaminants. In particular, next generation DNA sequencing for microbial community analysis, new compound-specific stable isotope and mass spectroscopy analyses will be integrated with traditional data collected from groundwater wells and soil borings at the site to improve the accuracy of the conceptual map of contaminant fate and transport at the site.

**International Development Research Centre Grant
Enhancing Productivity and Cognitive Ability of 10 Mil-
lion Rural Agricultural People in Uttar Pradesh in India
via Scale-Up and consumption of Double Fortified Salt
(2015-2018)**

Member(s): Diosady and other collaborators

Total project size: \$1,021,022

Cash Contributions:

International Development Research Centre: \$1,019,400

Adding iodine to salt has been one of the world's most successful public health campaigns, reaching 5 billion people globally and 800 million people in India daily. A 20-year effort by Canadian researchers has come up with a cost-effective way to fortify salt with both iron and iodine—a feat that has long eluded food scientists. Building on extensive pilot testing and impact assessments, work bring double fortified salt (DFS) to over 15 million people in one of India's poorest and most food insecure regions.

Expected results

- A cost-effective solution to anemia benefiting millions of women of child bearing age
- A sustainable model that combines health benefits and market opportunities to transfer DFS to local salt producers for distribution through public and private sector channels
- Regular and sustained intake of iodine and iron for a target of 15 million people in Uttar Pradesh

BioZone Core Professors Research



Elizabeth Edwards, Director

Bioremediation and Anaerobic Digestion

Utilizing the latest genomics and metagenomics tools to understand and exploit microbial communities that detoxify common pollutants, convert wastes into useful products, and to minimize solid waste streams.

<https://www.labs.chem-eng.utoronto.ca/edwards/>



D. Grant Allen

Environmental Bioprocess Engineering

Environmental bioprocess engineering for the treatment of industrial waste and wastewater streams, air quality, and the use of micro algae for the conversion of waste into value-added products.

<https://www.labs.chem-eng.utoronto.ca/allen/>



Levente Diosady

Food Engineering

Microencapsulation of food ingredients and nutraceuticals and the prevention of micronutrient deficiency diseases through the development of process technology that fortifies food with micronutrients such as trace metals and vitamins.

<https://chem-eng.utoronto.ca/faculty-staff/faculty-members/levente-l-diosady/>



Krishna Mahadevan

Metabolic Systems Engineering & Modeling

Engineering microbial systems for industrial and medical applications by employing bioinformatics, modeling of metabolic and regulatory networks, systems biology, and metabolic engineering, synthetic biology

<https://www.labs.chem-eng.utoronto.ca/mahadevan/>



Emma Master

Biocatalysts for agriculture forestry based bioproducts

Utilizing the latest genomics and metagenomics tools to understand and exploit microbial communities that detoxify common pollutants, convert wastes into useful products, and to minimize solid waste streams. Also holds Faculty position at Aalto University in Finland.

<https://www.labs.chem-eng.utoronto.ca/master/>



Alison McGuigan

Tissue engineering

The development of predictive structured heterogeneous tissue model systems for understanding mechanisms of tissue assembly and to improve drug discovery.

<https://www.mcguiganlab.com/>



Alexei Savchenko

Protein Production & Crystallization

Enzyme production and characterization facilitating enzyme discovery and synthetic biology, including: bacterial pathogenic factors; antimicrobial resistance enzymes; carbohydrate-active enzymes; biocatalysts. Characterization of protein function based on combination of structural, biochemical and in vivo methodologies. Also holds Faculty position at University of Calgary.

<https://www.labs.chem-eng.utoronto.ca/savchenko/>



Bradley Saville

Bioprocess technology & economic analysis

Conversion of biomass for production of biofuels and bioproducts, and the economic and life cycle analysis of biofuels and bioproducts.

<https://chem-eng.utoronto.ca/faculty-staff/faculty-members/bradley-a-saville/>



Alexander Yakunin

Enzyme Genomics

Engineering microbial systems for industrial and medical applications by employing bioinformatics, modeling of metabolic and regulatory networks, systems biology, and metabolic engineering. Also holds Faculty position at Bangor in the UK.

<https://www.labs.chem-eng.utoronto.ca/yakunin/>

National & International Collaborations

University of Toronto

Chemical Engineering & Applied Chemistry
Civil & Mineral Engineering
Mechanical & Industrial Engineering
Material Sciences and Engineering
Institute of Biomaterials and Biomedical Engineering
Earth Sciences
Leslie Dan Faculty of Pharmacy

Canadian

Laurentian University
Concordia University
McMaster University
Mount Saint Vincent University
Ryerson University
University of British Columbia
University of Calgary
University of Guelph
University of Ottawa
University of Western Ontario
Queen's University

International

Aalto University, Finland
Aix-Marseille Université, France
Argonne, National Laboratory, Illinois
Bangor University, UK
Boston University, Massachusetts
Children's Hospital Oakland Research Institute, USA
Cornell University, USA
Federal University of Minas Gerais, Brazil
Imperial College, London, UK
JVS Foods PVD, Jaipur, India
Max Planck Institute, Germany
Northwestern University, Illinois
The Nutrioton India Nutrition Initiative, India
Tamil Nadu Agricultural Univesity, India
Tufts University, Massachusetts
Univerisidade Federal de Pernambuco, Brazil
Universite des Antilles, Guadeloupe
University of Chicago, Illinois
University of Delhi, India
University of Helsinki, Finland
University of Nanjing, China



Researchers, Students, and Staff

Recruiting Top Research Talent from Around the World

BioZone is home to a very diverse and gifted pool of students, researchers, staff and PIs from a wide range of disciplines. Since the centre’s inception, we have attracted personnel and trainees from over 30 countries on 5 continents. Figure 3 below illustrates the geographical diversity of our current complement of BioZone researchers from twenty-five countries from all corners of the globe.

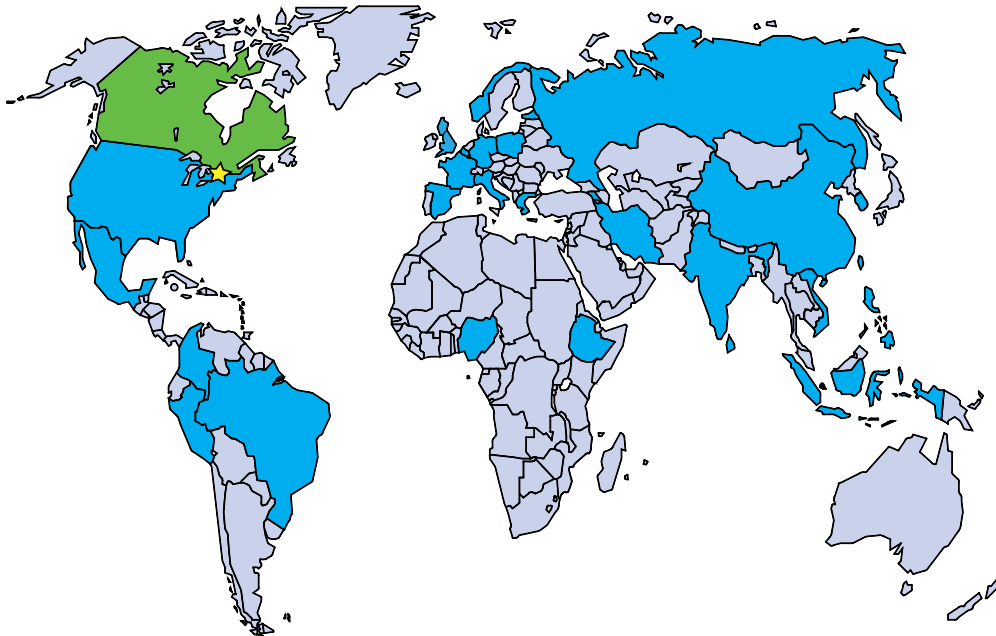


Figure 3. Countries of origin, highlighted in light blue, of BioZone researchers, graduate students and staff at the end of the reporting period. The location of the University of Toronto is denoted with a yellow star, and Canada is highlighted in green.

At the end of this reporting period, BioZone was home to 106 graduate students, postdoctoral fellows, staff and PIs (Fig. 4). For the 2016-2018 reporting period alone, 20 undergraduate students gained valuable hands-on experience working in BioZone’s laboratories including: six undergraduate theses, one co-op student and thirteen summer internships.

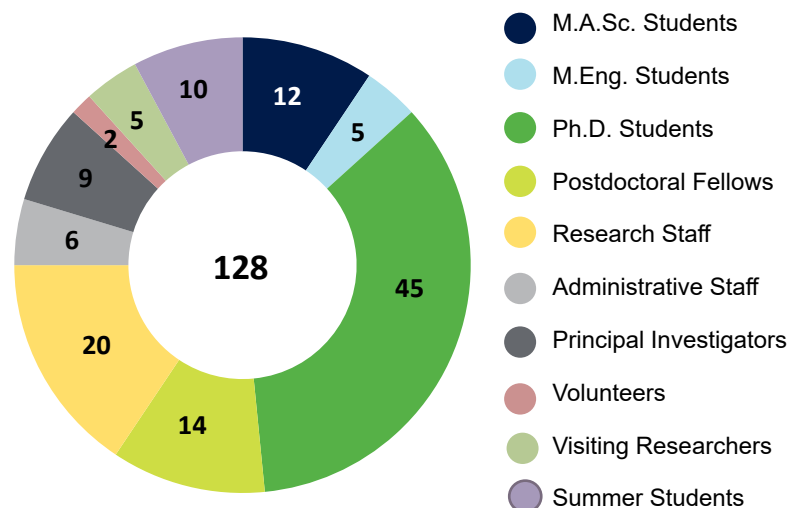


Figure 4. Headcount of BioZone personnel by category as of Summer 2018.

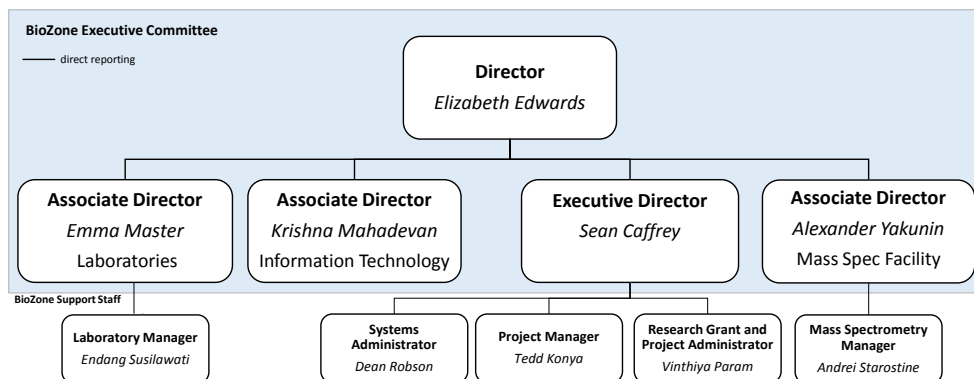


Figure 5. Overview of BioZone’s leadership showing Executive Committee and Administrative and Management Staff.

BioZone’s Director is appointed by the Dean of the University of Toronto’s Faculty of Applied Science and Engineering, and reports administratively to the Dean. Elizabeth Edwards was appointed as BioZone’s founding Director in January 2011 and was renewed for an additional term starting in June 2014.

BioZone’s strategic direction and day-to-day operations are overseen by the Centre’s Executive Committee (ECOMM), consisting of the Director, three Associate Directors and the Executive Director. The current membership and the related areas of responsibility are shown in the above organizational chart (Figure 5).

The ECOMM meets monthly to review new opportunities, provide an organizational framework for students and researchers, and oversee lab and computational resources. The committee also works closely with BioZone staff, as shown in the chart above, to ensure that researchers’ needs are met and their concerns promptly addressed.

Dedication to Research

BioZone emphasizes education and mentorship with dozens of graduate and undergraduate students undertaking research projects. This is in great part due to the research support team in BioZone consisting of both laboratory technicians and research associates. The seventeen outstanding research staff (Fig. 6) in BioZone not only assist in the education of our next generation of researchers, but also ensure continuity of best practices and oversight of our long-term collaborative research programs.

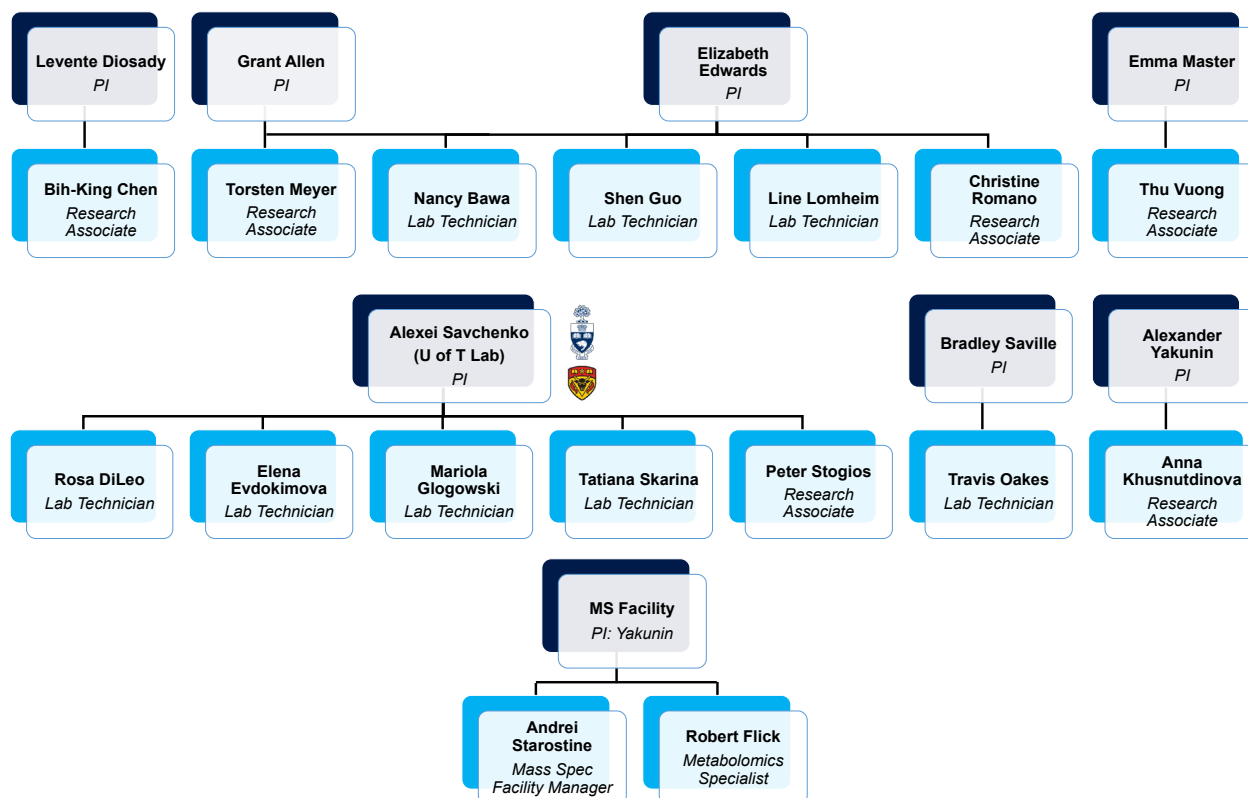


Figure 6. Distribution of research associates and laboratory technicians by principal investigator as of August 31, 2018.

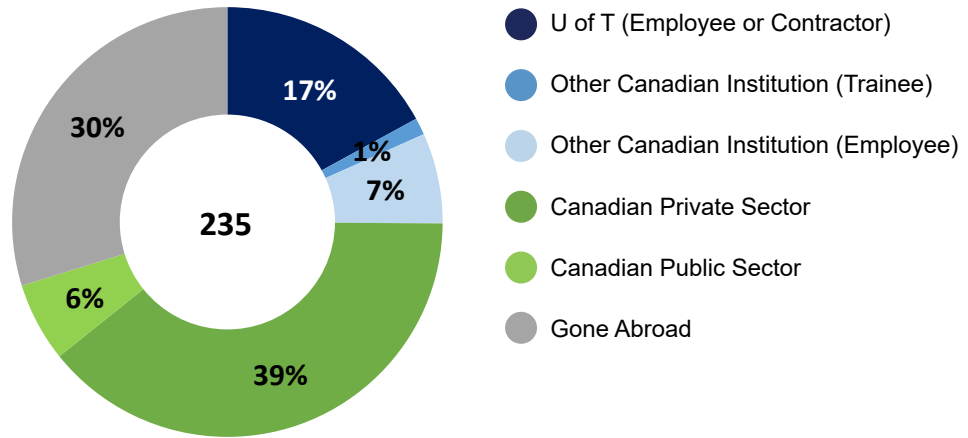


Figure 7. Breakdown of industry sectors reached by BioZone alumni, including former graduate students, postdoctoral fellows, research associates and technicians. Graph based on information for 235 BioZone alumni whose current positions are known.

BioZone Alumni

Since the inception of BioZone in 2007, a total of 166 graduate degrees have been awarded to students in BioZone. This includes 90 M.A.Sc., 22 M.Eng., 1 M.H.Sc., 11 M.Sc. and 52 Ph.D. degrees. In addition, 42 postdoctoral fellows completed their fellowships, 73 undergraduate theses have been completed and well over 100 summer students have been mentored over this period. Alumni from BioZone have gone onto professional and academic positions in Canada and abroad. Fig. 7 shows the breakdown by sector for the BioZone graduates for which information is available.

Many of BioZone’s graduates continue on to new and exciting endeavours in a variety of fields, including starting their own research labs, to breaking out and starting their own companies. For an update on just a few BioZone graduates, please refer to the “*Alumni Updates*” section on page 39.

BioZone alumni have branched out to all corners of the globe into a variety of career paths ranging from project management to outreach to academia. Some of the ventures our graduates have gone onto include:

- The American Chemical Society
- Apotex Inc.
- Bayer
- Gay Lea Foods Cooperative
- Genomatica
- Golder Associates
- Government of Ontario
- Hatch
- Intrexon Corporation
- Johnson & Johnson
- Lanzatech
- Luminex
- MIT
- NOVA Chemicals
- Novozymes
- Parmalat
- Pfizer Canada
- PwC
- Ramboll Environ
- Sanofi Pasteur
- ZymoResearch

Job Titles of Alumni

% of students in each category



Researcher Accomplishments

Awards

The outstanding work accomplished by BioZone’s students and researchers was recognized with over 60 awards and scholarships. The following list highlights just a few of the awards received and held by BioZone’s professors, post-docs and students:

- Biochemical Engineering Journal Young Investigator Award
- Canada Research Chair
- CIHR Training Program in Regenerative Medicine Graduate Fellowship Award
- Colin Hahnemann Bailey Fellowship
- C.W.Bowman Graduate Scholarship
- DuPont Canada Graduate Scholarship in Science and Technology
- Dr. Goran Enhorning Award in Pulmonary Research
- Dr. Joe A. Connolly Memorial Award
- Engineers Canada Gold Medal
- Faculty Award for outstanding teaching and research.
- Fellow of the Royal Society of Canada
- McLaughlin Foundation Award for MD/PhD Students
- McLean Award
- Mitacs Accelerate Fellowship
- Mitacs Globalink Graduate Fellowship
- NSERC Canada Graduate Scholarships - Master’s Program
- NSERC CREATE in Manufacturing, Materials and Mimetics (M3)
- NSERC CREATE Sustainable Aviation Award
- NSERC Postgraduate Scholarships-Doctoral Program
- Ontario Graduate Scholarship
- Ontario Trillium Scholarship
- Paul Cadario Doctoral Fellowship in Global Engineering
- Queen Elizabeth II Graduate Scholarship in Science & Technology
- Schlumberger Foundation Faculty for the Future Grant

See “Grants, Awards & Scholarships” on page 52 for a full detailed lists.

Publications

From September 2016 to August 2018, our team published nearly 90 peer-reviewed articles in international journals. In this time, our students and researchers also delivered over 100 invited talks, oral presentations and poster presentations at Canadian and international conferences and institutions. For a full list of all publications and presentations, including student theses, please see the “Publications” section on page 41.

Supporting Technology Transfer

Our goal is to provide benefits to society and the environment through the development of technology that addresses important problems.

During this reporting period BioZone researchers made three invention disclosures and filed two patent applications. BioZone supported the R&D and fundraising efforts of two companies spun out of BioZone, Adra Inc. and Phycus Biotechnologies, and supported the R&D efforts of several other start-up companies.

We have long-standing, strong research partnerships with several corporations (see “BioZone Sponsors” on page 56) and are actively seeking new partners for collaborative research. In addition, many of our alumni still maintain close ties to our research, providing another conduit for technology transfer through their careers and other endeavors.



Industry Support

BioZone gratefully acknowledges support from the wide range of public, nonprofit, and private sector partners listed on page 56 and 57 of this report, whose contributions have included personnel time, expertise, samples, equipment and research funding.

BioZone Association

The BioZone Association was launched in 2016, led by the BioZone Council. The purpose of the BioZone Association is to represent BioZone students, post-doctoral fellows, research assistants, and technicians and to promote a positive and productive work environment.

BioZone Association's Mandate:



Collaboration

To maintain a collegial and collaborative atmosphere within BioZone by encouraging social activities, events, active communication, and knowledge exchange.



Mission

To help shape the goals and mission of BioZone.



Promote

To promote BioZone as a leading research centre to academia (students, researchers, and collaborators) and industry, through a robust presence on external media such as professional social networks, the BioZone website, and through external events.



Efficiency

To promote efficient operation and maintenance of important shared BioZone equipment and facilities.

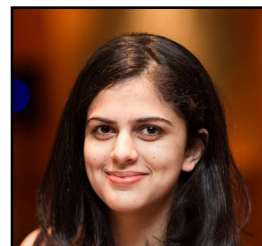
The 2018 BioZone Council



Mitchell Zak
Co-President



Scott Proulx
Co-President



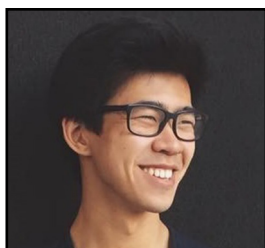
Ruhi Choudhary
Events



Azadeh Vatandoust
Events



Lais Pereira
*External
Communications*



Patrick Diep
*Internal
Communications*



Kaushikraj Venkatesan
Treasurer



Sean Caffrey
Ex-Officio

Outreach & Events

BioZone students, personnel and PIs organize and participate in a large variety of research-related events, volunteer activities and social outings. In addition to regular meetings among individual research groups, the events listed below highlight some of the activities that BioZone has taken part in to foster the exchange of ideas.

Research & Training

BioZone Summer and Fall Research Symposia

The 2017 Annual BioZone Summer and Fall Research Symposia, organized by the BioZone Leadership Council, was held on March 31 and November 10, 2017 respectively. The Spring symposium in 2018 was held on May 14, 2018. BioZone students displayed their work in 15-minute, 3-minute, and poster presentations to over 60 attendees. To conclude the day, prizes were awarded as follows:

The Summer 2017 Winners were:

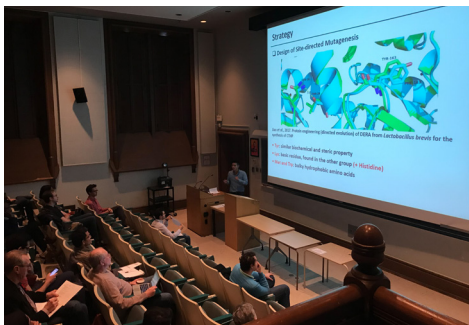
Best 15-Minute Presentation: Richard Ndubuisi
Best 3-Minute Presentation: Mitchell Zak
Best Poster Presentation: Christian Euler

The Fall 2017 Winners were:

Best 15-Minute Presentation: Naveen Venayak
Best 3-Minute Presentation: KiKi Chan

The Spring 2018 Winners were:

Best 20-Minute Presentation: Luz Puentes
Best 3-Minute Presentation Alessandra Biz
Best Poster Presentation: Christine Romano



iGEM Toronto

BioZone continues to support undergraduate researchers through providing research space to the University of Toronto's 2017 and 2018 iGEM team "iGEM Toronto." iGEM's (International Genetically Engineered Machine Foundation) mission is to promote the advancement of synthetic biology, and the development of an open community and collaboration. The iGEM Toronto team consists of undergraduate students who are working on a summer project that will be entered into the iGEM Jamboree in October at Massachusetts Institute of Technology of Technology. In 2018 the iGEM team won a silver medal in the overall competition.

In 2018 the team's project focused on demonstrating flotation of Escherichia coli using gas vesicle proteins (GvPs) as a novel cellular separation technique for bioremediation processes. Current techniques used in different industries, such as mining and municipal wastewater treatment, are mechanical, harmful to the environment and expensive. iGEM proposed that the system will be a more cost-effective separation technique for various bioremediation processes.

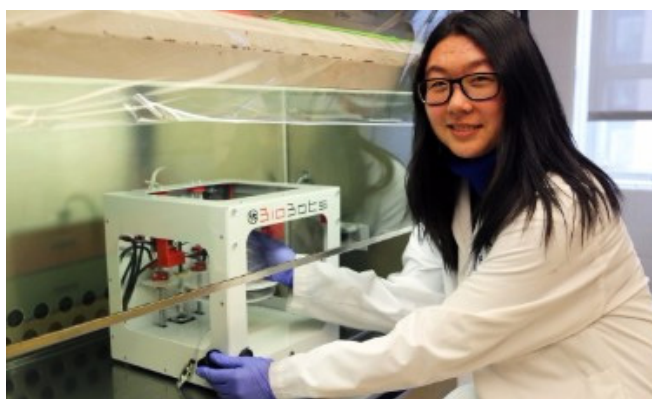


BioZone students at UnERD 2018

BioZone summer students Henry Wu and Erica Wang from Professor Grant Allen's lab and Ge Lan Wang from Prof. Levente Diosady's lab presented posters at the Undergraduate Research Day (UnERD). This annual one-day research conference held at the University of Toronto is hosted by students from the Faculty of Applied Science & Engineering and gives summer research-students the opportunity to share their research achievements in an academic showcase.

High School Student designed a process to create 3D tumors.

University of Toronto Schools high school student Jody Mou designed a device to print 3D tumor models while she was volunteering in Professor Alison McGuigans Lab. Mou won a regional biotech science fair for her work at BioZone and then even got the chance to present her project at the Sanofi Biogenius Canada finals in Ottawa.



BioZone Recognition Awards

Each year, BioZone recognizes the students, research associates, technicians, faculty, and staff that have made an outstanding contribution to the BioZone community. These awards are voted on by all BioZone members.

The 2016 recognition awards were presented to:

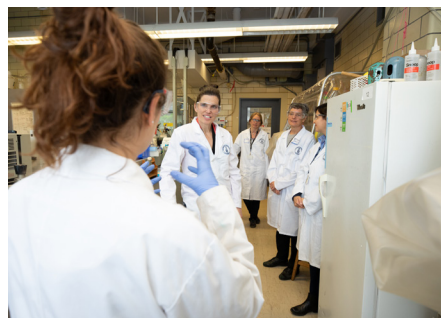
Mabel Wong for Community Service
Kayla Nemr for Technical Excellence
The BioZone Mass Spectrometry team (Andrei Starostine and Robert Flick) for Technical Excellence

The 2017 recognition awards were presented to:

Nadia Morson for Community Service
Line Lomheim for Technical Excellence
Sean Caffrey for Innovation

Outreach & Media

Federal Science Minister Kirsty Duncan visits BioZone



Federal Science Minister Kirsty Duncan visited BioZone on June 5, 2018 and had a tour Prof. Elizabeth Edward's Lab.

Science Rendezvous

Science Rendezvous is a free science street festival celebrating science and engineering. The event aims to bring interactive science to children and the general public. BioZone students take part in the Science Rendezvous every year. The 11th and 12th Annual Science Rendezvous events were held on May 13th 2017 and May 12th 2018 respectively. In both events, BioZone, PAPTAC (Pulp and Paper Technical Association of Canada) and chemical engineer volunteers ran a booth where children made paper from pulp.



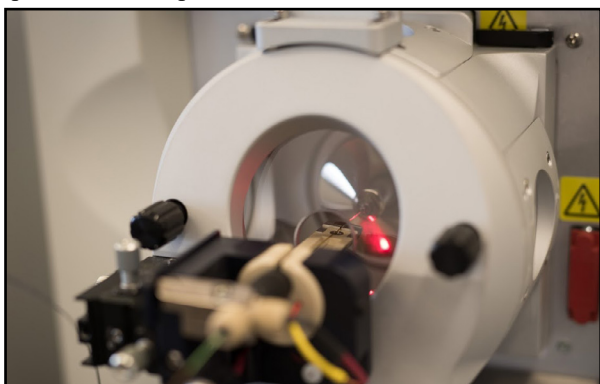
BioZone Mass Spectrometry Facility User meeting

On October 23, 2017, the BioZone Mass Spectrometry Facility held the annual Mass Spec Facility user meeting house to showcase the available services from the lab. The Mass Spectrometry Facility demonstrated their diversity in analytical techniques from proteomics, metabolomics, to small molecule analysis, as well as method development services and expert advice on these techniques.

The purpose of this event was to promote discussion on the potential uses of mass spectrometry in order to solve complex research questions and to promote the development of novel and relevant mass spectrometry protocols.

Topics discussed at the user meeting house included:

- New developments in mass spectrometry-based proteomics, small molecule analysis and metabolomics;
- How mass spectrometry can support research and product development;
- The types of analysis supported at the BioZone Mass Spectrometry Facility;
- Starting material requirements, sample preparation, and protocol development.



BioZone Research in the Media

Several BioZone researchers and their work were featured in local and national media outlets and publications since 2013:

- *"Interview with Professor Levente Diosady"*, with Levente Diosady, Here and Now Toronto, June 1, 2018.
- *"Don't be scared to collaborate"*, with Emma Master, research2reality.com, November 14, 2017.
- *"Lord of the Ring"*, with Elizabeth Edwards, The Chemical Institute of Canada, Summer 2017.
- *"Iron-rich salt — developed at U of T — is combating India's anemia epidemic"*, with Levente Diosady, CBC news, February 18, 2017.
- *"The invisible clean-up crew: Engineering microbial cultures to destroy pollutants"*, with Elizabeth Edwards, U of T Engineering News, February 17, 2017.

Exchanges

In addition to hosting a number of guest speakers throughout the year, visiting scholars Professor Savia Gavazza from the International Exchanges

As in previous years, we continued to build on the many domestic and international collaborations previously established by our researchers. BioZone hosted a number of international visitors and collaborators including:

- M.Eng student from University of Edinburgh (Scotland)
- Ph.D. student from Indian Institute of Technology (India)
- Professor from Federal University of Pernambuco (Brazil)
- Professor from Federal University of Minas Gerais (Brazil)
- M.Sc. student from Loughborough University (UK)
- M.Sc student from Wageningen University (Netherlands)
- Professor from Université des Antilles (Guadeloupe)
- Professor from Life Science & Environment Research Institute (Saudi Arabia)
- Professor from Rutgers (USA)
- Postdoctoral research fellow University of Manchester (UK)
- Professor from Ecole Polytechnique Federale De Lausanne (Switzerland)
- Professor from University of Helsinki (Finland)
- Ph.D. student from University of Tartu (Estonia)
- M.Sc. student from University of French West Indies (Guadeloupe)
- M.Sc student from AgroSup Dijon (France)

During this time, BioZone sent:

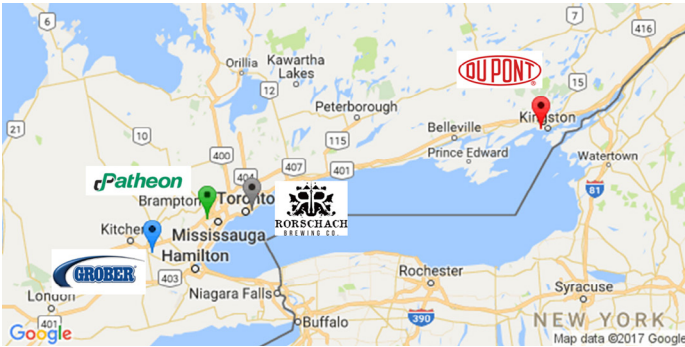
- Professor Emma Master to Finland as a part of her research grant from the European Research Council

Industry Tours

Through the many reserach projects leads, BioZone researchers and students have the opportunity to participate in site visits to industrial operations and gain hands-on experinece.

NSERC Industrial Biocatalysis Network Technology Tours

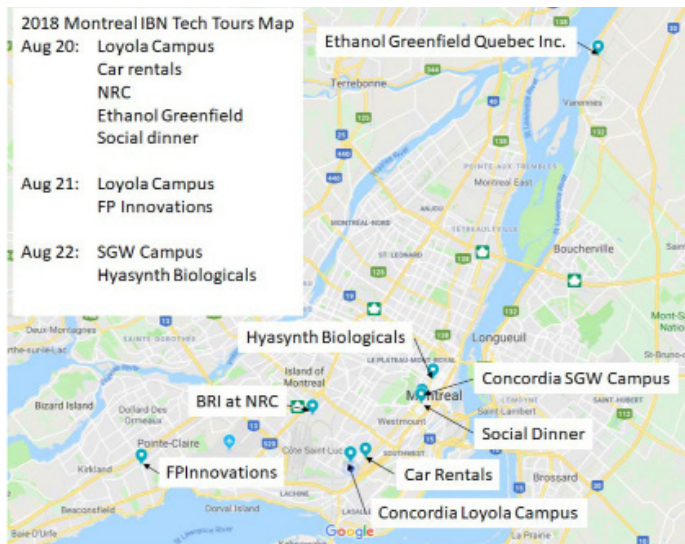
In 2017 HQP (highly qualified personnel) from the Industrial Biocatalysis Network toured companies in Southern Ontario including DuPont Canada Co, Rorschach Brewing Co, Grober Nutrition, and Patheon.



MRIS ORF-RE Elements of Biomining Mine Visits

In 2017 HQP participating in the ORF-RE Elements of Biomining project visited mine sites in Ontario's Sudbury region. These included Glencore and Vale.

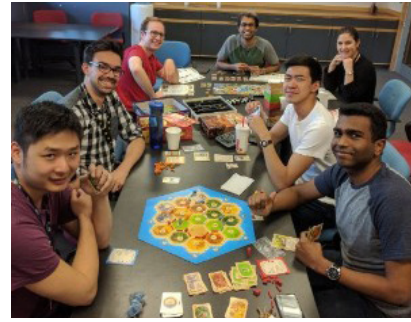
In 2018 HQP from the Industrial Biocatalysis Network visited companies in Quebec. These companies included Greenfeild Global, FPIinnovations, hyasynth.



Social & Team Events

BioZone Fall Retreat 2017

The BioZone Fall Trip took place on September 30, 2017 at the Hamilton Falls. The retreat covered a 6.2 km King's Forest Walk and the beautiful Albion Falls. This was followed by an impromptu stop at the Stoney Creek Apple Festival, where everyone got to try some delicious apple cider. The day ended with food and drinks, followed by some shuffleboard at the Pogue Mahone's.



BioZone Summer Social 2018

The BioZone student council organized a trip to Wonderland for the 2018 BioZone Summer Social.

Holiday Party

The annual potluck holiday party on Friday December 8th, 2017 was once again a smashing success. Students organized a fantastic spread along with plenty of fun and games, with a costume contest and a trivia game. One of the highlights of the night was a special performance by BioZone students Scott Proulx and Spencer Imbrugno who performed a special rendition of 12 years of Grad School.

The BioZone Fall Retreat 2018

The annual BioZone Fall Retreat was held on Saturday, October 13th 2018. The fall colours were on full display as the students went on a lovely walk through Rouge Valley Park. The hike was followed by a lunch and a beautiful stroll along Lake Ontario. Afterwards, the group ended up having food and drinks at Pogue Mahone's for the traditional post-retreat pub night. Everyone had a wonderful time, and eagerly awaiting next year's retreat!



BioZone Games Night

The BioZone student council organized a fun night with board games on site. Many popular board games were brought in for a competitive games night.

Tea Time

Every Tuesday at 3pm, students, post-docs, staff and professors gather for tea and cookies at this popular event that fosters friendship, collaboration and discussion among BioZone's many researchers and labs. Ten to twenty BioZone members regularly attend the weekly event, and we have more in attendance when there are special farewells saying good bye to our BioZone members!



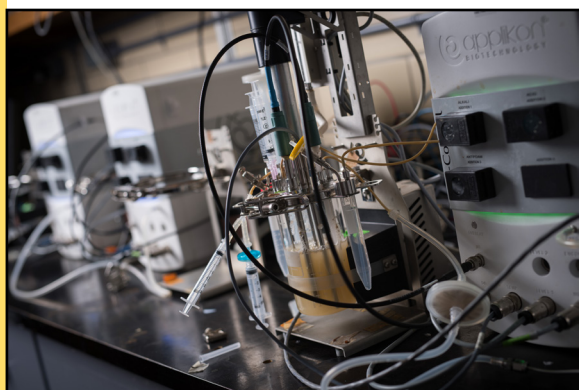
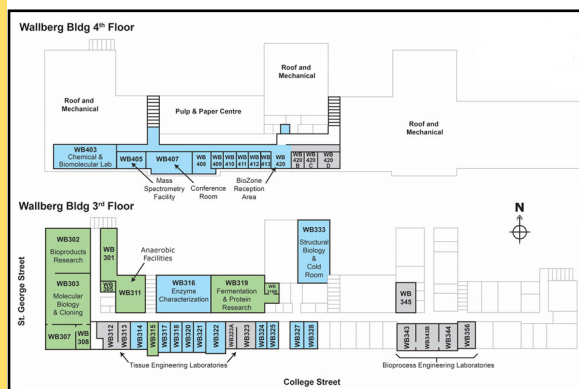
State-of-the-Art Facilities

BioZone's facilities provide a collaborative space and cross-disciplinary approach that enable researchers and industry to share knowledge, procedures and equipment as they tackle difficult technical problems in environment, energy and health.

Facilities are located in the Wallberg Building at the University of Toronto and provide over 1,800 m² of laboratory and research workspace, including several large, bright, collaborative research labs.

The labs house a wide array of state-of-the-art analytical instruments for molecular biology, protein purification and identification, enzyme kinetics, substrate and metabolite analysis, microscopy and cell growth.

The diversity of research within BioZone provides exposure to a wide range of expertise and analyses that can be useful for any given project, arming students and researchers with a broad array of state-of-the-art equipment to tackle complex problems.



Highlighted on the following pages are four of our state-of-the-art facilities with specialized capabilities focusing on:

- **Mass Spectrometry**
- **Biomanufacturing**
- **Microscopy**
- **Protein Crystallization**

For more information on the other equipment and facilities available at BioZone, please visit <https://www.biozone.utoronto.ca/feature-equipment/>

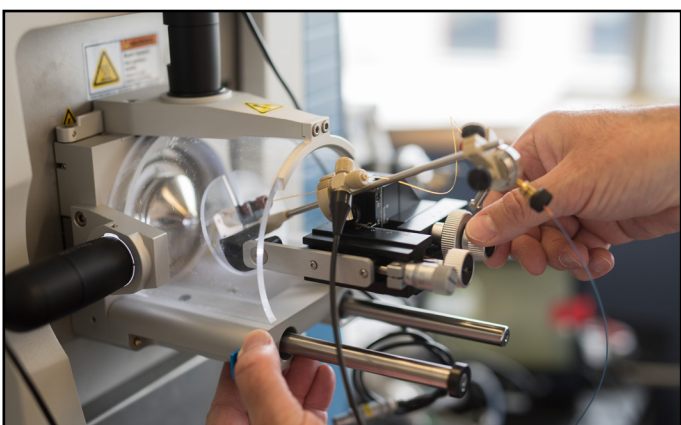
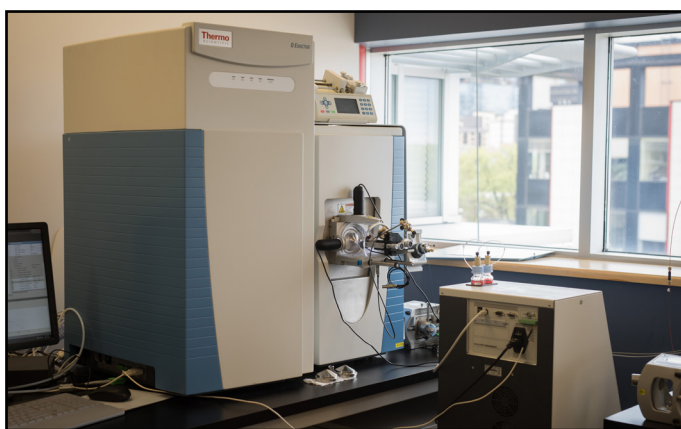
Mass Spectrometry

BioZone's Mass Spectrometry Facility (BioZone-MSF) operates as an analytical instrument facility serving both academic researchers and industrial clients. While the BioZone-MSF operates on a cost-recovery model, the mission of the facility is the development and implementation of novel mass spectrometry protocols for complex and difficult-to-measure samples.

This mission differentiates the BioZone-MSF from most commercial MS facilities which provide limited services based on established experimental platforms. Additionally, the BioZone-MSF places particular focus on expanding the knowledge and understanding of mass spectrometry users through education and student training.

Since 2014, the BioZone-MSF has supported over 39 research groups from the University of Toronto, 5 research groups outside the University of Toronto, 12 companies and analyzed over 10,000 samples.

The facility is operated by Facility Manager Andrei Starostine and Metabolomics Specialist Robert Flick.



Services offered by the BioZone-MSF include:

Small Molecule Analysis

- Accurate mass determination and/or quantification of analytes in a given sample. Samples are analyzed, identified, and validated through comparison to chemical standards. Examples include but are not limited to drug compounds, amino acids, vitamins, and short biopolymers.

Metabolomics

- Measurement of unique “chemical fingerprint(s)” resulting from cellular processes in an organism. By observing changes in this fingerprint as a result of cellular perturbations (deletion, insertion, mutation, external stress), we can gain a better understanding of an organism's biological mechanisms and associated phenotypes.

Proteomics

- The large-scale study of proteins produced in a given organism or cellular system. By monitoring changes in expression, co-translational and post-translational modifications, and interactions, we can gain a better understanding of an organism's cellular processes. Employing a “bottom-up” approach, we can identify and validate protein identity following proteolytic cleavage.

Sample Preparation

- To facilitate analysis, samples must be prepared in a manner suitable for mass spectrometry-based detection. Consultation and/or on-site preparation with regards to sample extraction and preparation is offered. This may involve growth and isolation of cells, quenching of cellular processes, analyte extraction and processing for mass spectrometry analysis.

Method Development

- Due to the variety of analytes that can be observed through mass spectrometry, specialized extraction, separation, and detection methods may be required. Our facility offers the development of custom methods to meet client requirements following consultation.

Instrumentation in the BioZone-MSF includes:

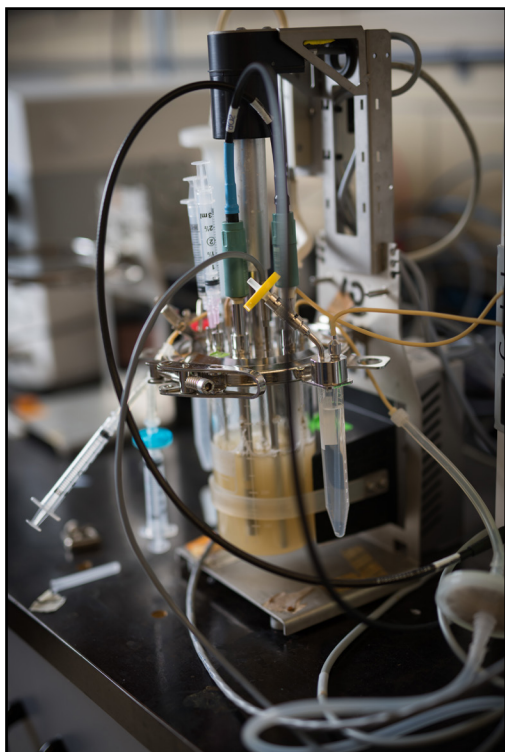
- Thermo Q-Exactive LC/MS - Hybrid Quadrupole-Orbitrap™ mass spectrometer
- Thermo Exactive LC/MS - Orbitrap™ mass spectrometer
- TOFWERK IMS-TOF- Ion mobility spectrometer (DTIMS) coupled to a high-speed time-of-flight mass spectrometer
- Thermo LTQ-XL LC/MS- Linear trap Quadrupole mass spectrometer
- Varian Saturn 2100T GC/MS- Electron Ionization equipped mass spectrometer

BioManufacturing

BioManufacturing, or the production of chemicals and materials using microbial fermentation, is playing an increasingly important role in the chemical and manufacturing industry. BioZone's ability to engineer and model biological systems opens avenues to produce novel and non-natural products. In doing so, BioZone embodies scale-up at an early stage, helping to ensure target strains will be commercially viable. BioZone is making further investments in bioManufacturing capacity to facilitate fee-for-service use by academic and industrial collaborators.

BioZone has a unique set of skills and tools for assessment of bioManufacturing processes from the microliter to 100L scale. Our liquid handling robotic and integrated plate reader platform allows us to perform high-throughput screening of up to hundreds of samples per day. This enables the assessment of a large number of variables from process conditions to medium composition, using appropriate experimental designs and response surface methodology.

Scaling-up, we have six 500mL bioreactors, fully equipped with mass flow controllers, pH probes and sensitive DO probes to enable precise control. From here, strains can be scaled to one of three 5L Infors bioreactors, or moved directly to 80L scale.



In addition to production vessels, we are fully equipped with state-of-the-art analytics, both offline and online. Our PrimaDB mass spectrometer allows on-line monitoring of CO₂, O₂ and volatiles such as ethanol – giving us unique insight into our process. Off-line measurements are typically performed using either HPLC or LC-MS, to give us a full range of analytical capabilities.

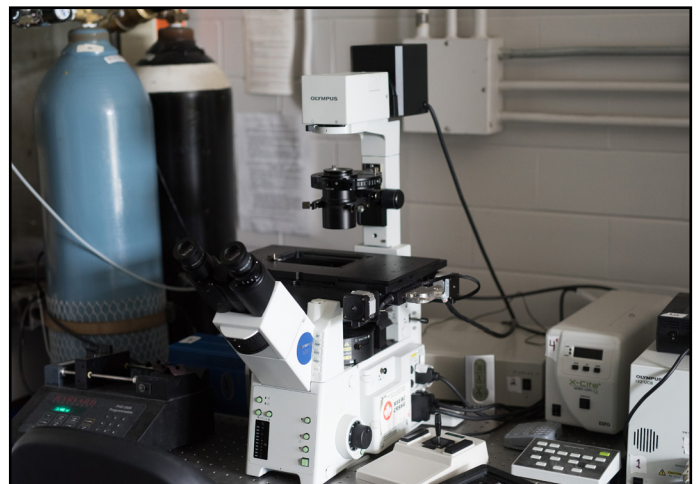
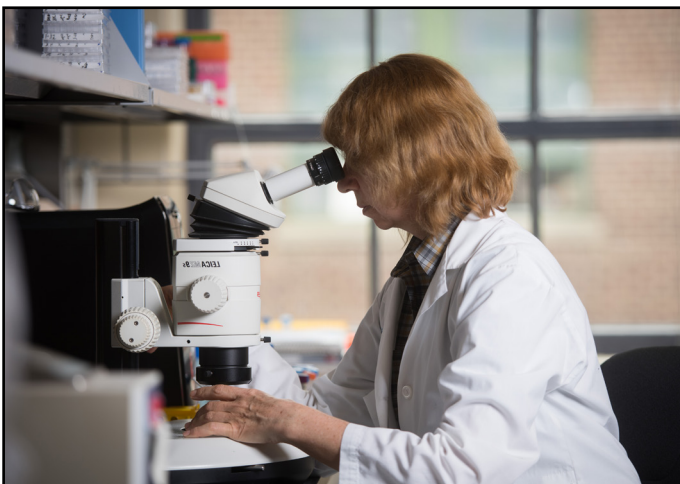
The bioreactor and analytical equipment, combined with the expertise available at BioZone in synthetic biology, metabolic engineering, and genome-scale modeling gives us a strong advantage in development and scale-up of organisms and processes for bioManufacturing. The facility is operated by Nancy Bawa.

Microscopy

BioZone houses both upright and inverted microscopes that can take bright field and fluorescence images. The automated microscope also has a stage top incubator to allow imaging of cells during cell culture at 37°C for up to 5 days. Furthermore, the automated microscope has a fully motorized stage allowing image stitching of images from adjacent fields of view. Microscopes are equipped with 4X, 10X, 20X, 40X, 63X and 100X lenses. In addition, the *ImageXpress Micro* is a high content screening microscope with environmental control. Images can be automatically collected in multiple locations within multiple wells of a well plate over time under conditions that allow cells to culture. The microscope models we currently carry in BioZone include:

- Olympus CKX1 live cell inverted microscope
- Olympus 120Q live cell inverted microscope
- Olympus BX51 microscope
- Leitz Laborlux S microscope
- Molecular Devices ImageXpress Micro Widefield High Content Screening System

Examples of current projects in BioZone that utilize the microscope facilities include: quantifying the alignment response of airway epithelial cells cultured on substrates containing guidance signals, characterizing the cooperative behaviour of epithelial cells re-organizing in confluent 2D monolayer sheets, assessing cellular invasion of cancer cells into surrounding stromal tissues in 3D, and real-time monitoring of engineered tumor growth in response to drug treatments.

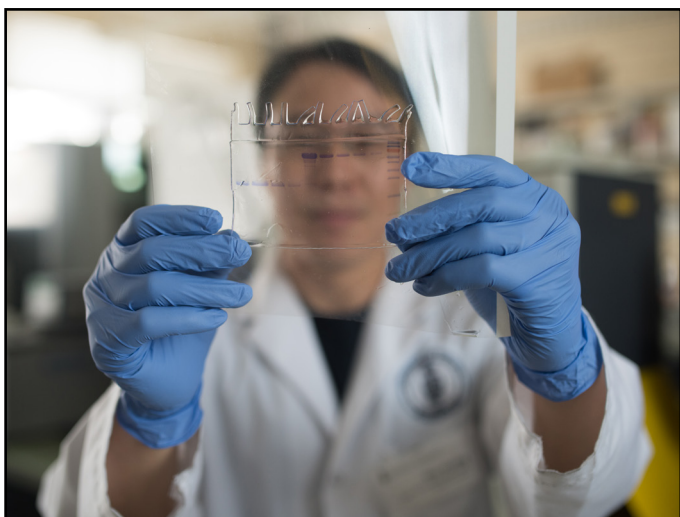


Protein Production, Screening & Crystallization

The BioZone Protein Production and Crystallization Facility specializes in:

- cloning
- protein production
- protein purification
- enzyme functional characterization
- protein 3D structural characterization

These services allow users to: assign function to genes, determine the molecular basis for substrate recognition, identify the roles of sequence motifs in enzyme function, determine how to inhibit enzyme function, and tailor the properties (i.e., specificity, stability, catalytic rate) of enzymes.



The Facility houses:

- protein purification and crystallization equipment
- chromatography/FPLC systems
- Mosquito crystallization robot
- specialized crystallization reagent screens
- Rigaku Micromax-007 x-ray diffractometer system

In addition to advanced instrumentation, the facility houses thousands of cloned genes and characterized enzymes and a highly experienced, specialized, and collaborative team with 40+ years of collective experience in molecular structure determination and interpretation.

The facility is managed by Dr. Peter Stogios.

BioZone Staff and Students

BioZone's strength resides in its people. We are home to a talented group of over 100 highly qualified personnel and trainees who bring a wide range of expertise and experience to their work, and tackle challenging research goals in a supportive and collegial community.

The following pages include profiles of BioZone members:

BioZone students and Research Staff: **Page 34**

Research Support Staff: **Page 35**

Undergraduate Experience: **Page 37**

Alumni: **Page 38**



BioZone Researchers and Students

BioZone has grown over the years to attract the best and brightest researchers from around the world. The following includes a list of graduate students, post-doctoral research fellows, research associates and laboratory technicians who were at BioZone between August 31, 2016 and September 1, 2018.

M.Sc. Students

Teresa Dean
Fakhria Muhammad Razeq
Hajar Pourbafrani
Viive Sarv

M.A.Sc. Students

Raphael Arakelian
Yee Kei (Kiki) Chan
Ruhi Choudhary
Patrick Diep
Spencer Imbrogno
Parnian Jadidian
Suzana Kraus
Rachel Kwan
Elisse Magnuson
Orysia Meouch
Roman Malekzai
Richard Ndubuisi
Lais Pereira
Chris Shyi
Benjamin Slater
Kimberly Tok
Nila Wu
Johnny Xiao
Jaehoon Ya
Tian Ai (Alice) Zhu

M.Eng. Students

Nikoo Abtahi
Jahul Juneja
Kaustubh Kadam
Awais Khan
Graham Mantay
Corina Ramirez
Avinash Shankar Ram

Ph.D. Students

Maryam Arefmanesh
Amir Arellano Saab
Sofia Bonilla
Jose Cadavid Cardenas
Xu (Charlie) Chen
Zahra Choolaei
Ileana Co
Kevin Correia
Elisa D'Arcangelo
Christian Euler
Amir Reza Meysami Fard
Julie-Anne Gandier
Hamed Ghazisaidi
Dafni Ginnari
Adriana Gomez
Nigel Guilford
Sadaf Kalhour

Ph.D. Students

Masood Khaksar Toroghi
TaeHo Kim
Natalie Landon-Brace
Sofia Lemak
Sergio Andres Luna Nino
Elisa McGee
Oluwasegun Modupe
Olivia Molenda
Nadia Morson
Kayla Nemr
Mehdi Nouraei
Jon Obnamia
Kylie O'Donnell
Ade Oyewole
Aditya Vik Pandit
Michail Paraskevopoulos
James Poon
Scott Proulx
Luz Puentes Jacome
Darren Rodenhizer
Fawzi Salama
Anupama Sharan
Kavya Siddartha
John Soleas
Shyam Srinivasan
Sheida Stephens

Ph.D. Students

Dylan Valleau
Azadeh Vatandoust
Naveen Venayak
Kaushik Raj Venkatesan
Po-Hsiang (Tommy)
Wang
Ruoan Wang
Mabel Wong
Ruoyu Yan
Mitchell Zak

Postdoctoral Fellows

Alessandra Biz
Chao Chen
Zinaida Eltsova
Tatiana Fedorchuk
Temesgen Fitamo
Mahbod Hajighasemi
Yaser Khojasteh-Salkuyeh
Batyrova Khorcheska
Kiruba Krishnaswamy
Yilan Liu
Fei Luo
Sedric Pankras
Anubhav Pratap Singh
Olanrewaju Raji

Postdoctoral Fellows

Courtney Toth
Andrew Quaile
Juveria Siddiqui
Caroline Vanderghem
Thu Vuong
Ivy (Minqing) Yang
Dan Zeng

Research Associates

Yaldah Azimi
Bih-King Chen
Maryam Foumani
Anna Khusnutdinova
Torsten Meyer
Christine Romano
Peter Stogios
Weijun Wang

Technical & Research

Staff

Nancy Bawa
Greg Brown
Jinjin Chen
Pei Lin Chu

Technical & Research

Staff Cont.

Rosa Di Leo
Elena Evdokimova
Robert Flick
Andrew Jo
Shen Guo
HyunWoo (Peter) Lee
Line Lomheim
Benjamin Pichette
Ben MacCormick
Travis Oakes
Tatiana Skarina
Andrei Starostine
Bella Xu

Research Support

The research undertaken by BioZone researchers could not be accomplished without the support of administrative and technical staff. All members of our support staff have a background in science and engineering which helps in meeting the needs of a large, collaborative research group.



Dr. Sean Caffrey
Executive Director

Sean provides oversight for BioZone administrative and technical staff, ensures effective and sustainable operations, acquires funding support, maintains external stakeholder relations (partner building), and helps students and staff translate research discoveries. Sean obtained an MBA and a Ph.D. in Microbial Functionality Genomics from the University of Calgary.



Endang Susilawati
Lab Manager

Susie is an experienced researcher who joined BioZone in 2009, bringing a wealth of technical experience to the task of managing lab operations. She holds an M.Sc. in Crop and Soil Sciences from Michigan State University and was a researcher at the Indonesian Oil Palm Research Institute. Susie manages daily lab activities in BioZone and provides students and researchers with information regarding safety, training, supplies and ordering. She is responsible for the maintenance of shared equipment and student lab duties.



Tedd Konya
Project Manager

Tedd provides project management support for several of the large applications on-going at BioZone. Tedd comes to BioZone from the Dalla Lana School of Public Health, where he managed a lab in the Division of Occupational & Environmental Health. Tedd holds a B.S. in Biology (Fairleigh Dickinson University), Master of Arts in Teaching (University of Pittsburgh), Master of Public Health (UofT), and most recently completed a Certificate in Project Management (UofT).

Dean Robson
Information Technology Specialist

Dean manages BioZone's server and network infrastructure and provides IT support to BioZone's faculty, researchers, and staff. In addition to his responsibilities with BioZone, Dean also provides IT support to the Department of Chemical Engineering and Applied Chemistry. Dean has a B.Sc. from Lakehead University in Computer Science and previously worked at the University of Toronto in the Faculty of Arts & Science, IIT.



Andrei Starostine
Mass Spectrometry Facility Manager

Andrei provides technical support and expertise for the application of mass spectrometry to a wide range of biological and inorganic analyses, including high resolution protein identification and small molecules characterization. He has developed experimental methods for chromatographic separation of protein complexes and for organic low molecular structural determination. Andrei is responsible for managing the MS Facility and training students and researchers on the use of LC and GC-MS techniques in chemistry and biology.



Robert Flick
Mass Spectrometry Facility Metabolomics Specialist

Robert provides experimental and analytical support for the application of mass spectrometry ranging from high resolution protein identification to small molecule characterization and metabolomics. He has developed a variety of experimental methods for chromatographic separation and subsequent mass spectrometry-based detection in order to further the scientific research being conducted in BioZone. He operates under the BioZone Mass Spectrometry Facility providing services to researchers both affiliated and not affiliated with the University of Toronto. Robert obtained an M.Sc. in Biochemistry from the University of Toronto.



Vinithya Paramananthasivan
Research Grant & Project Administrator

Vinithya assists with the administration of various grants and projects within Biozone. She holds a Masters's degree in Biological Sciences from the University of Auckland and has previous experience as a Research Administrator at Mount Sinai Hospital and the University of Toronto.



The Undergraduate Experience

An important component of BioZone's mission includes the training and education of undergraduate researchers. Here is what a few of our current undergrads are saying about their time in BioZone:

"I have to say that working at BioZone as a summer student was one of the best experiences during my time at the University. The people that I have met are very friendly, intelligent and responsible. Also the tea-times on Tuesdays are always delightful, those are wonderful times to get to know everyone and get to feel the tightly-knit community of BioZone. There were also a lot of opportunities for me to learn things that I would not have learned from my program. Overall, it was a very pleasant experience and I will always be proud to have been a part of it."

- Jim Bao, Summer Student



"Having completed an eight month work term in the Savchenko Laboratory within BioZone, I have developed valuable skills, both technical and transferable. The opportunity to contribute to protein purification and crystallization has been an incredible one and with each round of the procedure that I completed, I gained confidence in my ability as a scientist. As an undergraduate student, it can be a bit intimidating to work independently alongside skilled technicians who have been honing their abilities for years but I always felt welcome to ask questions about the procedures I was completing and was very grateful for this atmosphere of open communication. I feel that my experience at BioZone will help me succeed as I approach graduation and begin to think about my future education and career plans."

- Nathalie Mesa, Co-op Student



Alumni Updates

BioZone alumni are involved in exciting endeavours around the world. We are very pleased to be able to include a few updates about their current activities.

Sofia Bonilla, *Postdoctoral Fellow, 2018*

I had a great time in BioZone doing my PhD in the Allen lab. I have great memories of the 7 years I spent in BioZone and all the things I learned while there. Look forward to visiting soon! Now I live in the Netherlands and work as a Postdoctoral Research Fellow in the Bioprocess Engineering group at Wageningen University. My current research efforts are towards advancing multiproduct microalgal biorefineries. The methods currently used for cell disruption are successful at breaking cells but the valuable compounds are virtually impossible to recover because they are part of an emulsion and/or their valuable properties are lost in the process. The aim of my project is to develop enzyme-based processes to disrupt/weaken algal cell walls and facilitate the mild and controlled extraction of valuable products. On a personal note, we are expecting a new addition to the family in June 2019.

Mahbod Hajighasemi, *Postdoctoral Fellow, 2018*

Since leaving BioZone on September 2018, I've been working as a Scientist at Sanofi Pasteur, the vaccine division of Sanofi. I'm mostly engaged in metabolite analysis and fermentation of *Bordetella pertussis*, the causative agent of whooping cough, using flow cytometric assessments, confocal microscopy, Raman and NIR spectroscopy, BioProfile analysis and immunoassays. Our main objectives are to reduce the process variability (upstream and downstream) and to improve the production yield of bacterial antigens which serve as acellular pertussis vaccine once purified. My son Alborz is turning 1 year old soon; his mom and I are just wondering where all that energy comes from!

Kart Kanger, *Visiting Researcher, 2017*

After an exciting and inspiring year as a visiting graduate student in Edwards' lab I returned to Estonia to continue my PhD studies at the University of Tartu. I am currently a 4th-year PhD student in Environmental Technology and my research is focused on antibiotic resistance genes in various biotechnological applications. The experiments conducted in BioZone are an important part of my thesis and I still remain in close contact with my BioZone supervisors and co-workers. I am grateful for the scientific experience and the lasting relationships gained in BioZone.

"PhD at the BioZone was a really great experience. It's not just that I had an excellent thesis supervisor. But I think the support I found really was unparalleled."

"BioZone is an excellent place to work because of the friendly work environment and supportive culture. Colleagues quickly feel like family and are always ready to step in and help solve your research challenges by drawing on their diverse range of experiences. "

"BioZone continues to produce top-tier work, helping to create the ideal environment for incoming science/engineering specialists."

"I have great memories of the 7 years I spent in BioZone and all the things I learned while there (BioZone)."

"I am grateful for the scientific experience and the lasting relationships gained in BioZone."

"I miss BioZone, the incredible researchers who know so much and are always willing to share, the super supportive staff that always work so hard to bring the best learning/research/community experience to each BioZone member, the lab, and so much more."

"The foundations for much of what I am doing were built upon opportunities for partnerships and access to resources afforded to me by the collaborative and collegial environment of BioZone. "

Suzana Kraus, *M.A.Sc.*, 2018

I finished my MASC with Dr. Elizabeth Edwards a couple of months ago and I really miss my friends and colleagues from BioZone! Being in the lab was always challenging, but the friends I made there really helped me through these two years. My master's project was in a field site in Brazil, and I was lucky enough to be able to continue working in the same project, but now as staff scientist in Geosyntec. It's been great to be in the other side of the project, but still being able to interact with the rest of the team. Remediation is a fascinating field!

Fei Luo, *Postdoctoral Fellow*, 2018

After receiving my PhD degree and Postdoc experience in BioZone, I started working as an environmental engineer consultant in EcoMetrix Incorporated in 2018. I help clients in resource and energy industries to find solutions to their environmental challenges by assembling technology tool kits that are tailored towards each client and project needs, and deliver effective solutions with both conventional and innovative technologies. I believe the experience in BioZone prepared me for the current position, where problem solving, fast learning, and communication skills are keys, in addition to technical background. I miss BioZone, the incredible researchers who know so much and are always willing to share, the super supportive staff that always work so hard to bring the best learning/research/community experience to each BioZone member, the lab, and so much more.

Ben MacCormick, *M.A.Sc.*, 2016

I completed my MASC in 2016 in Prof. Master's Lab, where I stayed for another year as a Research Assistant to continue my work on synthesizing novel biopolymers from plant-derived carbohydrates using a combination of enzymatic modifications and green chemistry techniques. Since leaving BioZone, I have moved home to the Annapolis Valley of Nova Scotia where I have started a hobby farm and am working as a Production Supervisor at BioVectra Inc. in Windsor, NS. BioVectra is a cGMP contract manufacturer of a variety of pharmaceuticals and molecular biology reagents, with the new facility in Windsor focusing on fermentation-based manufacturing of protein and small molecule drugs. To date, this position has focused largely on equipment and facility commissioning such as fine tuning of fermenter hardware and automation, qualification of downstream processing and purification equipment, and R+D trial production batches.

Aditya Pandit, *Ph.D.*, 2018

A PhD at the BioZone was a really great experience. It's not just that I had an excellent thesis supervisor. But I think the support I found really was unparalleled, both in terms of my colleagues but as well as the resources available. The equipment and other the technical resources allowed be to really work at the cutting edge of science. And the funding available made it possible for me to travel to several conferences, which is really important for any grad student. In the end, I was able to take what I did out of my PhD and with the help of the university, file some IP and spin that out into a company. Today, our company still works with BioZone and we find the experience very valuable. I really think all these benefits would not be possible in another Centre.

Fakhria Razek, *M.A.Sc.*, 2017

After completing my masters with Prof. Master, I moved to Ottawa where I started working at as a Senior Regulatory Affairs Officer at Health Canada. I am a part of a team that is responsible for maintaining Health Canada's Drug Product Database and applying regulatory requirements for the issuance of drug identification numbers.

Although I ended up far away from my research area, the transferable skills I have gained through my graduate studies in BioZone are invaluable for my current position. I'm glad to have had the experience working alongside amazing group of people. I wish the BioZone community continuous success in their scientific endeavours.

Darren Rodenhizer, *Ph.D.*, 2018

During my time in BioZone, I worked to develop tissue-engineered tumor models to help find better drugs for cancer. After graduating from BioZone in 2018, I co-founded a company to bring tissue-engineered products to market. Our company has been enrolled in the University of Toronto Early Stage Technology Program (2018 Cohort), and is currently part of the Creative Destruction Lab's Health Stream (Toronto) Program for 2018 - 2019. BioZone is an excellent place to work because of the friendly work environment and supportive culture. Colleagues quickly feel like family and are always ready to step in and help solve your research challenges by drawing on their diverse range of experiences.

Elisse Magnuson, *M.A.Sc.*, 2017

I thoroughly enjoyed my time in BioZone both personally and professionally. It is an outstanding environment for learning and collaborating. I completed my M.A.Sc. with Elizabeth Edwards in 2017 on the topic of benzene bioremediation. I am now a Ph.D. student at McGill University working on Arctic microbial ecology.

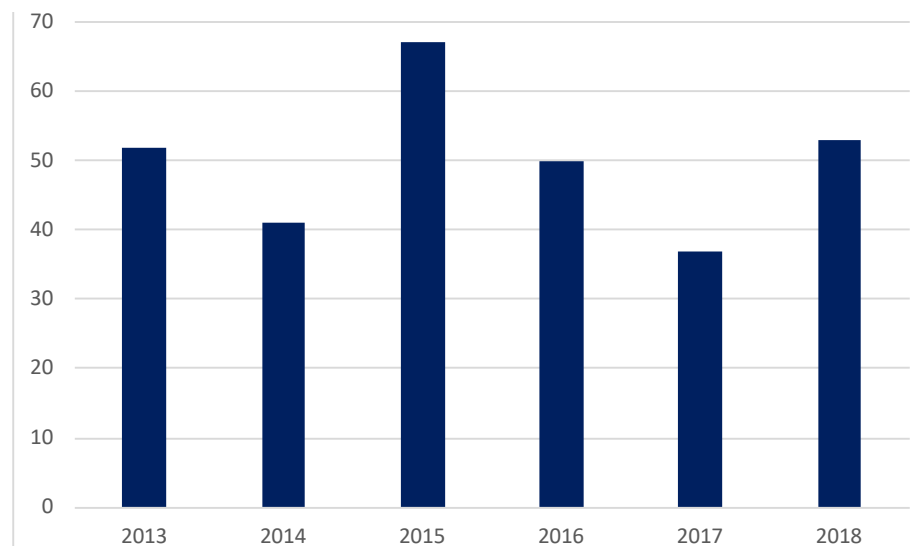
Chris Salmean, *Visiting Researcher*, 2018

Since finishing my work in Professor Allen's lab I have started a PhD in mechanical engineering in Professor QIU Huihe's lab at Hong Kong University of Science and Technology. My focus is on the enhancement of boiling phenomena through microscale surface modification, with the aim to apply these fundamentals to 3D-printed chemical and mechanical systems in the near future. I don't miss Toronto's winters but there are definitely many other aspects which I look back on fondly! I hope to return to Canada at some point so it's comforting that Biozone continues to produce top-tier work, helping to create the ideal environment for incoming science/engineering specialists.

Andy Quaile, *Postdoctoral Fellow*, 2018

As a research scientist for Nucro-Technics, I design, develop and validate bioanalytical mass spectrometry methods for our pharmaceutical industry clients. These methods are designed to detect and quantitate all kinds of small molecules, metabolites, peptides and proteins in an astoundingly broad range of chemical and biological matrices. Though my current role still allows me to continually learn and apply new knowledge and techniques to challenging problems, the foundations for much of what I am doing were built upon opportunities for partnerships and access to resources afforded to me by the collaborative and collegial environment of BioZone.

Publications



Number of journal articles and book chapters per year by BioZone research groups

The following publications were published during the September 2016 to August 2018 reporting period.

Refereed Articles

2016

Luo, F., Devine, C.E., Edwards, E.A. (2016). **Cultivating microbial dark matter in benzene-degrading methanogenic consortia.** *Environ Microbiol*, 18(9): 2923-36.

Xiao, Y., Reis, L.A., Feric, N., Knee, E.J., Gu, J., Cao, S., Laschinger, C., Londono, C., Antolovich, J., McGuigan, A.P., Radisic, M. (2016). **Diabetic wound regeneration using peptide-modified hydrogels to target re-epithelialization.** *Proc Natl Acad Sci U S A*, 113(40): E5792-E5801

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- Lucker, Petra. (2017). **Cardiac cell alignment and migration.** Ph.D., *Dept. of Chemical Engineering and Applied Chemistry*, University of Toronto.
- Magnuson, Elisse. (2017). **Characterization of the Microbial Community and Activity of Nitrate-Reducing, Benzene-Degrading Enrichment Cultures.** M.A.Sc., *Dept. of Chemical Engineering and Applied Chemistry*, University of Toronto.
- Malekzai, Roman. (2017). **Towards hydrophobin-mediated surface modification of lignocellulose fractions: characterization of class 1 hydrophobin interactions with cellulose and lignin and subsequent impact on *T. reesei* cellulose CBHI binding and activity.** M.A.Sc., *Dept. of Chemical Engineering and Applied Chemistry*, University of Toronto.
- McGee, Elisa. (2017). **Prevention of Iron-Polyphenol Complex Formation in Iron Fortified Tea.** Ph.D., *Dept. of Chemical Engineering and Applied Chemistry*, University of Toronto.
- Ndubuisi, Ugwuanyi Richard. (2017). **Catalytic Production of Liquid Hydrocarbons from the Decarboxylation of an Aqueous Emulsion of Canola Oil.** M.A.Sc., *Dept. of Chemical Engineering and Applied Chemistry*, University of Toronto.
- Pandit, Aditya. (2017). **Engineering *E. coli* for Electrically Enhanced Biochemicals Production.** Ph.D., *Dept. of Chemical Engineering and Applied Chemistry*, University of Toronto.
- Poon, James. (2017). **Engineering surface mechanical properties to organize engineered epithelium.** Ph.D., *Dept. of Chemical Engineering and Applied Chemistry*, University of Toronto.
- Ramirez, Corina. (2017). **Spirulina Production for Nutrition in the Phillipines.** M.Eng., *Dept. of Chemical Engineering and Applied Chemistry*, University of Toronto.
- Razeq, Fakhria. (2017). **Discovery and Biochemical Characterization of New CAZymes from PULs and Metagenomics Sequences. Design of Algal Film Photobioreactors for Algal Biomass Production.** M.A.Sc., *Dept. of Chemical Engineering and Applied Chemistry*, University of Toronto.
- Xiao, Johnny. (2017). **Developing a Clostridial Heterologous Expression Host and Producing a Prenylated Flavin Cofactor: Steps in Elucidating an Anaerobic Mechanism for Activating Benzene.** M.A.Sc., *Dept. of Chemical Engineering and Applied Chemistry*, University of Toronto.
- Ya, Jaehoon. (2017). **Electro-dewatering Treatment of Pul and Paper Mill Biosludge: The Effects of Conditioners.** M.A.Sc., *Dept. of Chemical Engineering and Applied Chemistry*, University of Toronto.
- Yan, Ruoyu. (2017). **Characterization of Novel GH115 glucuronidases for Enzymatic Tailoring of Xylans.** Ph.D., *Dept. of Chemical Engineering and Applied Chemistry*, University of Toronto.

Conference Invited Talks

Professor Elizabeth Edwards

Metagenomics of Microbial Dechlorinating Consortia, invited talk at the *Eawag Seminar Series*. Zurich, Switzerland. August 20, 2018

Metagenomics of Microbial Dechlorinating Consortia, invited talk at the *Canadian Society of Microbiologists*. Winnipeg, Manitoba. June 19, 2018.

Mining Anaerobic Microbial Communities and their Metagenomics, invited talk at the *Green Chemistry Initiative*. Toronto, Canada. May 24, 2018.

Metagenomics of Microbial Dechlorinating Consortia invited talk at *Genoscope*. Paris, France. November 16, 2017.

Open Science, invited talk at *The 9th Canadian Science Policy Conference*. Ottawa ON. November 3, 2017.

Metagenomics of Microbial Dechlorinating Consortia, invited talk at *Academia Sinica*. Taipei, Taiwan. October 26, 2017.

Cooperation in subsurface microbial communities, invited talk at *Zhejiang University*. Hangzhou, China. October 23, 2017.

Bioleaching of Nickel-Containing Waste Tailings, invited talk at *The 9th National Conference on Environmental Chemistry*. Zhejiang University. Hangzhou, China. October 20, 2017.

Cooperation in subsurface microbial communities - some examples, invited talk at *Nanjing University*. Nanjing, China. October 18, 2017.

Potential for bioremediation and detoxification of persistent halogenated compounds - beyond TCE, invited talk at *The 2nd Global Soil Biodiversity Conference*. Nanjing, China. October 16, 2017

Chlordecone and Hexachlorocyclohexane biodegradation – some updates, invited talk at *Geosyntec Consultants Research Day*. Guelph, Ontario. September 2017.

Anaerobic Benzene Biodegradation: Challenges and Opportunities, invited talk at *The University of Calgary*. Calgary, Alberta. June 22, 2017.

Anaerobic Benzene Degradation, invited talk at *The 6th International Symposium on Applied Microbiology and Molecular Biology in Oil systems*. San Diego, California. June 8, 2017.

Current studies in chlorinated compounds bioremediation, invited talk at the *Workshop and conference on Water reuse monitoring and treatment technologies*. Recife, Brazil. May 17th-19th, 2017.

NSERC CREATE (Magnet): Harnessing natural biogeochemical cycles for waste treatment: The Example of Anaerobic Digestion. April 6, 2017.

Anaerobic Benzene Degradation, invited talk at *The REM-TEC conference*. Denver, US. March 7-9, 2017.

Anaerobic benzene carboxylation, invited talk at *The Royal Society Kavli Meeting*. Milton Keynes, UK. December 15, 2016.

Looking inside microbial dechlorinating communities. November 17, 2016.

Harnessing natural biogeochemical cycles – Kick off to Biotechnology Week, invited talk at *The University of Waterloo*. Waterloo, Ontario. September 23, 2016.

Professor Radhakrishna Mahadevan

Synthetic Biology in Human Health, invited talk at the *First National Synthetic Biology Conference*. Toronto, Canada. March 6, 2018.

Design principles for control of metabolism: Role of redundancy and orthogonality, invited talk at the *ECI Conference on Biochemical and Molecular Engineering*. New Port Beach, United States of America. July 18, 2017.

Genome-scale Metabolic Modeling and Applications, invited talk at the *2017 Metabolomics Conference*. Brisbane, Australia. June 25-28, 2017.

Model-based Engineering of Metabolism, invited talk at the *Department of Microbiology, Latrobe University*. Bundoora, Australia. June 22, 2017.

Orthogonal Design of Metabolic Pathways, invited talk at the *International Conference on Biomolecular Engineering*. San Diego, United States of America. January 08-11, 2017. San Diego, USA.

Professor Emma Master

Biocatalytic Cascades to Diverse Hemicellulose Building Blocks, invited talk at the *Gordon Research Conference on Biocatalysis*. Biddeford, United States of America. July 8 - 13, 2018.

Enzymes for hemicellulose-derived building blocks and cross-linkers, keynote speaker talk at Hemicellulose Symposium. Stockholm, Sweden, April 17, 2018.

Surface analysis techniques to evaluate enzyme function on increasingly complex lignocellulosic materials, invited talk at the *Symposium on Plant Biomass Conversion by Fungi*. Utrecht, The Netherlands. August 28-29, 2017.

Polysaccharide utilization loci as sources of unique carbohydrate active enzymes, invited talk at the *5th International Conference on Novel Enzymes*. Groningen, The Netherlands, October 11-14, 2016.

Professor Alison McGuigan

Engineered cancer-stromal culture models to explore cancer associated fibroblasts and tumor cell interactions, invited talk at the *Gordon Research Conference (GRC) on Signal Transduction by Engineered Extracellular Matrices*. Andover, NH, USA. July 22-27, 2018.

Tissue engineered models for probing cell-cell communication during tissue morphogenesis, invited talk at the *BIRS workshop on Mathematical Approaches to Cell-Cell Communication and Collective Behaviours*. Banff, Alberta. July 8-13, 2017.

Tissue Engineered Tumor models for Exploring Cellular Phenotype in Heterogeneous Microenvironments, invited talk at the *Terry Fox Research Institute Ontario Node Annual Symposium*. Toronto, Ontario. December 4, 2017.

Engineered Tissue Platforms for Probing Fundamental Tissue Biology and Identifying Novel Therapeutics, invited Award presentation speaker at the *67th Canadian Chemical Engineering Conference*. Edmonton, Alberta. October 22-25, 2017.

Designing predictive in vitro tissue mimetic systems for drug discovery, invited talk at the *University of Michigan*. Ann Arbor, Michigan. Oct 5, 2017.

Engineered cancer-stromal interfaces to explore the impact of cancer associated fibroblasts on tumor cell phenotype, invited talk at the *Gordon Research Conference (GRC) on Tissue Repair and Regeneration*. New Hampshire, USA. June 4-9, 2017.

An engineered cancer-stromal culture model to explore the impact of cancer associated fibroblasts on tumor cell phenotype, invited talk at *Ontario-on-a-chip*. Toronto, Canada. May 25 -26, 2017.

An Engineered Tumor for Exploring Cellular Phenotype and Microenvironment in Hypoxic Gradients, invited talk at the *Engineered Cells and Tissues as Platforms for Discovery and Therapy Keystone Symposia*. Boston, USA. March 9-12, 2017.

An engineered tissue for exploring cellular phenotype and microenvironment in heterogeneous 3D culture, invited talk at *Till and McCulloch meeting*. Whistler, Canada. Oct 24-26, 2016.

An engineered tumour for exploring cellular phenotype and microenvironment in heterogeneous 3D culture, invited talk at *Frontiers in Translational Research: Ex-vivo Models of Human Disease Symposium*. Toronto, Canada. September 15-16, 2016.

Professor Alexei Savchenko

STRUCTURAL GENOMICS: visualizing bacterial proteins for functional characterization. The cases of good, bad and ugly, invited talk at the *University of Calgary, Center for Molecular Simulation*. Calgary, Canada. May, 2018.

The prokaryotic pathogen's toolkit to meddle with host ubiquitination, invited talk at Northwestern University, The Feinberg School of Medicine, Department of Microbiology-Immunology, Chicago, IL, USA. April, 2018.

Professor Alexander Yakunin

Biochemical studies of microbial UbiX prenyl transferases, invited talk at *The Royal Society Kavli meeting "Prenylated Flavin: Biochemistry and Application"*. Buckinghamshire, United Kingdom. December 12-14, 2016.

Enzyme discovery for functional annotation of unknown genes and industrial applications, invited talk at the *School of Biological Sciences, Bangor University*. Bangor, United Kingdom. February 28, 2018.

Partial list of Conference Presentations

Allen, D.G., Bonilla, S., Ghazisaidi, H., Meyer, T., Tran, H., Sei, Y., Ya, J. **Challenges and Opportunities for Processing Biosludge from Wastewater Treatment Systems in the Pulp and Paper Industry**, oral presentation at the *67th Canadian Chemical Engineering Conference*. Edmonton, Canada. October 28-31, 2017.

Azimi, Y., Agarwal, A., Aitchison, J.S., Allen, D.G. **The Impact of Waveguide Structural Properties on Enhancing Algal Biofilm Growth**, oral presentation at the *10th International Conference on Biofilm Reactors (IWA)*. Dublin, Ireland. May 9-12, 2017.

- Azimi, Y., Agarwal, A., Aitchison, J.S., Allen, D.G. **Photobioreactors Integrating Light-leaking Waveguides: The Role of Waveguide Geometry and Surface Texture on Light Distribution and Algal Biofilm Growth**, poster presentation at the *7th International Conference on Algal Biomass, Biofuels and Bioproducts*. Miami, United States of America. June 18-21, 2017.
- Chen, X., Howe, J.Y., Luo, F., Dogel, S. Edwards, E.A. **Correlative microscopy of benzene degrading culture under methanogenic condition - Visualization of microorganisms and their activity**, poster presentation at the *17th International Symposium on Microbial Ecology*. Leipzig, Germany. August 16, 2018.
- Choolaei, Z., Flick, R., Edwards, E.A., Yakunin, A.F. **Oxidative Activity of the Bacillus subtilis Laccase BSU0630 against Model Lignin Substrates and Polymeric Lignin**, poster presentation at the *NSERC Industrial Biocatalysis Network AGM*. Montreal, QC, Canada. May 30-31, 2018.
- D'Arcangelo, E., McGuigan, A.P. **Compartmentalized Hydrogels: A Phenotypic Assay for Characterizing Tumor-Stroma Interactions**, poster presentation at *Ontario on a Chip*. Toronto, Canada. May 25-26, 2017.
- D'Arcangelo, E., McGuigan, A.P. **Compartmentalized Hydrogels: A Phenotypic Assay for Characterizing**, poster presentation at *Frontiers in Translational Research: Ex-vivo Models of Human Disease*. Toronto, Canada. September 15-16, 2016.
- D'Arcangelo, E., Ailles, L., McGuigan, A.P. **The Use Of A Compartmentalized Hydrogel Assay To Characterize The Impact Of Activated Stroma On Tumor Cell Invasiveness**, poster presentation at the *EACR conference: Goodbye flat biology -In Vivo Inspired Cancer Biology and Therapy*. Berlin, Germany. September 9-12, 2018.
- Dean, T., McGuigan, A.P. **Validation of a HNSCC/CAF co-culture model of invasion in the TRACER platform**, poster presentation at *Frontiers in Translational Research: Ex-vivo Models of Human Disease*. Toronto, Canada. September 15-16, 2016.
- Euler, C.E., Mahadevan, R. **Design, construction, and characterization of an optogenetic toggle switch**, oral Presentation at the *Industrial Biocatalysis Network Annual General Meeting*. Toronto, Canada. May 30-31, 2017.
- Evans, G., Allen, D.G., Acosta, E., Bender, T., Cluett, W. **We Never Talk: Peer to Peer Observation and Formative Feedback as Steps to Evolving Academic Culture**, oral presentation at the *Canadian Engineering Education Conference*. Toronto, Canada. June 4-7, 2017.
- Guo, S., Luo, F., Toth, C.R.A., Bawa, N., Webb, J., Dworatzek, S., Chen, C., Guo, Y., Magnuson, E., Shyi, C., Xiao, J., Bradshaw, K., Edwards, E.A. **Microbial natural attenuation of ten anoxic benzene-contaminated sites attributed to enrichment of two key benzene degraders**, poster presentation at the *17th International Symposium on Microbial Ecology*. Leipzig, Germany. August 16, 2018.
- Hajjighasemi, M., Nocek, B., Popovic, A., Tchigvintsev, A., Brown, G., Flick, R., Zhu, X., Xu, X., Cui, H., Joachimiak, A., Savchenko, A., Edwards, E., Yakunin, A.F. **Enzymatic Depolymerisation of Biodegradable Polyesters by Microbial Carboxylesterases**, poster presentation at the *NSERC Industrial Biocatalysis Network AGM*. Toronto, ON, Canada. May 30-31, 2017.
- Imbrogno, S., Master, E.R. **Chemo-Enzymatic Upgrading of Hemicellulosic Oligosaccharides**, poster presentation at the *World Congress on Industrial Biotechnology*. Montreal, Canada. July 23-26, 2017.
- Inglis, A., Head, N., Chowdhury, A., Nunez Garcia, A., Gerhard, J., Hayman, J., Eimers, J., Reynolds, D., Hogberg, D., Auger, M., Austrins, L., Sidebottom, A., Edwards, E., Lomheim, L., Weber, K., Wallace, S., O'Carroll, D. **Electrokinetically-Emplaced Amendments for Enhanced Bioremediation of Chlorinated Solvents in Clay: A Pilot Field Test**, poster presentation at the *Eleventh International Conference on the Remediation of Chlorinated and Recalcitrant Compounds*. Palm Springs, USA. April 8-12, 2018.
- Kim, T., Flick, R., Brunzelle, J., Singer, A., Evdokimova, E., Brown, G., Chan Joo, J., Minasov, G.A., Anderson, W.F., Mahadevan, R., Savchenko, A., Yakunin, A.F. **Structural and biochemical studies of novel Aldo-keto Reductases (AKRs) for the biocatalytic conversion of 3-hydroxybutanal to 1,3-butanediol**, poster presentation at the *Biochemical and Molecular Engineering*. Newport Beach, United States of America. July 16-20, 2017.
- Klamt, S., Regensburger, G., Gerst, M.P, Jungreuthmayer, C., Schuster, S., Mahadevan, R. Zanghellini, J., Müller, S. **Elementary Flux Vectors: Closing the Gap between Elementary Flux Modes and Flux Balance Analysis in Metabolic Networks**, oral presentation at the *Metabolic Pathway Analysis Conference*. Bozeman, United States of America. July 24-28, 2017.
- Kraus, S., Lomheim, L., Li, A., Ding, A.J., Edwards, E., Henderson, J.K. **Evaluation of Potential Aerobic and Anaerobic Degradation of Chlorinated Anilines and Chlorinated Benzenes in a Complex Site in Latin America**, poster presentation at the *RemTEC Conference*. Denver, Colorado, USA. March 7-9, 2017.
- Kraus, S., Edwards, E.A. **Biodegradation of multiple organic compounds and associated microbial communities**, poster presentation, poster presentation at the *17th International Symposium on Microbial Ecology*. Leipzig, Germany. August 16, 2018.
- Kraus, S., Edwards, E.A., Lomheim, L. **Aerobic and Anaerobic Degradation Of Chlorinated Compounds in a Complex Site in Brazil**, oral presentation at the *RENEW Annual Meeting*. Kingston, ON, Canada. November 2, 2017.
- Lee, H., Guildford, G.H., Edwards, E.A. **The microbial community of a sequentially fed two state anaerobic digester treating solid organic waste mixed with food waste**, poster presentation at the *IWA World conference on Anaerobic digestion*. Beijing, China. Oct 17-20, 2017.

- Lomheim, L., Susilawati, E., Flick, R., Starostine, A., Rambinaising, S., Laquitaine, L., Gaspard, S., Edwards, E. **Evidence for Anaerobic Microbial Dechlorination of Chlordecone in Microcosms from Guadeloupe Soil**, poster presentation at the *17th International Symposium on Microbial Ecology*. Leipzig, Germany. August 16, 2018.
- Luo, F., Edwards, E.A. **Combining Treatability Studies and Molecular Tools to Provide Insights into Benzene Remediation in Groundwater Systems**, oral presentation at the *2nd Global Soil Biodiversity Conference*. Nanjing, China. October 16, 2017.
- Magnuson, E., Luo, F., Edwards, E.A. **Microbial Community Dynamics in Nitrate-reducing Benzene-degrading Cultures**, poster presentation at the *NSERC Industrial Biocatalysis Network AGM*. Toronto, ON, Canada. May 30-31, 2017.
- Mahadevan, R. **Engineering Fe Oxidizing Bacteria for Bioleaching**, oral presentation at the *Elements of Biomining Annual General Meeting*. Sudbury, Canada. August 2-3, 2017.
- Molenda, O., Tang, S., Lemak, S., Lomheim, L., Yakunin, A.F., Edwards, E.A. **Eight new Dehalococcoides mccartyi genomes and a snap shot of both beneficial and parasitic DNA exchange in the KB-1 consortium**, poster presentation at the *DehaloCon II – conference on anaerobic reductive dehalogenation* Leipzig, Germany. March 26 -29, 2017.
- Morson, N., Molenda, O., Richarson, R., Edwards, E. **Horizontal gene transfer in Dechlorinating cultures**, poster presentation at the *DehaloCon II conference on anaerobic reductive dehalogenation*. Leipzig, Germany. March 26-29, 2017.
- Pandit, A., Srinivasan, S., Mahadevan, R. **Orthogonal Pathway Design**, oral presentation at the *Industrial Biocatalysis Network Annual General Meeting*. Toronto, Canada. May 30-31, 2017.
- Proulx, S., Yakunin, A.F., Mahadevan, R. **Addressing the oxygen incompatibility of the muconic acid pathway**, poster presentation at the *20th Annual CSCHE Quebec Ontario Biotechnology Meetup*. Hamilton, Canada. May 17, 2018.
- Puentes Jácome, L. A., Edwards, E.A. **Enrichment of lindane - dehalogenating bacteria for enzyme discovery**, oral presentation at the *2nd Global Soil Biodiversity Conference*. Nanjing, China. October 16, 2017.
- Puentes Jácome, L.A., Qiao, W., Lomheim, L., Gaspard, S., Tang, X., Edwards, E.A. **Microbial reductive dechlorination of hexachlorocyclohexane isomers: progress and challenges**, oral presentation at the *RENEW Annual Meeting*. Kingston, ON, Canada. November 2, 2017.
- Quaile, A., Valteau, D., Stogios, P., Watanabe, N., Savchenko, A. **Unique bacterial protein folds evolved to manipulate host ubiquitination system**, oral presentation at the *Protein Structure, Function and Malfunction Meeting*. Saskatchewan, Canada. June 15-17, 2017.
- Raj, K., Khusnutdinova, A.N., Partow, S., Joo, J.C., Yakunin, A.F., Mahadevan, R. **Complete Biosynthesis of Adipic Acid in S. cerevisiae**, poster presentation at the *ECI Conference - Biochemical and Molecular Engineering*. Newport Beach, United States of America. July 16-20, 2017.
- Razeq, F., Master, E.R. **Production and characterization of a protein with unknown function from a polysaccharide utilization locus encoding xylan-active enzymes**, poster presentation at the *Gordon Research Conference. Cellulosomes, Cellulases and Other Carbohydrate Active Enzymes*. New Hampshire, USA. July 23-28, 2017.
- Rodenhizer, D., Zhang, J., Wouters, B., McGuigan, A.P. **A Patient-Derived Organoid Tissue Engineered Model For Quantifying Microenvironmental Reprogramming Of Tumour Cell Phenotype**, poster presentation at the *EACR conference: Goodbye flat biology -In Vivo Inspired Cancer Biology and Therapy*. Berlin, Germany. September 9-12, 2018.
- Romano, C., Moldoveanu, G., Ren, D., Yakunin, A., Edwards, E. Papangelakis, V. **Microbial Leaching of Nickel from Low-Grade Pyrrhotite Ores**, poster presentation at Goldschmidt. Boston, USA. August 17, 2018.
- Shyi, C.T., Edwards, E. **Probing anaerobic benzene degradation under nitrate reducing conditions**, poster presentation at the *NSERC Industrial Biocatalysis Network AGM*. Montreal, QC, Canada. May 30-31, 2018.
- Siddiqui, J., Diosady, L.L. **Reverse-enteric iron microencapsulation with chitosan and maltodextrin using spray drying: Tea fortification**, poster presentation at the *2nd International Conference on Food Chemistry & Nutrition*. Vancouver, BC, Canada. July 24-26, 2017.
- Sinichi, S., Diosady, L. **Rapid biodiesel and protein production by integrating isopropyl alcohol extraction and recovery from yellow mustard**, poster presentation at the *Great Plains Lipid Conference*. Winnipeg, Manitoba. June 3-4, 2017.
- Skarina, T., Evdokimova, E., Di Leo, R., Stogios, P., Watanabe, N., Tao, D., Savchenko, A. **Structure guided characterisation of type VI effectors**, oral presentation at the *Annual Meeting of NAID Funded Structural Genomics Centers*. Seattle, United States of America. October, 2017.
- Soleas, J.P., D’Arcangelo, E., Karoubi, G., McGuigan, A.P., Waddell, T.K. **Architectural manipulation of multipotent lung progenitor cells to control cell fate choice**, poster presentation at the *International Society for Stem Cell Research Annual Conference*. Boston, USA. June 14-17, 2017.
- Soleas, J.P., D’Arcangelo, E., Huang, L., Nostro, M.C., Karoubi, G., McGuigan, A.P., Waddell, T.K. **Guided self-assembly of SOX2+SOX9+ human lung progenitors into simplified developmentally inspired tubular architecture**, oral presentation at the *International Society for Stem Cell Research (ISSCR) Annual meeting*. Melbourne, Australia. June 20-23, 2018.

- Soleas, J., McGuigan, A.P., Waddell, T.K. **Architectural manipulation of multipotent lung epithelial progenitors to control cell fate choice**, poster presentation at *Till and McCulloch meeting*. Whistler, Canada. October 24-26, 2016.
- Soleas, J.P., D’Arcangelo, E., Karoubi, G., McGuigan, A.P., Waddell, T.K. **Architectural manipulation of multipotent lung progenitor cells to control cell fate choice**, poster presentation at the *Clinician Investigator Trainee Association of Canada Annual Conference*. Toronto, Canada. November 20-22, 2017.
- Stogios, P., Evdokimova, E., Wright, G.D., Savchenko, A. **Structural characterization of the intrinsic colistin resistance enzyme from *Moraxella catarrhalis***, poster presentation at the *Banff Conference on Infectious Diseases*. Banff, Canada. May 23-27, 2018.
- Stogios, P., Skarina, T., Savchenko, A. **Structural studies of carboxylate reductase and enoate reductase**, poster presentation at the *BioCEB: Biochemicals from Cellulosic Biomass AGM*, Toronto, Canada. June, 2018.
- Stogios, P., Xu, M., Skarina, T., Savchenko, A. **Structural and Functional Characterization of Environmental Antibiotic Resistance Enzymes Reveals New Mechanistic Diversity**, poster presentation at the *67th Annual Canadian Society of Microbiologists Meeting*. Waterloo, Canada. June 20-23, 2017.
- Stogios, P., Skarina, T., Savchenko, A. **Characterization of a pre-mobilized MCR-1 ortholog: crystal structure of the intrinsic colistin resistance enzyme from *Moraxella catarrhalis***, poster presentation at the *Keystone symposia on Molecular and Cellular Biology*. Santa Fe, United States of America. October 29 - November 1, 2017.
- Toth, C.R.A., Luo, F., Guo, S., Bawa, N., Webb, J., Dworatzek, S., Chen, C., Guo, Y., Magnuson, E., Shyi, C., Xiao, J., Bradshaw, K., Edwards, E.A. **Microbial natural attenuation of ten anoxic benzene-contaminated sites attributed to enrichment of two key benzene degraders**, poster presentation at the *17th International Symposium on Microbial Ecology*. Leipzig, Germany. August 16, 2018.
- Valleau, V., Quaille, A., Urbanus, M., Cui, H., Xu, X., Evdokimova, E., Chang, C., Ensminger, A.W., Savchenko, A. **The prokaryotic pathogen’s toolkit to meddle with host ubiquitination**, oral presentation at the *Federation of American Societies for Experimental Biology Meeting*. Colorado, United States of America. July, 2017.
- Valleau, D., Urbanus, U., Skarina, T., Evdokimova, E., Chang, C., Ensminger, A.W., Savchenko, A. **Hijacking of the host ubiquitination processes by bacterial pathogens**, oral presentation at the *Banff Conference on Infectious Diseases (BCID)*. Banff, Canada. May 23-27, 2018.
- Valleau, D., Quaille A.T., Urbanus, U., Cui, H., Xu, X., Evdokimova, E., Chang, C., Ensminger, A.W., Savchenko, A. **Bacteria take on host ubiquitination: unique tools and mechanisms**, oral presentation at the *American Society of Microbiology (ASM) Annual Meeting*. Atlanta, USA. June 1-5, 2018.
- Valleau, D., Urbanus, U., Cui, H., Xu, X., Evdokimova, E., Chang, C., Ensminger, A.W., Savchenko, A. **Getting in on the act: prokaryotic pathogens meddle with host ubiquitination**, oral presentation at the *68th Annual Canadian Society of Microbiologists*. Winnipeg, Canada. June 18 -21, 2018.
- Valleau, D., Skarina, T., Savchenko, A. **Getting in on the act: prokaryotic pathogens meddle with host ubiquitination**, poster presentation at *67th Annual Canadian Society of Microbiologists Meeting*. Waterloo, Canada. June 20-23, 2017.
- Valleau, D., Skarina, T., Savchenko, A. **The discovery of ubiquitin deamidases in the pathogenic arsenal of *Legionella pneumophila***, poster presentation at the Cold Spring Harbor Meeting. New York, United States of America. September 12-16, 2017.
- Venayak, N., Von Kamp, A., Klamt, S., Mahadevan, R. **Identifying optimal metabolic nodes and intervention strategies for dynamically controlled microorganisms using two stage minimal cut sets**, oral presentation at the *Metabolic Pathway Analysis Conference*. Bozeman, United States of America. July 24-28, 2017.
- Wang, P.H., Khusnutdinova, A., Xiao, J., Nemr, K., Luo, F., Flick, R., Edwards, E.A., Yakunin, A.F. **Prenylated FMN: Biosynthesis and Biochemical Studies**, poster presentation at the *NSERC Industrial Biocatalysis Network AGM*. Toronto, ON, Canada. May 30-31, 2017.
- Wong, M.T., Yan, R., Jurak, E., Razeq, F.M., Kataja, K., Ikonen, M., Wang, W., Master, E.R. **Identification and characterization of new carbohydrate active enzymes to advance lignocellulose utilization**, poster presentation at the *NSERC Industrial Biocatalysis Network AGM*. Toronto, ON, Canada. May 30-31, 2017.
- Xiao, J., Edwards, E.A. **Uncovering the role of prFMN in Aromatic Biodegradation**, oral presentation at the *NSERC Industrial Biocatalysis Network AGM*. Montreal, QC, Canada. May 30-31, 2018.
- Xiao, J., Wang, P.H., Khusnutdinova, A., Nemr, K., Luo, F., Flick, R., Mahadevan, R., Edwards, E.A., Yakunin, A.F. **The Biosynthesis of Prenylated Flavin Mononucleotide in Prokaryotes - A Novel Cofactor in Aromatic Biodegradation**, poster presentation at the *NSERC Industrial Biocatalysis Network AGM*. Toronto, ON, Canada. May 30-31, 2017.
- Xu, M., Skarina, T., Evdokimova, E., Di Leo, R., Stogios, P., Savchenko, A. **Structural and Functional Characterization of the Environmental Antibiotic Resistome Determinants**, oral presentation at the *Keystone symposia on Molecular and Cellular Biology*. Santa Fe, United States of America. October 29 - November 1, 2017.
- Xu, B., Bakooshli, M.A., Davoudi, S., Ebrahimi, M., Vitiello, L., McGuigan, A.P., Gilbert, P.M. **Development of a Novel Model in vitro to Study Bi-directional Niche Interactions in Human Skeletal Muscle Tissues Following Injury**, poster presentation at *Medicine by Design 2nd Annual Symposium*. Toronto, Canada. December 5, 2017.
- Young, M., Dean, T., D’Arcangelo, E., Rodenhizer, D., Ailles, L., McGuigan, A.P. **Engineered cancerstomal interfaces to probe cancer associated fibroblast-tumor cell interaction mechanisms**, poster presentation at the *EACR Conference on Cancer Genomics*. Cambridge, UK. June 25-28, 2017.
- Zeng, D., Azimi, Y. **Algae Cultivation on Transparent Membranes for the Design of Membranebased Algale Biofilm Photobioreactors**, oral presentation at the *International Biotechnology Symposium*. August 12-17, 2018.

Grants, Awards & Scholarships

During 2017 and 2018, BioZone researchers, postdoctoral fellows and students were recognized for their ongoing excellence in research, teaching and communication with scholarships, awards and professional accolades. Several of our professors also received prestigious grants from Canadian and international funders in support of their innovative research programs.

Grants

The following grants were led by BioZone PIs during the period between September 2016 to August 2018.

International

BHIVE (Bio-derived High Value polymers through novel Enzyme function)

Sponsor: European Research Council

PI: Emma Master

Capturing Oxidoreductases for Carbohydrate Oligomer Activation (COCOA)

Sponsor: Academy of Finland

PI: Emma Master

Canadian

A Novel 3D Tissue-Engineered Platform to Identify Novel Therapy Targets in Head and Neck Squamous Cell Carcinoma

Sponsor: Canadian Institutes of Health Research

PI: Alison McGuigan

A Tissue Engineering Platform to Identify Target Combinations in Tumour Stoma to Render Tumours Therapy Sensitive

Sponsors: Canadian Institutes of Health Research - Collaborative Health Research Project, Natural Sciences and Engineering Research Council of Canada - Collaborative Health Research Project Grant

PI: Alison McGuigan

An Optimized Waveguide Based Light Delivery System for Algal Biofilm Reactor.

Sponsor: Connaught Foundation

PI: Grant Allen

Anaerobic Digestion of Solid Waste: A New Approach to Accommodating Feedstock Variability to Achieve Stable Operation at an Affordable Cost

Sponsor: Natural Sciences and Engineering Research Council of Canada – Collaborative Research and Development Grant

PI: Elizabeth Edwards

Biocatalytic cascades for hemicellulose reassembly ("BI-OSEMBL")

Sponsor: Tandem Forest Values

PI: Emma Master

Collaborative Research: Functional and Evolutionary Bases of Substrate-Specificity in Wood-Decaying Basidiomycetes

Sponsor: National Science Foundation Subgrant (Clark University)

PI: Emma Master

Operations and Maintenance Support for the BioZone MS Facility

Sponsor: Natural Sciences and Engineering Research Council of Canada

PI: Alexander Yakunin

Banting Postdoctoral Fellowship Awards

Sponsor: Canadian Institutes of Health Research - Banting Postdoctoral Fellowship

PI: Levente Diosady

Biochemicals from Cellulosic Biomass (BioCeB)

Sponsor: Ministry of Research and Innovation

PI: Radhakrishnan Mahadevan (co-lead)

Bioleaching of Nickeliferous Pyrrhotite Tailings: Bioprocessing of Nickeliferous Sulphidic Wastes from Mining Activities

Sponsor: Natural Sciences and Engineering Research Council of Canada – Collaborative Research and Development Grant

PI: Vladamiro Papangelakis

Co-Investigators: Elizabeth Edwards, Radhakrishnan Mahadevan

Biological Production of Xylitol from Hydrolyzates

Sponsors: Connect Canada, Ontario Centres of Excellence

PI: Bradley Saville

Brassica Oilseed Protein Processing

Sponsor: Natural Sciences and Engineering Research Council of Canada - Idea to Innovation Grant

PI: Levente Diosady

CFD Modelling of Hydrolysis

Sponsor: Natural Sciences and Engineering Research Council of Canada – Discovery Grant

PI: Bradley Saville

Biocatalytic Activation of Macromolecular Building Blocks

Sponsor: Natural Sciences and Engineering Research Council of Canada – Discovery Grant

PI: Emma Master

Chemo-enzymatic Reassembly of Underused Biomass Fractions

Sponsor: Natural Sciences and Engineering Research Council of Canada – Strategic Partnership Grant

PI: Emma Master

Dean Strategic Fund: MS Facility (DSF14-17)

Sponsor: University of Toronto; Faculty of Applied Science & Engineering – Dean Strategic Fund

Dean Strategic Fund: Biomanufacturing

Sponsor: University of Toronto; Faculty of Applied Science & Engineering – Dean Strategic Fund

Developing Biofilm based Microalgal Bioreactors for Efficient Production of Fuels, Chemicals and Clean Water

Sponsor: Natural Sciences and Engineering Research Council of Canada – Strategic Partnership Grant

PI: D. Grant Allen

Development of 100% Biobased Adhesive for Applications in Engineered Wood Products

Sponsors: Ecosynthetix, Natural Sciences and Engineering Research Council of Canada – Engage Grant

PI: Emma Master

Elements of Bio-Mining (EBM): Genomics-Driven improvements in Mine Operations

Sponsor: Ministry of Research and Innovation

PI: Vlad Papangelakis

Engineering the RNA-guided Cascade complex for genome editing.

Sponsor: Natural Sciences and Engineering Research Council of Canada

PI: Alexander Yakunin

Enhancing Dewatering, Drying, Combustion and Utilization of Pulp and Paper Mill Biosludge

Sponsor: Natural Sciences and Engineering Research Council of Canada

PI: Grant Allen

Enhanced Anaerobic Bioremediation of Chlorinated Pesticides and their Metabolites in Soil and Groundwater: Development and Demonstration of Field-Ready Technologies

Sponsor: Ontario Ministry of Research, Innovation and Science - Ontario-China Research and Innovation Fund

PI: Elizabeth Edwards

Enhancing Productivity and Cognitive Ability of 10 Million Rural Agricultural People in Uttar Pradesh in India via Scale-Up and Consumption of Double Fortified Salt

Sponsor: International Development Research Centre

PI: Levente Diosady

Environmental and Economic Analysis on a Life Cycle Basis of Canadian H₂ Sources for Biofuel Production

Sponsor: Networks of Centres of Excellence: BioFuelNet

PI: Bradley Saville

Exploitation of Host Ubiquitination Pathways by Pathogenic E. coli

Sponsor: Canadian Institutes of Health Research

PI: Alexei Savchenko

Genomics Driven Engineering of Hosts for Bio-Nylon.

Sponsor: Genome Canada

PI: Radhakrishnan Mahadevan

Harnessing the Power of Algal-Bacterial Structures to Convert Wastes to Value-Added Products

Sponsor: Natural Sciences and Engineering Research Council of Canada

PI: Grant Allen

Identification of the microorganisms enhancing cyanide degradation during gold recovery from a heap leach operation

Sponsor: Natural Sciences and Engineering Research Council of Canada

PI: Alexander Yakunin

Identification of the microorganisms enhancing cyanide degradation during gold recovery from a heap leach operation

Sponsor: Ontario Centres of Excellence

PI: Alexander Yakunin

Industrial Biocatalysis Network

Sponsors: Natural Sciences and Engineering Research Council of Canada – Strategic Partnership Grant, CanSyn Chemical Corporation, E.I. DuPont Canada, ELANCO - Animal Health: A Division of Eli Lilly Canada, Lallemand, Monaghan Biosciences, SunCor, BP Technology Ventures

PI(s): Elizabeth Edwards, Radhakrishnan Mahadevan, Emma Master, Alexei Savchenko, Alexander Yakunin

Industrial Research Chair in Sustainable Energy and Chemical Recovery in Biomass Processing

Sponsors: NSERC

PI: Grant Allen

Inhibition of Human Nucleotide Sanitation Enzymes for Cancer Suppression

Sponsor: Canadian Cancer Society Research Institute

PI: Alexander Yakunin

Investigating the Development of 100% Biobased Adhesive for Applications in Engineered Wood Products

Sponsor: Natural Sciences and Engineering Research Council of Canada – Engage Grant

PI: Emma Master

Market Assessment Study for Bio-based 1,3-Butanediol as a Specialty Chemical in North America

Sponsor: Natural Sciences and Engineering Research Council of Canada - Idea to Innovation Grant

PI: Radhakrishnan Mahadevan

Metagenomic Study of Dechlorinating Microbial Communities in vitro and in situ

Sponsor: MITACS - Accelerate Ontario

PI: Elizabeth Edwards

Mining the Legionella core “effectome” for molecular modulators of conserved eukaryotic cell signaling

Sponsor: Natural Sciences and Engineering Research Council of Canada - Discovery Grant

PI: Alexei Savchenko

Ontario-China Young Scientist Exchange Program (YSEP)

Sponsor: Ontario Ministry of Research, Innovation and Science - Ontario-China Young Scientist Exchange

PI: Elizabeth Edwards

Optimization of Astaxanthin Production in Large-Scale Cultivation of Microalgae by Utilization Industrial CO₂ Emissions.

Sponsor: MITACS

PI: Grant Allen

Pathway Search Using Simulated Annealing

Sponsor: Natural Sciences and Engineering Research Council of Canada - U of T Excellence Award

PI: Radhakrishnan Mahadevan

Production of Bio-based 1,3-butanediol

Sponsor: Connaught Fund - Innovation Award

PI: Radhakrishnan Mahadevan

Quadruple Fortified Salt: An Efficient and Scaleable Vehicle for Simultaneous Delivery of Iron, Folic Acid, Vitamin B12 and Iodine in Low Resource Settings

Sponsor: Grand Challenges Canada - Saving Lives at Birth

PI: Levente Diosady

Reducing Maternal Mortality by Improving Iron Status of Women through Iron Fortification of Tea

Sponsor: Grand Challenges Canada - Saving Lives at Birth

PI: Levente Diosady

Remediation Education Network (RENEW) Training Program

Sponsor: Natural Sciences and Engineering Research Council of Canada – Collaborative Research and Training Experience Program

PI: Brent Sleep

Co-Investigator: Elizabeth Edwards

Solving the Antibiotic Resistance Crisis

Sponsor: Ontario Research Fund – Research Excellence Subgrant (McMaster University)

PI: Alexei Savchenko

Strategic Network Enhancement Initiative

Sponsor: Natural Sciences and Engineering Research Council of Canada – Strategic Partnership Grant

PI: Elizabeth Edwards

Structural studies and protein engineering of microbial defluorinases.

Sponsor: Samsung Advanced Institute

PI: Alexander Yakunin

Synbiotics: Functional genomics and technoeconomic models for advanced biopolymer synthesis

Sponsor: Genome Canada – Large-scale Applied Research Project

PIs: Emma Master and Elizabeth Edwards

Awards

International

2017 Young Investigator Award

Biochemical Engineering Journal

Radhakrishna Mahadevan

Canadian

2018 Officer of the Order of Canada

Government of Canada

Levente Diosady

2017 McLean Award

Connaught Fund

Alison McGuigan

Canada Research Chair (Tier 1) in Anaerobic Biotechnology, 2014 to present

Government of Canada

Elizabeth Edwards

Faculty Award for outstanding teaching and research 2017

University of Toronto; Department of Chemical Engineering & Applied Chemistry

Elizabeth Edwards

Hatch Innovation Award
Chemical Institute of Canada
Alison McGuigan

Quality of Student Experience Award
University of Toronto; Faculty of Applied Science & Engineering
Endang Susilawati

Royal Society of Canada's College of New Scholars, Artists and Scientists 2018
Royal College of Canada
Alison McGuigan

The Canadian Journal of Chemical Engineering Lecture-ship Award
Chemical Institute of Canada
Alison McGuigan

Student Scholarships

Applied Science Graduate Faculty Fellowship
University of Toronto

CIHR Training Program in Regenerative Medicine Graduate Fellowship Award
Canadian Institutes of Health Research

Colin Hahnemann Bailey Fellowship Departmental Fellowship
University of Toronto; Department of Chemical Engineering & Applied Chemistry

CONACTY Scholarship
Government of Mexico

Dr. C.W.Boman Scholarship in Chemical Engineering
Canadian Universities

Dr. Goran Enhorning Award in Pulmonary Research
University of Toronto; Faculty of Medicine

Dr. Joe A. Connolly Memorial Award
University of Toronto; Faculty of Medicine

Dupont Canada Graduate Scholarship in Science and Technology
Dupont Inc.

Eco-Tec Founder's Scholarship
University of Toronto; Department of Chemical Engineering & Applied Chemistry

McLaughlin Foundation Award for MD/PhD Students
University of Toronto; Faculty of Medicine

McLean Foundation Graduate Scholarship in Science and Technology (2)
University of Toronto; Department of Chemical Engineering & Applied Chemistry

Mitacs Accelerate Fellowship
MITACS

Mitacs Globalink Graduate Fellowship
MITACS

NSERC Canada Graduate Scholarships - Master's Program (2)
Natural Sciences and Engineering Research Council of Canada

NSERC CREATE in Manufacturing, Materials and Mimetics (M3)
Natural Sciences and Engineering Research Council of Canada

NSERC CREATE Sustainable Aviation Award
Natural Sciences and Engineering Research Council of Canada

NSERC Postgraduate Scholarships-Doctoral Program (3)
Natural Sciences and Engineering Research Council of Canada

Ontario Graduate Scholarship (6)
Ontario Ministry of Training, Colleges and Universities

Ontario Trillium Scholarship
Ontario Ministry of Training, Colleges and Universities

Paul Cadario Doctoral Fellowship in Global Engineering
University of Toronto; Faculty of Applied Science & Engineering

Queen Elizabeth II Graduate Scholarship in Science & Technology (3)
Ontario Ministry of Training, Colleges and Universities

Schlumberger Foundation Faculty for the Future Graduate Scholarship Fund
Schlumberger Foundation

State Scholarship Fund
China Scholarship Council

University of Toronto Fellowship
University of Toronto

We would like to thank the public sector agencies who continue supporting BioZone researchers.



We wish to thank many industrial partners, some of whom are shown below, who have supported our ongoing research.



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UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

Report on BioZone

2016 - 2018

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