



ACTIVITY REPORT 2015-2019

Institut de biologie intégrative
et des systèmes (IBIS)



UNIVERSITÉ
LAVAL

RESEARCH, WRITING AND EDITING

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With the collaboration of the Institute's researchers and members

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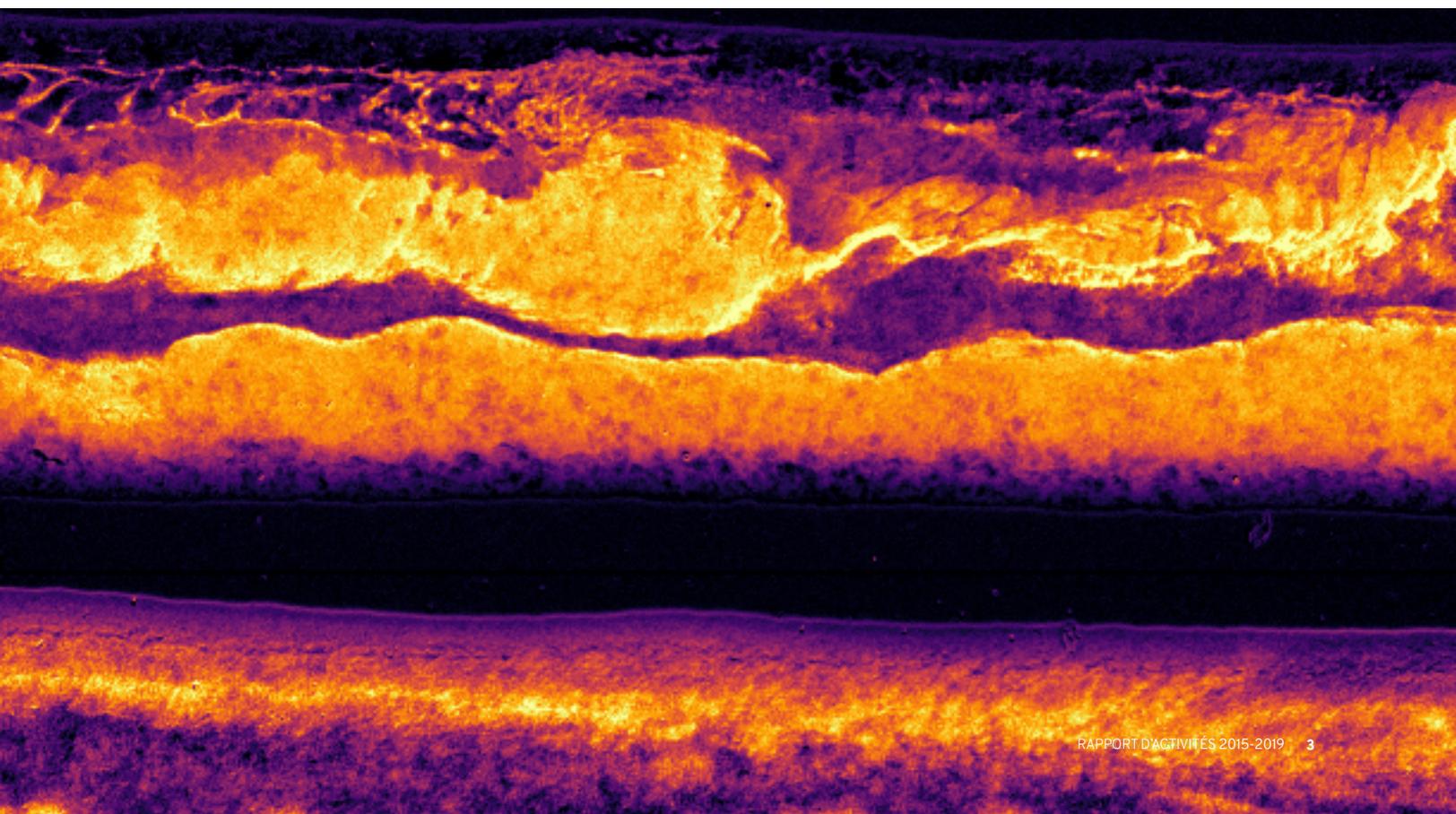
DESIGN AND GRAPHICS

Bérénice Bougas, Reprography Department of Laval University

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A WORD FROM THE DIRECTOR



Interdisciplinarity and integrative research. These are the terms that characterize IBIS, whose ten years of existence and scientific achievements are being celebrated this year, to the great benefit of our society. In the following pages, you will be able to take stock of our activities and achievements between 2015 and 2019, all in direct relation with our mission: TRAIN highly qualified personnel in the fields of natural sciences, forestry, agriculture and biomedical research; INNOVATE in human, animal and plant health, food and forestry production, protection of the environment and biodiversity; and DISSEMINATE knowledge to a wider audience and dissemination of research.

These impressive results testify of both the dynamism of the research teams who are a member of our institute, as well as the remarkable support provided by all the employees of IBIS who, by investing themselves to the best of their abilities in their tasks and responsibilities, support us on a daily basis in our research activities and student training. The extraordinary synergy that exists among IBIS staff members is like the glue that holds the pieces together, leading to the successful advancement of research, excellence in training and an inclusive and equitable workplace for all.

We are particularly proud and pleased to have recruited no less than six new research teams led by young researchers from three faculties who have come to strengthen our ranks and thus contribute to the interdisciplinary and integrative character that distinguishes IBIS. The leadership of our researchers in their respective fields has resulted in prestigious awards and prizes, as well as significant research funding in some of the most competitive grant programs. This has led to the implementation of major projects in close collaboration with our partners of the government and private sectors.

The international presence of IBIS has been increased over the past four years by the implementation of research projects in collaboration with partners in more than 20 countries, covering all continents. In terms of training, more than half of our students and postdoctoral fellows are recruited from outside Canada. We are also very proud to have hosted Physalia International training workshops, which attracted participants from no less than 18 countries to IBIS.

The pooling of equipment acquired by IBIS researchers through major equipment grants has made it possible to expand the infrastructure of our three service platforms (Genomic Analysis and Sequencing, Bioinformatics, Imaging and Microscopy) and thus maintain the level of excellence that has characterized the training and research carried out at IBIS from its very beginning. Upgrading these platforms also allows us to continue to meet the needs of several other research centres and teams at Laval University, as well as those of our many government and industry partners. For example, over 95% of the activities of our imaging and microscopy platform is dedicated to serving the needs of researchers not affiliated with IBIS. The team from our scientific store serves the entire academic community by providing thousands of scientific and everyday products throughout the campus.

Our platform services are also sought after by research teams from elsewhere in Quebec, Canada and even internationally. In fact, our genomics analysis and sequencing platform is undoubtedly the largest in Canada specializing in the production and processing of genomic data of non-model species in the animal, plant and microbial world.

In short, the highlights mentioned in this report, which cover the achievements of the past four years, attest to the considerable, even essential, contribution of IBIS to the recognition of Laval University as one of the largest research universities in Canada, where it now ranks as 7th. IBIS also continues to contribute to the ever-increasing leadership of Laval University on the international stage, both in terms of its research achievements and of the excellence of the training it provides.

On a more personal note, I would like to take this opportunity to warmly thank the Vice-Rector of Research and Innovation, as well as the faculties of Medicine; Science and Engineering; Forestry, Geography and Geomatics; and Agriculture and Food Sciences for their continuous support. Finally, I thank Mrs. Bérénice Bougas for her unwavering support in the execution of administrative tasks, sometimes barely reconcilable with research and teaching activities, which are the responsibility of any institute's director.

Louis Bernatchez, Director
Professor, Department of Biology

INTERDISCIPLINARITY— A COMMON MISSION

By combining the innovative approaches of “omics” sciences such as genomics, proteomics, metabolomics and bioinformatics with the experimental approach and field work, researchers from the *Institut de biologie intégrative et des systèmes* (IBIS) generate new knowledge in basic and applied research. Our researchers study fundamental biological and evolutionary processes in an integrative way, from structural aspects and molecular interactions to the functioning of the cell, microbiome, population biology, all the way to ecosystem dynamics, in an integrative approach aimed at the global understanding of these processes. These studies are carried out with the aim of better applying knowledge to real issues of immediate interest.

IBIS is a key player in fundamental and applied integrative biology and synthetic biology, as well as a major magnet for graduate training, all in an environment of respect, openness and collaboration.



MISSION

- > To understand fundamental biological and evolutionary processes through fundamental **RESEARCH** and to apply it to the understanding of ecosystems and systems functioning.
- > To contribute to the **TRAINING** of highly qualified personnel.
- > To ensure the **TRANSMISSION** of knowledge to a wide audience.
- > To participate in human, animal and plant health **INNOVATION** as well as food and forestry production.



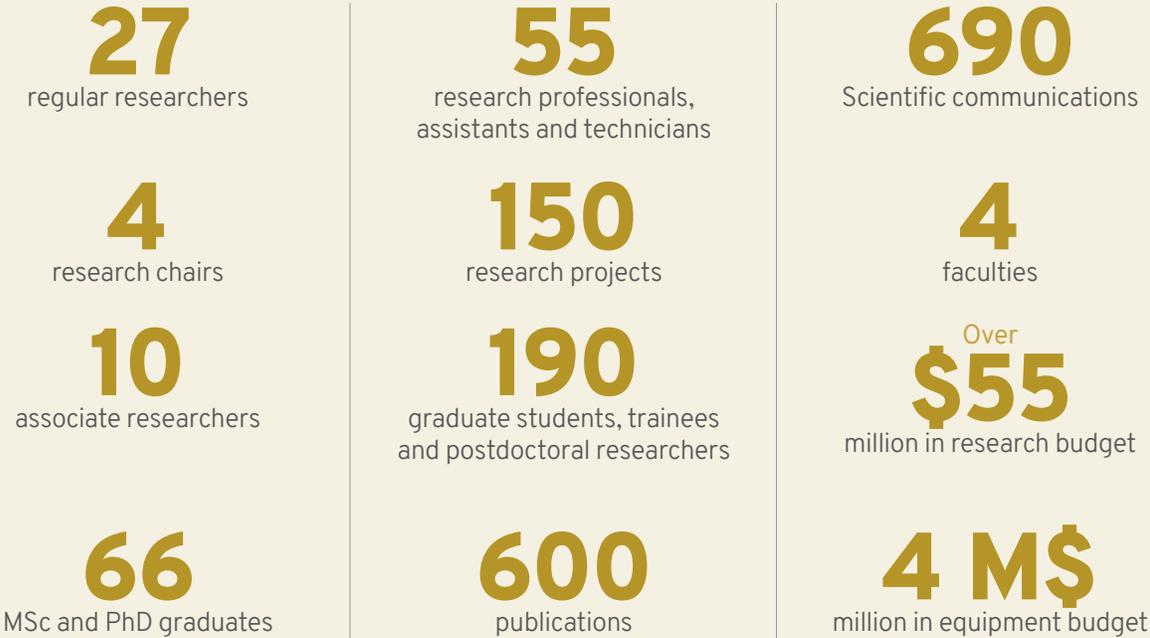
IBIS: DYNAMISM AND PRODUCTIVITY IN RESEARCH

The years 2015-2019 have been productive for the 27 regular IBIS researchers, with more than \$55M in research budget (\$13M/year on average) and over \$4M in equipment and facilities budget.

Fostering close collaborations and an interdisciplinary approach, the Institute’s regular researchers cooperated for their research, with teamwork representing more than 81%

of the average annual budget of the last four years, while individual grants represent 13% of the budget. The four Canada Research Chairs account for 4% of the budget and service contracts performed by individual researchers account for 2% of the budget. Moreover, the average operating budget of IBIS (salaries, infrastructure and equipment maintenance, platform platforms) is over \$2.5 million/year.

IBIS IN NUMBERS (FROM 2015 TO 2019)



Infrastructure and equipment grants obtained in 2015-2019 allowed to renew the equipment used by IBIS researchers and to add state-of-the-art instruments, enabling them to use innovative “omics” scientific approaches to carry out their research operations. A flow cytometer dedicated to integrative biology research, a multimode cytometer, a DNA sequencer for an integrated genomics ecology research program, a digital quantitative PCR apparatus for research on Arctic viral ecology, two Illumina MiseQ sequencers and six Ion Proton sequencers were purchased by IBIS researchers to increase their genomics analysis potential. To this laboratory equipment, an SGI UV 300 128 cores server with 2 Tb of memory was added by François Belzile and Roger C. Levesque to further increase the data processing potential. These devices are made available to all through our various platforms and thus serve the needs of the entire academic community as well as those of our many local, national and international partners and clients.

A major infrastructure grant from the Canada Foundation for Innovation (CFI) was awarded in 2015 to six regular and associate researchers from IBIS (out of a total of ten applicants) to set up the Environmental and Medical Sciences Research Laboratory (LARSEM) located on the Institute’s premises. This project, currently under construction includes a level 2 aquatic containment room, and will enable world-class research on aquatic organisms, including zebrafish. This new infrastructure will allow Laval University researchers and other external

users to carry out genetic selection projects, to develop new approaches to restock exploited species, to assess the impact of environmental disturbances on aquatic ecosystems, and to study disease control in aquaculture and human health, neurodegenerative diseases and the molecular mechanisms of behaviour.



DIVERSE AND ABUNDANT SOURCES OF FUNDING

Sources of research funding at IBIS come from numerous federal (Genome Canada, NSERC, CIHR, CIHR-JPIAMR, Cystic Fibrosis Canada, CFI, Agriculture and Agri-Food Canada, World Affairs Canada, POLAR, Apogee Canada, Mitacs) and provincial (G enome Qu ebec, FRQNT, FRQS, MAPAQ) granting agencies, the international Human Frontiers Science Program, private research funds in the agri-food and health sectors, as well as numerous research contracts. The vast majority of funded projects are carried out with partners from all sectors.

The operating budget, however, is mainly provided by Laval University (operations and salaries of permanent positions), the various faculties who contribute in terms of material for professors and students, and the revenues generated by the three service platforms and the scientific store, which make possible the payment of equipment maintenance contracts, the renewal and purchase of new equipment and the salaries of contractual personnel necessary for the proper functioning of the platforms.

CHAIRS—EXCELLENCE OF THE WORK CARRIED OUT AT IBIS

Recognizing the excellence and merit of their research, four Canada Research Chairs in Genomics and Evolution and one chair in the Faculty of Medicine are held by IBIS researchers.

Name of Research Chair	Holder	End Date	Total amount \$
Research Chair in Genomics and Conservation of Aquatic Resources (Tier 1)	Louis Bernatchez	2020	1 400 000
Research Chair in Forest Genomics (Tier 1)	Jean Bousquet	2021	1 400 000
Research Chair in Evolutionary Cell and Systems Biology (Tier 2)	Christian Landry	2022	500 000
Sentinel North Partnership Research Chair on Ecosystemic Approaches to Health (Tier 2)	Mélanie Lemire	2024	375 000

RESEARCH CHAIR IN GENOMICS AND CONSERVATION OF AQUATIC RESOURCES

Its primary mission is to generate knowledge on the evolutionary factors governing the genetic diversity of populations that will stimulate the economic viability and social value of aquatic species in three complementary areas of activity: sport or commercial fishing, biodiversity conservation and aquaculture.

The research aims to:

- > Gain ground-breaking knowledge that will stimulate the long-term economic viability and social value of aquatic species.
- > Increase the training of biologists, researchers and research professionals with cutting-edge knowledge in priority research areas in Canada, including evolutionary genomics, conservation, and bioinformatics.
- > Increase the visibility of academic research to the public by informing the public of the role of research in improving the management and conservation of natural resources.



RESEARCH CHAIR IN FOREST GENOMICS

Its mission is to develop and apply genomics science to tree species and forests to increase their productivity and resilience.

This research aims at developing better conservation measures to preserve the genetic diversity of forests, and to accelerate the development of adapted and productive varieties for reforestation. Accelerated selection systems by genomic profiling are made available to identify promising trees from their early seedling stage. In partnership with stakeholders of the forest sector, this enables the

development of varieties specifically destined to reforestation by identifying their greater productivity and anticipated adaptability to climate change, while saving 20 to 30 years of field assessment.

RESEARCH CHAIR IN EVOLUTIONARY CELL AND SYSTEMS BIOLOGY

Its goal is to use systems biology to understand how genomes and cell networks evolve.

This research aims at increasing the understanding of the forces that have led to the evolution of biodiversity at the microscopic and molecular levels. This will help shed light on our origins and could lead to advancements in bioengineering in sectors including biotechnology and medicine.



SENTINEL NORTH PARTNERSHIP RESEARCH CHAIR ON ECOSYSTEMIC APPROACHES TO HEALTH

Its mission is to develop interdisciplinary research and intervention projects, in close partnership with Aboriginal and coastal communities, to understand the complex effects of environmental changes on health and to support preventive and conservation actions related to northern ecosystems and their role in supporting health and well-being.

The research aims at contributing to the biomonitoring of environmental contaminants in local foods and northern populations, to study the effects of contaminants on human health, the prevalence and incidence of zoonoses, the effects of local and regional development on the quality of local food and water on northern health, the impact of climate and ecosystem change on local food systems and northern health, and to transfer the acquired knowledge to indigenous communities.

DISSEMINATION OF RESEARCH RESULTS

Between 2015 and 2019, over 600 articles were published by IBIS researchers and their teams in peer-reviewed scientific journals. Most scientific papers were published either in recognized scientific journals (Nature, Science, Proceedings of the National Academy of Sciences USA) or in the most influential journals in the different fields of specialization of IBIS researchers.

In addition to published scientific articles, IBIS researchers and their students have contributed to the dissemination of their expertise and the development of their collaborations by doing nearly 700 presentations of their work at national and international conferences. To this, we can add some 20 reports and book chapters.



NEW TEAMS AT THE INSTITUTE

Over the past four years, IBIS has welcomed six new teams, which have strengthened the multidisciplinary and integrative aspects of its research projects.



Ilga Porth – 2015

Ilga Porth, Professor at the Department of Wood and Forest Sciences, arrived with her expertise on the analysis of the genetic foundations of wood quality traits in the context of tree improvement, with a focus on the enhancement of wood components. Ilga Porth and her team are also looking to understand and improve the resilience to biotic and abiotic stresses of forest species. She also studies the genomic foundations of the invasive attributes of several major exotic forest pests found in Canada.



Alexander Culley – 2015

Alexander Culley, Associate Professor at the Department of Biochemistry, Microbiology and Bioinformatics, has developed a research expertise around two major themes: viral aquatic ecology in a changing climate and the discovery of new viruses. The Arctic is a model environment for the exploration of these two themes because it is experiencing some of the most dramatic changes on Earth as a result of climate change and it is home to a great diversity of aquatic habitats with largely mischaracterized viral communities. Alexander Culley and his team aim at gaining a better long-term understanding of the impact, diversity and dynamics of in situ virus communities in various aquatic habitats in the Arctic, and to understand how viral ecology is affected by rapid and evolutionary changes in this ecosystem.



Juan Carlos Villarreal – 2015

Juan Carlos Villarreal, Professor in the Department of Biology, arrived with an expertise in systematics, diversity, phylogeny and symbiotic interactions between bryophytes and bacteria in tropical environments, especially between anthocerotops and cycadea. His research also addresses biodiversity, conservation and the influence of climate change on the groups of organisms that make up the majority of photosynthetic biomass and the base of the boreal food chain: bryophytes and lichens. The latter play a fundamental role in the global biogeochemical cycles of carbon and nitrogen both directly and through their interactions with the microbial biome.



Jean-Sébastien Moore – 2017

Jean-Sébastien Moore, Associate Professor at the Department of Biology, arrived with an expertise in genetics and genomics of northern fish populations of economic and cultural importance. Jean-Sébastien Moore and his team use an integrative approach combining population genomics and acoustic telemetry to characterize the interactions between migration, dispersion and gene flow. They want to understand how these processes will influence the populations' ability to adapt to a changing Arctic. Much of their work focuses on anadromous salmonids, particularly Arctic char.



Mélanie Lemire – 2018

Mélanie Lemire, Assistant Professor at the Department of Social and Preventive Medicine and researcher attached to the Population Health and Optimal Health Practises—Axis of the CHU de Québec's research centre, brings her expertise in health science to the Institute. Holder of the Nasivvik Research Chair on Ecosystemic Approaches to Health, her mission is to develop interdisciplinary research and intervention projects in close partnership with Aboriginal and coastal communities, to understand the complex effects of environmental change on health and to support preventive and conservation actions related to northern ecosystems and their role in supporting health and well-being.



Ahmad Abdel-Mawgoud Saleh – 2019

Ahmad Abdel-Mawgoud Saleh, Assistant Professor at the Department of Biochemistry, Microbiology and Bioinformatics, brings his expertise in synthetic chemical biology to the Institute. His team works to develop synthetic biology strategies for the biosynthesis and discovery of synthetic chemicals, in particular lipid-based drugs and biofuels, in order to make them suitable for human consumption. They are working on the discovery and invention of new fine chemicals that meet human needs in the fields of health, energy and bioremediation. Their research is conducted using synthetic biology (SB) approaches on microbial hosts which are used as platforms, while aiming at the sustainable production of fine, safe and environmentally friendly chemicals.

RESEARCH RELATED TO SOCIETAL ISSUES

The main purpose of the research activities carried out at IBIS is to acquire fundamental knowledge and to gain skills and develop solutions in terms of human and animal health, food production, fight against climate change, environmental protection and biodiversity conservation. Below are examples of projects that have direct applications to society.

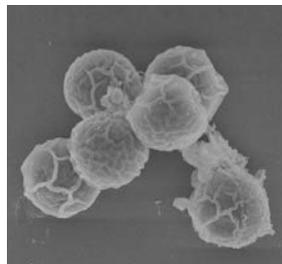
ENVIRONMENTAL PROTECTION–BIODIVERSITY CONSERVATION–MANAGEMENT OF EXPLOITED SPECIES

Work carried out by **Louis Bernatchez**'s team on environmental DNA in collaboration with the *Ministère des Forêts, de la Faune et des Parcs* (MFFP) confirmed the presence of grass carp (Asian carp) in Quebec waters, an invasive species that can cause considerable harm to aquatic ecosystems. They have since proceeded to the technology transfer of their method, which is now routinely used by this department. Another project with practical implications, also in partnership with the MFFP, was on costs and benefits of brook char stocking in Quebec. Results from this study led to the implementation of a new management plan for this species across the province.

An essential aspect to predict the extent of the impact of climate change in polar regions is to understand how endemic organisms are affected. As in most ecosystems on Earth, microbes are the most abundant and diverse groups of biological entities in the Arctic. The main objective of **Alexander Culley**'s research program is to characterize the diversity of microbes and their dynamics, and to increase the understanding of their role in polar microbial ecology. To this end, his team described new marine viral RNA communities in Antarctica, characterized their seasonal dynamics, discovered new habitats of microbial mats in Arctic lakes, demonstrated the importance of snow microbial communities in fresh water hydrological networks, explored the viral diversity among different types of thaw ponds in the subarctic habitat and developed new molecular approaches to study aquatic microbial ecology.



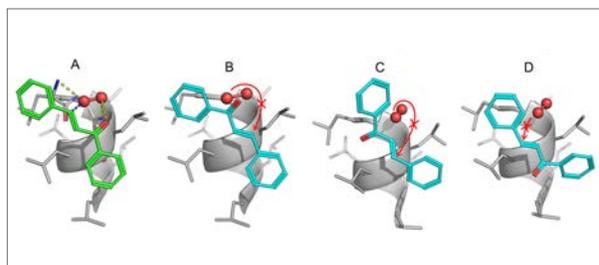
Monique Turmel and **Claude Lemieux**'s team obtained the sequence of the organelle or nuclear genomes of various green algae to shed some light on certain problematic nodes of the tree of life, and to better understand the evolution of these organisms and their genomes. These sequences are important resources to do a follow-up of the studied algae in various environments by using metagenomic approaches.



Arctic char is essential to food security in Nunavut and constitutes the most caught wildlife species on this territory. Commercial fishing of Arctic char has supported the local economic development for decades and represents more than \$1.4 million annually in Nunavut. Effective management ensuring the long-term sustainability of this resource is paramount, as was reflected in the first Integrated Fisheries Management Plan for Arctic char in Canada. Recent work by **Jean-Sébastien Moore**'s team in collaboration with Fisheries and Oceans Canada on the biology of Arctic char migrations contributes to the sustainable management of this species. The transfer of these results to local managers is necessary to achieve their Arctic char management objectives.



Molecular modelling by **Patrick Lagüe**'s group and his collaborators helped develop and understand how catalysts, which are able to function in water, operate. Their work was inspired by enzymes found in living cells. This discovery raises the possibility of substantially reducing the use of toxic and non-recyclable organic solvents in a lot of chemical reactions, particularly during drug synthesis.



Canada is receiving more and more vegetable and animal food products from around the world. Canada Customs and Canadian agencies face the growing challenge of identifying and confirming the health and safety of various food types. **Roger C. Lévesque**'s team, with the Genome Analyses and Sequencing Platform of IBIS and Thermo Fisher Company, innovated in microbial diagnosis by developing a new screening and serotyping method called SalmoSeq. This new and fast technology is based on AmpliSeq, which was initially used for the screening and monitoring of the effectiveness of chemotherapy as a treatment for cancer. SalmoSeq helps rapidly identify the level of virulence of Salmonella and can also be applied to other microbial species. This new technology will be used by the Canadian Food Inspection Agency (CFIA), hence allowing it to meet its strategic priorities, including Canada's food health and safety.



FOREST PROTECTION AND FORESTRY PRODUCTION

Work by **Jean Bousquet**'s team and his collaborators on genomic selection led to the operational deployment of this technology to the *Ministère des Forêts, de la Faune et des Parcs* and at JD Irving to allow the early selection of trees and genetic crosses to perform, through resources and genomic tools developed by the team. Prediction models based on genomics aim for growth, wood quality and resistance to biotic and abiotic stresses in the context of different spruce improvement and planting programs. Spruce is the most widely used species in reforestation in Canada.



The spruce budworm causes extensive damage to trees, which can eventually lead to death. By characterizing the three dimensional structure of spruce budworm's type-II enzyme farnesyl diphosphate synthase (FPPS), **Rong Shi**'s team shed some light on the structural basis of this enzyme's substrate specificity. This work provides new information on the structure and inhibition of FPPS-II of this forest pest and proposes new inhibitor design strategies, thus paving the way for the development of selective and environmentally friendly pesticides that could have a significant impact in forest protection.



AGRICULTURE

Work by **François Belzile**'s team helped develop a series of bioinformatics tools to facilitate the rapid obtention of genetic data from DNA sequences. This technique is based on three tools (Fast-GBS, SRG Extractor and HaplotypeMiner), and the obtention of a catalogue of genetic variants is greatly accelerated and makes it possible to bring more biological sense to the extracted information. It is possible to use these tools, for example, to conduct a rapid genetic analysis of soybean varieties and to translate data from genes into useful information on the precise genetic background determining the maturity of these varieties.



Sorghum (*Sorghum bicolor*) is a cereal that is crucially important for food security in Haiti, where it is commonly known as pitimi. First appeared in 2013 in Louisiana and Texas, a new biotype of the yellow sugarcane aphid, *Melanaphis sacchari*, rapidly devastated plantations of sorghum in a number of Central American and Caribbean countries. Local sorghum varieties have proven to be very sensitive to this new pest, which led to the collapse of Haitian production in 2015 and 2016. Since the iAKOSAA project led by **Patrice Dion** already supported varietal improvement work by Chibas, a centre dedicated to agricultural research in Haiti, and through exceptional efforts made by Global Affairs Canada, work by his team helped distribute 270 tons of seeds from a new sorghum variant tolerant to *M. sacchari* at more than 80 000 producers, thus ensuring what local press called "rebirth of sorghum chain in Haiti" and providing cereals to the most vulnerable families of the country.

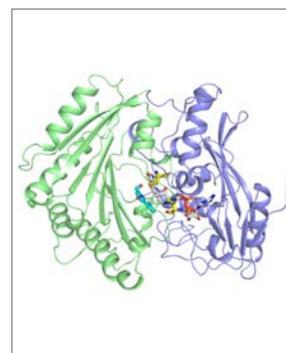
ANIMAL AND HUMAN HEALTH

Work by **Steve Charrette's** team on the *Aeromonas salmonicida* bacteria, responsible for major infections in Quebec fish farms, demonstrated in nearly all cases that when an infectious episode affects a fish farm and a bacterium is resistant to an antibiotic, it will resist to all antibiotics available for aquaculture. The team is developing alternative solutions to address this problem, including phage therapy. Researchers demonstrated the great effectiveness of half a dozen phages that can attack *Aeromonas salmonicida* bacteria.

Hereditary tyrosinemia type 1 is caused by a fumarylacetoacetate hydrolase (FAH) deficiency. The global frequency of HT1 is one per 100 000 births, but certain regions have a much higher incidence (1:1 800). The defect in FAH results in the accumulation of toxic metabolites, mainly in the liver. **Robert Tanguay's** team discovered miRNA markers to prevent liver cancer formation in a murine model of tyrosinemia.

Work by **Manon Couture's** team helped elucidate the enzymatic mechanism of the ChuS protein of pathogenic *E. coli*. This enzyme helps the bacterium obtain iron from human hemoglobin and thus meet the essential element requirements essential to its growth. This discovery paves the way for the development of new therapeutic molecules.

Natural products and their derivatives obtained from bacteria, including a number of antibiotics, are important for human health. Research from **Rong Shi's** team focuses on the biosynthesis enzymes of these bioactive molecules. His research aims at decrypting the molecular mechanism behind the changes in these bioactive molecules at the atomic level using X-ray crystallography. This will pave the way to the development of novel derivatives with enhanced or new activity. His group revealed, among others, atomic details of substrate recycling by a flavoenzyme, the first of its kind in secondary metabolisms.



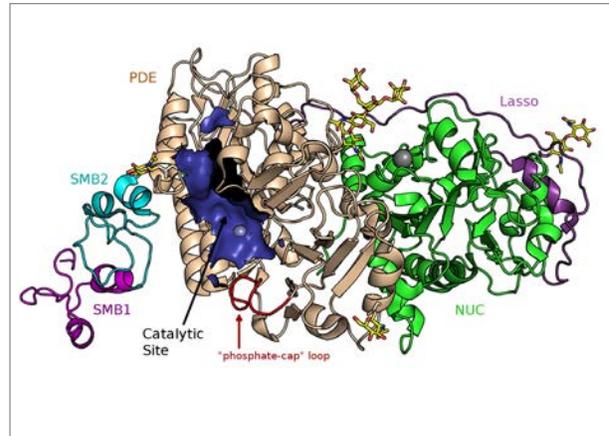
Knowledge acquired by **Mélanie Lemire's** team on mercury and lead exposure prompted Nunavik Public Health to develop and carry out several interventions and actions aimed at reducing lead exposure in pregnant women and children from Nunavik, as well as to promote the use of lead-free ammunition and increase the support to related actions at the federal level. These results also led to the Minamata Convention on Mercury, which came into force in the fall of 2017. The team's recent results, obtained in collaboration with Pierre Ayotte and his staff, helped discover a new selenium compound in the blood of the Inuit and Mattaaq beluga, named selenoneine. This compound has the potential to interact with mercury and to protect against its neuro-developmental toxicity. These results will lead to a revision of the risk assessment of selenium in the Canadian North and to public health interventions in the Arctic as well as elsewhere among coastal populations.



Work by **Patrick Laqu e**'s team helped characterize the structure and dynamics of the human NPP1 protein. This enzyme is associated to different pathologies in humans, such as aortic valve calcification, glioblastoma, arthritis and type 2 diabetes. It is therefore a prime therapeutic target, and results of this work are critical for drug development.

Roger C. Levesque's team developed approaches in microbial genomics enabling the complete sequencing and assembly of the bacterial chromosome, plasmids, phages, as well as a detailed analysis of virulence and antibiotic resistance encoding genes found in foodborne pathogens and in respiratory infections. This work was supported by the Genome Analysis and Sequencing Platform of IBIS. The creation in 2015 of the International Pseudomonas Consortium Database (IPCD), comprising more than 65 researchers internationally, helped his team analyze over 1763 isolates of *Pseudomonas aeruginosa* dating back to 1880 to this day and coming from 53 countries, covering five continents. The major Syst-OMICS project of salmonellae brought an important contribution based on genomic and phenotypic analysis of 3 163 isolates from *Salmonella enterica*. This metadata was integrated into two databases available online at <https://ipcd.ibis.ulaval.ca/> as well as <https://salfos.ibis.ulaval.ca/> and serves to develop new diagnostic and predictive technologies using machine learning. Data from these two major projects connect fundamental and clinical science and will lead to a better understanding of microbial pathogenesis and a better control of antibiotic treatments in human therapy.

Due to their expertise and their innovative and collaborative approaches, almost half of researchers from IBIS got grants from Genome Canada in the Genomic Applications Partnership Program (GAPP) and Large Scale Applied Research Project (LSARP) competitions for their projects in agriculture, agrifood, fisheries, aquaculture and forestry. These projects generate data on tens of thousands of samples that are mainly processed at IBIS by these research teams and platforms who carry out genomics and bioinformatics analyses. Ten IBIS researchers were involved in nine Genome Canada projects as project lead, co-lead or collaborator between 2015 and 2019.



CHAIRES—EXCELLENCE DES TRAVAUX MENÉS À L'IBIS

Soulignant l'excellence et le bien-fondé de leurs travaux de recherche, quatre chaires de recherche du Canada en génomique et en évolution ainsi qu'une chaire de la Faculté de médecine sont détenues par des chercheurs de l'IBIS.

Project Name IBIS Researchers Involved	Program	Start-up Year
<p>BioSurveillance of Forest Alien Enemies (BioSAFE) genomecanada.ca/en/biosurveillance-alien-forest-enemies-biosafe Richard Hamelin (lead) / Ilga Porth (lead) Louis Bernier (co-investigator) / Christian Landry (co-investigator) Roger Levesque (co-investigator)</p>	LSARP	2016
<p>CoAdapTree: Healthy Trees for Future Climates genomecanada.ca/en/coadapttree-healthy-trees-future-climates Richard Hamelin (lead)</p>	LSARP	2016
<p>Enhancing Production in Coho: Culture, Community, Catch (EPIC4) genomecanada.ca/en/enhancing-production-coho-culture-community-catch-epic4 Louis Bernatchez (lead) / Jean-Sébastien Moore (co-investigator)</p>	LSARP	2015
<p>Fast Tests for Rating and Amelioration of Conifers (FastTRAC) genomecanada.ca/en/fast-tests-rating-and-amelioration-conifers-fasttrac Jean Bousquet (lead) / Nathalie Isabel (co-investigator)</p>	GAPP	2015
<p>Protecting Canada's Forests Against Invasive Alien Species by Next Generation Biosurveillance genomecanada.ca/en/protecting-canadas-forests-against-invasive-alien-species-next-generation-biosurveillance Richard Hamelin (lead)</p>	GAPP	2015
<p>SoyaGen: Improving Yield and Disease Resistance in Short-Season Soybean genomecanada.ca/en/soyagen-improving-yield-and-disease-resistance-shortseason-soybean François Belzile (lead) / Richard Bélanger (co-investigator)</p>	LSARP	2015
<p>Spruce-Up: Advanced Spruce Genomics for Productive and Resilient Forests genomecanada.ca/en/spruce-advanced-spruce-genomics-productive-and-resilient-forests Jean Bousquet (lead) / Nathalie Isabel (co-investigator)</p>	LSARP	2016
<p>Sustaining and Securing Canada's Honey Bees Using 'Omics Tools genomecanada.ca/en/sustaining-and-securing-canadas-honey-bees-using-omic-tools Nicolas Derome (co-investigator)</p>	LSARP	2015
<p>A Syst-OMICS Approach to Ensuring Food Safety and Reducing the Economic Burden of Salmonellosis genomecanada.ca/en/systemics-approach-ensuring-food-safety-and-reducing-economic-burden-salmonellosis Roger C. Levesque (lead)</p>	LSARP	2015

OUR SERVICE PLATFORMS:

Essential expertise and know-how in support of research projects

IBIS developed an important know-how and a number of services in support of research projects. Our service platforms provide expertise and experience in mature technologies and innovative ones in order to propose an original and state-of-the-art approach to researchers, enabling them to achieve their research objectives. Our services are provided both internally and externally, to researchers and private companies.

SERVICES AVAILABLE

- > Genome analysis and sequencing
- > Bioinformatics
- > Imaging and microscopy
- > Scientific store



GENOME ANALYSIS AND SEQUENCING

Our genome analysis and sequencing services have existed for more than 25 years and, since 2010, a next-generation sequencing service is also offered. Our expertise is particularly well adapted to genome studies of non-model organisms, but also to those with reference genome. Our team's flexibility helps them adapt and develop protocols according to the needs of researchers.

Our professionals analyzed, between 2015 and 2019, more than 100 000 samples using next generation sequencing by Ion Proton and MiSeq, three quarters of which are for IBIS-based researchers.

A total of 536 requests for next generation sequencing were processed, most coming from Laval University researchers. Requests coming from external researchers and companies represent 41% of these, including 6% from outside Canada.



BIOINFORMATICS

Professionals of the Bioinformatics Platform serve researchers from the Laval University's community and elsewhere. The team is working on the development of original solutions to process genetic data requiring cutting-edge computational and programming techniques. It has at its disposal high performance data storage and calculation computer equipment. They regularly collaborate with researchers and students in order to provide technical training and to share their expertise in bioinformatics, helping them to use supercomputers and to carry out their research projects. For example, we developed several GBS data analysis and processing pipelines (SRG-Extractor, DepthFinder, Fast-GBS.v2). Training sessions for the analysis of 16S sequences in metagenomics were given to more than 12 research teams. The team shares more than 26 scientific publications as co-author.

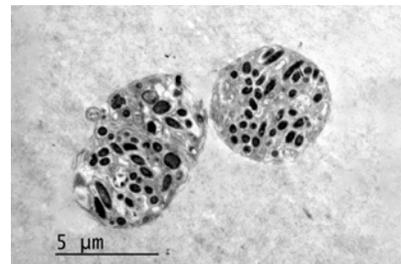
IMAGING AND MICROSCOPY

Professionals of the Imaging and Microscopy Platform share their expertise in electron and optical microscopy, histology and immunohistochemistry by serving research teams at Laval University and its affiliated centres. The team guides users in microscopy, in particular during protocol development, as well as for sample preparation, microscopic observations and interpretation of the results obtained. They also provide training sessions related to the proper use of these devices, for those who wish to supplement their knowledge at this level.

A variety of departments at Laval University are covered by this service. Requests for sample preparations are treated for research teams of the departments of Medicine, Biochemistry, Microbiology, Wood and Forestry Science, Physics, and Mining, Metallurgy and Materials. Requests from external researchers and companies represent 10% of the total.

SCIENTIFIC STORE

The Biobars Scientific Store is a warehouse for products related to science, such as laboratory supplies, chemicals and various materials at the disposal of Laval University members. The store's team processes thousands of orders per year. All requests are from researchers, departments and faculties of Laval University.



STUDENT TRAINING AT IBIS

Every year, more than 100 graduate students and about 40 postdoctoral researchers are trained at IBIS. Students benefit from the exceptional expertise of research professionals and technicians as well as numerous scientific video animations for their training.

The interdisciplinary nature of the research work taking place at IBIS allows them to collaborate and enrich their exchanges on issues related to their project.

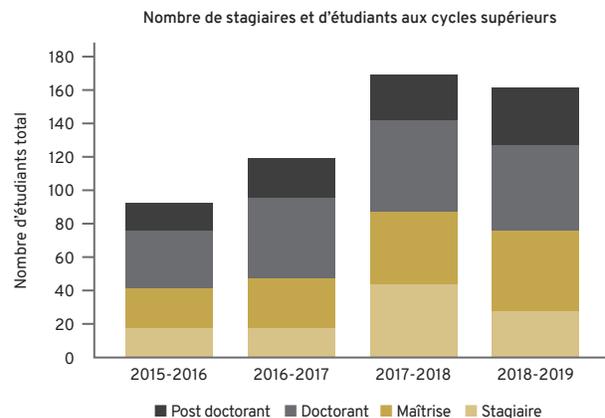
International students account for more than half of the graduate and internship students on our research teams, demonstrating the international interest in the research taking place at IBIS.

Research teams recruit high-calibre students to conduct their research project. Between 15% and 20% of our students were awarded an excellence scholarship from various programs and organizations, including Vanier (Marc-André Lemay, 2016) and Banting (Hugo Cayuela, 2018).

Recognized for the excellence of their research, their scientific communications or their involvement, our students regularly win prizes and scholarships when they participate in scientific congresses and science camps. In 2018, 22 students and postdoctoral researchers won prizes at conferences.

Myriam Labbé (centre), a doctoral student, received the great honours of the *Mon projet nordique* competition organized by the *Institut nordique du Québec* and the *Fonds de recherche du Québec nature et technologies* (FRQNT).

Between 2015 and 2019, 41 master's students and 25 doctoral students graduated. Most graduates obtained jobs in their field in government, private or academic organizations.



Marie-Pier Brochu and François Rouleau received a Scientific Leadership and Sustainable Development Scholarship from Laval University in 2018.



A. Baillargeon, Director of interdepartmental relations of Société du Plan Nord, M.-F. Desbiens, Head of FROSC Programs, M. Falardeau, laureate, C. PineI, FRQNT Programs Director, M. Lassonde, FRQNT Scientific Director, M. Labbé, M. Miranda laureates, S. Gagnon, laureate, C.-O. Simard, laureate, P. Lamontagne-Hallé, laureate, and B. Biqué, I.N.Q. Programs manager.

The scientific video animations set up at IBIS allow students and postdoctoral researchers to improve their training. Students are invited to play an important role in their training during their stay and, to do so, they have access to meetings of the Bioinformatics Club, the Interlab, “Journal clubs,” and IBIS conferences. Organized over lunchtime, these meetings take place on a weekly or bi-weekly basis, depending on the events. Reading clubs, the Bioinformatics Club and the Interlabs are run by students, postdoctoral researchers or research professionals.

The Bioinformatics Club, run by students and research professionals, regularly organizes training sessions ranging from a few hours to a few days, as well as presentations by students and postdoctoral researchers. Since 2015, a dozen introductory training courses in different programming languages have been organized to provide students and researchers with new tools and methods for data processing and analysis. Examples include an introduction to computer calculations, Python package, an introduction to R and ggplot2, and training on the integration of Bash, R and Python. Each of these courses brought together some 40 students and researchers.



Our seminars, complementary to the Interlabs, allow us to welcome nationally and internationally renowned researchers. They are organized by IBIS researchers and are an opportunity to develop future collaborations. Between 2015 and 2019, no less than 60 researchers from ten countries, including Canada, the United States, Australia, the Netherlands and Japan, came to present their work and meet members of IBIS and the four attached faculties.

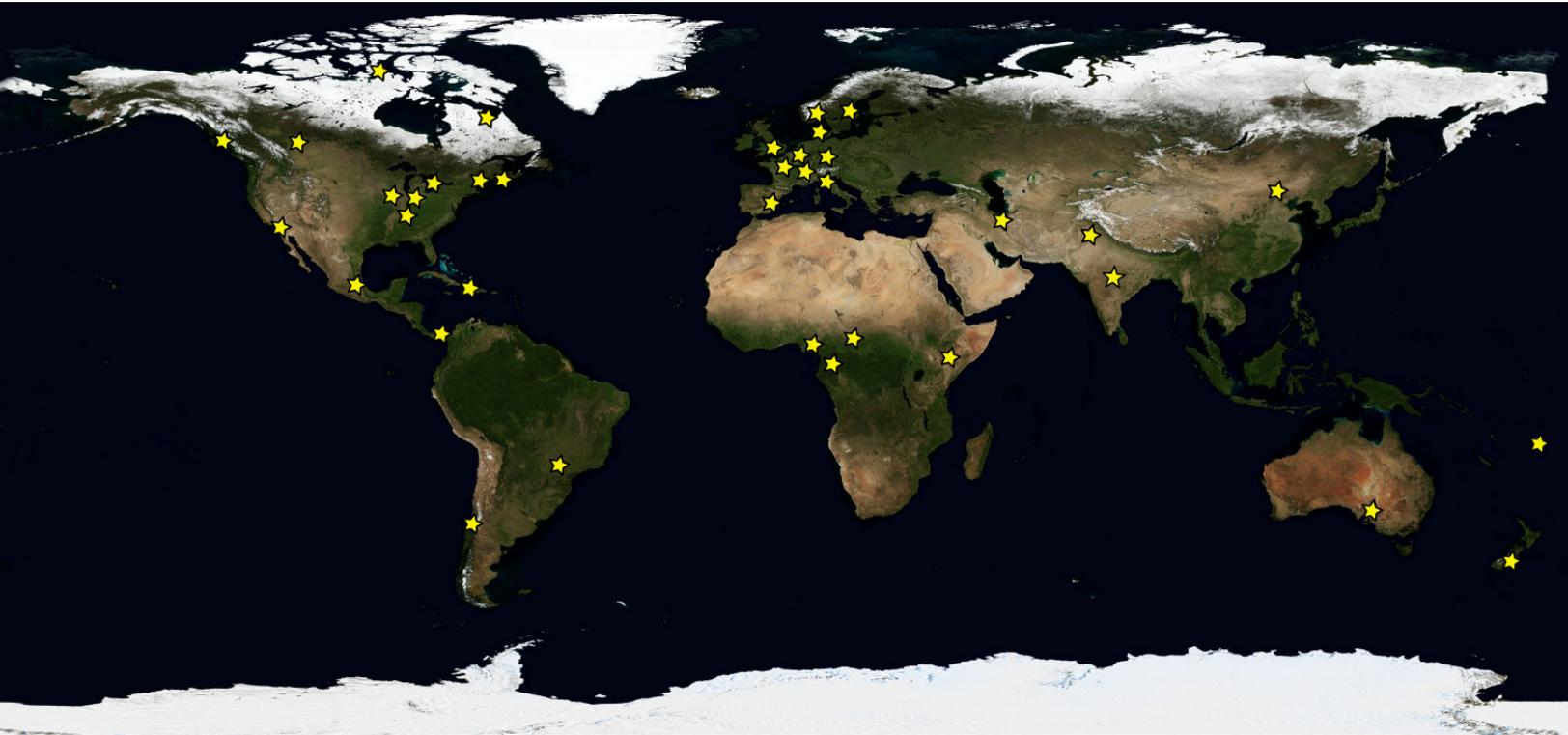


In 2018, the Institute hosted two workshops on population genomics and environmental DNA, both presented by Physalia Courses, an organization based in Berlin, Germany, that offers workshops in bioinformatics and genetics. Sixty researchers and students from 18 countries participated.

More Physalia Courses are planned in the coming years.



NATIONAL AND INTERNATIONAL COLLABORATIONS



IBIS researchers are deeply involved in their respective research fields and contribute to the international recognition of the Institute's expertise. They have developed important projects in collaboration with other researchers at the national and international level, showcasing IBIS's work in more than 20 countries, on all continents.

Our researcher's expertise allows them to be welcomed in internationally renowned institutions to improve and share their knowledge. Eight of our researchers have stayed abroad, including:

- > **Connie Lovejoy** who stayed in the laboratories of the Université Pierre et Marie Curie in Banyuls-sur-Mer (France) to carry out advanced flow cryometry analyses.
- > **Manon Couture** has perfected her training in microfluidic technology at the University of Michigan.
- > A stay at the EMBRAPA soya research station in Londrina (Brazil) enabled François Belzile to develop association analyses for resistance to *Diaporthe phaseolarum* in soybeans.
- > **Christian Landry** visited the University of Tokyo (Japan) twice to improve his knowledge in synthetic biology and the Kavli Institute for Theoretical Physics (KITP) of UC Santa Barbara to acquire knowledge of evolutionary cell biology.
- > **Roger C. Levesque** stayed at the Institut Pasteur (France) with the aim of perfecting microbial genomics and machine learning applied to enteric pathogens and opportunistic multi-resistant pathogens. In exchange, nine researchers were welcomed in the laboratories of IBIS members.

VISITING RESEARCHERS AT IBIS

2015-2016

Cortland Griswold, University of Guelph
Christian Landry's laboratory
Evolutionary genetics and theory of evolution

Tove Gabrielsen, UNIS, Svalbard, Norway
Connie Lovejoy's laboratory.
Microbial eukaryote project in the Arctic Ocean

2016-2017

Vincent Leignel from the University of Le Mans, France
Monique Turmel and **Claude Lemieux's** laboratory
Assembly and annotation of crab mitogenomes from
abyssal vents project

Yu Zhang, Department of Biological Science and
Technology Shaanxi University of Technology, Shaanxi
Province, PR China
François Belzile's laboratory
Association analyses for sclerotinia resistance in soybeans.

2017-2018

Marie-Louise Avana, University of Dschang, Cameroon
Damase Khasa's laboratory
Genomics of wild populations of yams (*Dioscorea bulbifera* L.)
from Cameroon and wild populations of Shea (*Vitellaria
paradoxa* C. F. Gaertn.) from Cameroon and Chad

Rasheed Adeleke, Agricultural Research Council, Pretoria,
South Africa

Damase Khasa's laboratory
Internship planning work for South African students in
metagenomics projects at coal mine sites in South Africa

Sylvia Bonilla, Facultad de Ciencias Universidad
de la República Uruguay
Connie Lovejoy's laboratory
Project to analyze phytoplankton and cyanobacteria
in lakes

Marie Nyange of the University of Kinshasa, Democratic
Republic of Congo
Damase Khasa's laboratory
Project on the intensification of agroforestry systems
for the production of purple yams (*Dioscorea alata*) to
increase food security for populations living near the Luki
Biosphere Reserve in the Democratic Republic
of the Congo

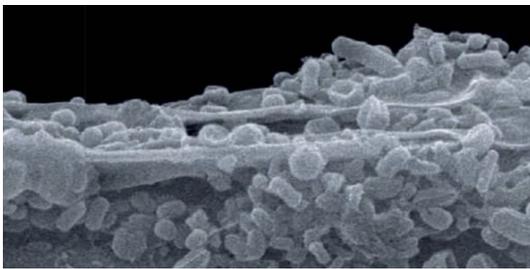
Nozomu Yachie, University of Tokyo
Christian Landry's laboratory
Synthetic biology

2018-2019

Philippe Silar, Université Paris 7–Paris Diderot
Louis Bernier's laboratory. Project on the biodiversity
of Lasiosphaeriaceae fungi

AWARDS AND RECOGNITION

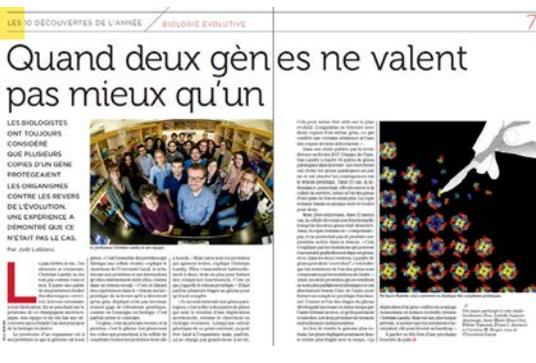
Each year, Québec Science selects the ten most impressive discoveries made in Quebec. In 2015, the discovery made by **Salma Taktek** from **Yves Piché** and **Hani Antoun's** team on the association between plant roots, mycorrhizae and bacteria capable of solubilizing phosphate was selected as one of the ten discoveries of the year and won the public's first prize.



In 2017, the local newspaper Le Soleil, listed the most remarkable scientific breakthroughs of the year and this list included the effects of the presence of a gene's copy in the genome of the yeast *Saccharomyces cerevisiae* by **Christian Landry** and his team.



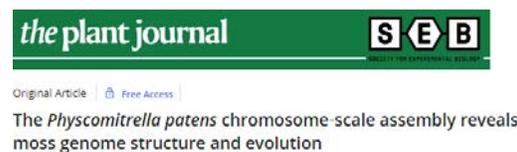
In 2017, **Christian Landry** and his team's discovery in evolutionary biology on the effects of the presence of a gene's copy in the genome of the yeast *Saccharomyces cerevisiae* was selected as one of the ten discoveries of the year.



En 2018, le Soleil a retenu au palmarès des percées scientifiques les plus remarquables, les résultats en épigénétique de **Louis Bernatchez** et son équipe montrant les effets sur la mortalité des populations sauvages de saumons élevés en pisciculture et relâchés en nature dans le but de remédier au déclin des populations.



Juan Carlos Villarreal and his collaborators received 2018's Most Outstanding Paper Award from The Plant Journal for the article: "The *Physcomitrella patens* chromosome-scale assembly reveals moss genome structure and evolution".



NATIONAL AND INTERNATIONAL RECOGNITION BY PEERS

In 2018, **Damase Khasa** was named the Water Management Theme Leader for the Canada-India Research Centre of Excellence (CIRCE; IC-Impacts).



Christian Landry was awarded the NSERC E.W.R. Steacie Memorial Fellowship in 2017. The goal of this fellowship is to promote the career advancement of outstanding and promising faculty members who are internationally renowned for their innovative research.



Bourse commémorative E.W.R. Steacie
Département de biologie
Université Laval

Jean-Sébastien Moore was awarded the Early Career Award 2017 from the American Fisheries Society, Genetics Section. This award recognizes the contribution of early career researchers in the field of fisheries genetics.



GENETICS SECTION

HOME NEWS NEWSLETTERS COASTWIDE JOBS AWARDS OFFICERS MEMBERSHIP CONTACT

CONGRATULATIONS TO OUR 2017 EARLY CAREER AWARD WINNER DR. JEAN-SÉBASTIEN MOORE!

August 10, 2017 | Awards



The AFS Genetics Section would like to congratulate Dr. Jean-Sébastien Moore as the recipient of the 2017 Early Career Award. The goal of the Early Career Award is to promote innovative genetics research, increase interest in fisheries genetics careers, and enhance professional connections among fisheries geneticists. Jean-Sébastien is an Assistant Professor at Laval University in the Département de Biologie and Institut de Biologie Intégrative et des Systèmes. After studying effects of gene flow on stickleback evolution, Jean-Sébastien headed north to

In 2016, **Louis Bernatchez** was elected as a member of the Hall of Excellence, Genetics Section, of the American Fisheries Society. This recognition is awarded annually to a researcher who internationally distinguished themselves for their overall achievements in genetics applied to fisheries management and aquatic wildlife conservation. He also received the Molecular Ecology award from the publisher Wiley, which is annually awarded to a researcher who has internationally distinguished themselves for their overall achievements in the field of molecular ecology and conservation genetics.

American Fisheries Society Genetics Section Hall of Excellence



ACADEMIC AWARDS

RECONNAISSANCES UNIVERSITAIRES

Summa Award

Each year, the Faculty of Science and Engineering recognizes the remarkable careers of its members who have distinguished themselves in teaching, research, service to the faculty community or for their outstanding career. Two of our professors were awarded the Summa Award in 2015 and 2016: **Steve Charette** in teaching and **Christian Landry** in research.



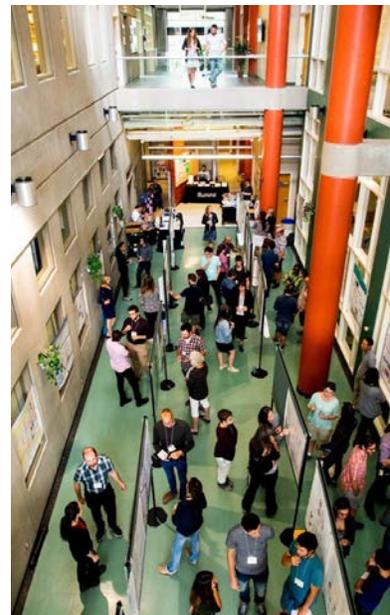
Professeur Étoile Award

Every year, the Faculty of Science and Engineering recognizes the work of its professors and lecturers who have received excellent ratings from their students with the *Professeur Étoile* Award. Eight professors member of the Institute distinguished themselves: Professors **Nadia Aubin-Horth** and **Steve Charette** received the title for a 5th year.



KNOWLEDGE TRANSFER AND POPULARIZATION

Since 2010, IBIS students have been involved in organizing an annual event called the *Journée scientifique des étudiants de l'IBIS* (IBIS Student Science Day), where they present their projects or research results. It is an excellent opportunity for students to discuss and develop new collaborations. Approximately 100 participants, students, postdoctoral fellows, research professionals and researchers from the Institute have annually attended this event for the past five years. An internationally renowned speaker is invited to speak at this event.



MINILABORATOIRE EN CLASSE (IN-CLASS MINILAB)

Roger C. Levesque's team works closely with Génome Québec and the Education Platform for Genomics Valorization. This platform is primarily intended for high school students and science and technology teaching staff. It introduces the basic concepts of genetics, in addition to introducing the more advanced concepts of genomics. Génome Québec also offers free classroom activities to enable students to put their knowledge into practice.



DESTINATION ADN
MINILABORATOIRE SCIENTIFIQUE EN CLASSE

FLIGHT 450 MINILAB IN CLASSROOM—DESTINATION DNA

This mini-laboratory activity is a learning and assessment situation for students in secondary 3 to 5. During this minilab, high school students take part in a scientific investigation and live an enriching experience. They perform a polymerase chain reaction (PCR) to replicate real human DNA fragments and then analyze PCR results by migrating the DNA into an agarose gel through electrophoresis. The kit includes all the materials required for DNA manipulation. It is delivered free of charge to participating schools and includes everything needed for the activity (thermocycler, transilluminator, centrifuge, test tubes, pipettes, etc.). Between 2017 in the spring of 2019, more than 2332 high school students from 26 schools participated in this scientific outreach activity, allowing to increase their knowledge of DNA.

IBIS researchers regularly popularize and disseminate their knowledge to the general public through media interventions, both in print, radio and television. Between 2015 and 2019, approximately 70 articles were written (in French, English and Spanish), 20 radio interventions were done, and 15 television appearances were conducted. Here are some examples:

Roger C. Levesque was invited on Radio-Canada's *Les années lumières* to explain his project on salmonella strain sequencing in order to develop means to eradicate it (August 2015).



Louis Bernatchez was invited to the *La semaine verte* program on ICI Radio-Canada Première. He explained the use of environmental DNA as a tool for the management of fish species exploited by the fishing industry (November 2016).



The work of Alexander Culley, Warwick Vincent (associated professor at IBIS) and their team in the Arctic was presented in the magazine *Québec Science* in 2017.



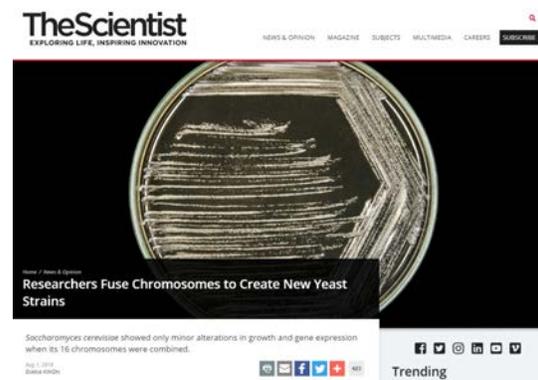
Jean Bousquet was invited on Radio-Canada's *Première Heure* radio show to explain his Spruce-Up research project with Genome Canada, and how genomic tools can be used to identify the potential of trees to adapt to climate change (May 2017).



The work of **Mélanie Lemire** and her team on the exposure of Nunavik residents to contaminants was the subject of a feature in *Le Soleil* (February 2019).



The work of **Christian Landry** and his team on the creation of new yeast strains by chromosome fusion was presented in *The Scientist* magazine.



The work of **Nicolas Derome** and his team on probiotics in bees was the object of a feature by Jean-François Cliche of *Le Soleil* (May 2018).



IBIS researchers are also featured in mainstream newspapers in the countries where their projects are taking place. For example, **Patrice Dion's** work in agriculture in Haiti was presented in the Haitian newspaper *Le Nouvelliste*. *La Prensa*, a Panamanian newspaper, presented **Juan Carlos Villarréal's** work on the Arctic and his career.





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