

Sentinel  
North



SHEDDING LIGHT ON THE NORTH  
ENVIRONMENT | HEALTH | INNOVATION

ACTIVITY REPORT  
2018 | 2019



Sentinel North



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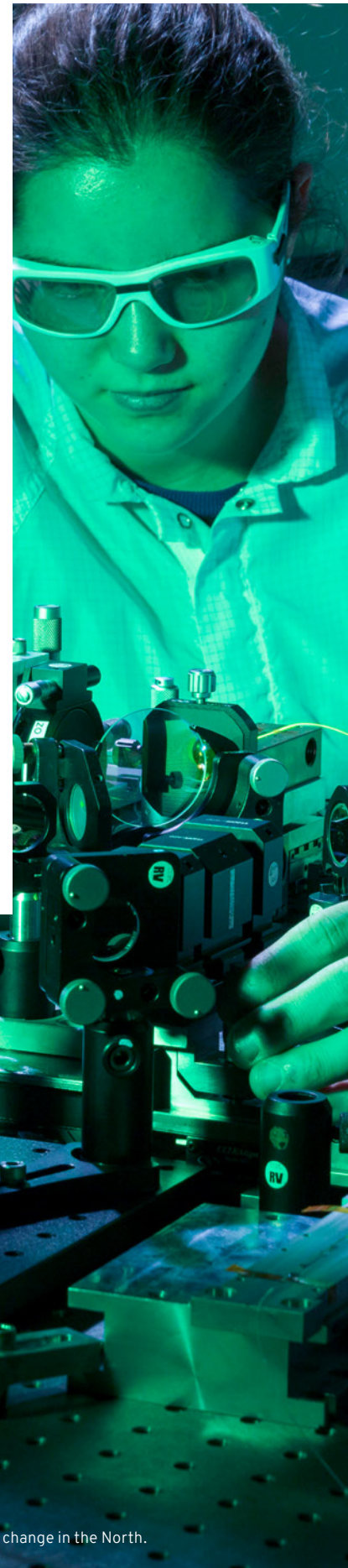
With its Sentinel North strategy, Université Laval is building on half a century of excellence in northern and optics/photonics research to conduct transformative research, develop innovative new technologies, train a new generation of transdisciplinary researchers, and improve our understanding of the northern environment and its impact on humans and their health.

The program is made possible, in part, thanks to funding from the Canada First Research Excellence Fund.

Canada



UNIVERSITÉ  
LAVAL



New photonic sensor platforms are being developed to improve our understanding of the dynamics of environmental change in the North.



Sentinel  
North



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ENVIRONMENT | HEALTH | INNOVATION

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Projects that combine neuroscience and optics/photonics shed light on how living tissues are organized.

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## Vision

To shed light on the northern environment and its impact on humans by means of innovative light-based technologies and trans-sectoral initiatives in support of sustainable health and development.

# Message from Management

Over the past few years, the growth of Sentinel North has injected a new dynamic into the way research is being conducted at Université Laval. By lowering the barriers between disciplines, the program has succeeded in mobilizing the full diversity of our institution's research community. The strategy rapidly resulted in the creation of new research and training initiatives in a spirit of convergence, collaboration and innovation, and in a better understanding of changes in the northern environment and their impact on human beings and their health.

Sentinel North now involves more than 600 professors, graduate students, postdoctoral fellows and professionals from 34 departments, 30 research centres and 7 faculties, working with more than 400 partners and collaborators from 120 institutions in more than 20 countries.

The year 2018-2019 was particularly rich in achievements:

- Several new research projects were launched, including 11 joint projects with Norwegian and French teams, bringing to 45 the total number of transdisciplinary teams working within the program.
- The recruitment of 6 new Sentinel North research chairs brings to 24 the number of new professors hired since the beginning of the program who directly contribute to its mission.
- The research teams have produced and delivered more than 700 scientific publications and communications, the majority of which are the result of new collaborations between researchers of varied expertise.

- Our 2018 Scientific Meeting enabled more than 350 students, researchers, collaborators and partners to disseminate their research results and forge ties with Canadian and international collaborators and partners.
- Our research excellence scholarships competitions led to the recruitment of 24 master's and doctoral students and 10 high-level postdoctoral fellows.
- Our international PhD schools and mobility programs provided more than 100 students, postdoctoral fellows and professionals from 15 countries with access to experiential training in the Arctic and at international institutions, accompanied by established mentors.

Building on these accomplishments, we are entering the second phase of the program with tremendous momentum and a concrete indication of the major impact that Sentinel North is having on the training of new transdisciplinary researchers, the consolidation of our international collaborations, the commitment of our partners, and the leadership role of Université Laval in research areas that inform and support sustainable health and development in the North. During the next phase, we anticipate the growing engagement of young researchers in the leadership of this great collective initiative. This new generation of leaders will help transform the way we approach the major societal issues of our time; towards a more integrated, collaborative, convergent and open approach.



**Eugénie Brouillet**  
Vice Rector, Research and Innovation  
Chair, Sentinel North Steering Committee



**Martin Fortier**  
Executive Director, Sentinel North  
Assistant to the Vice Rector, Research and Innovation



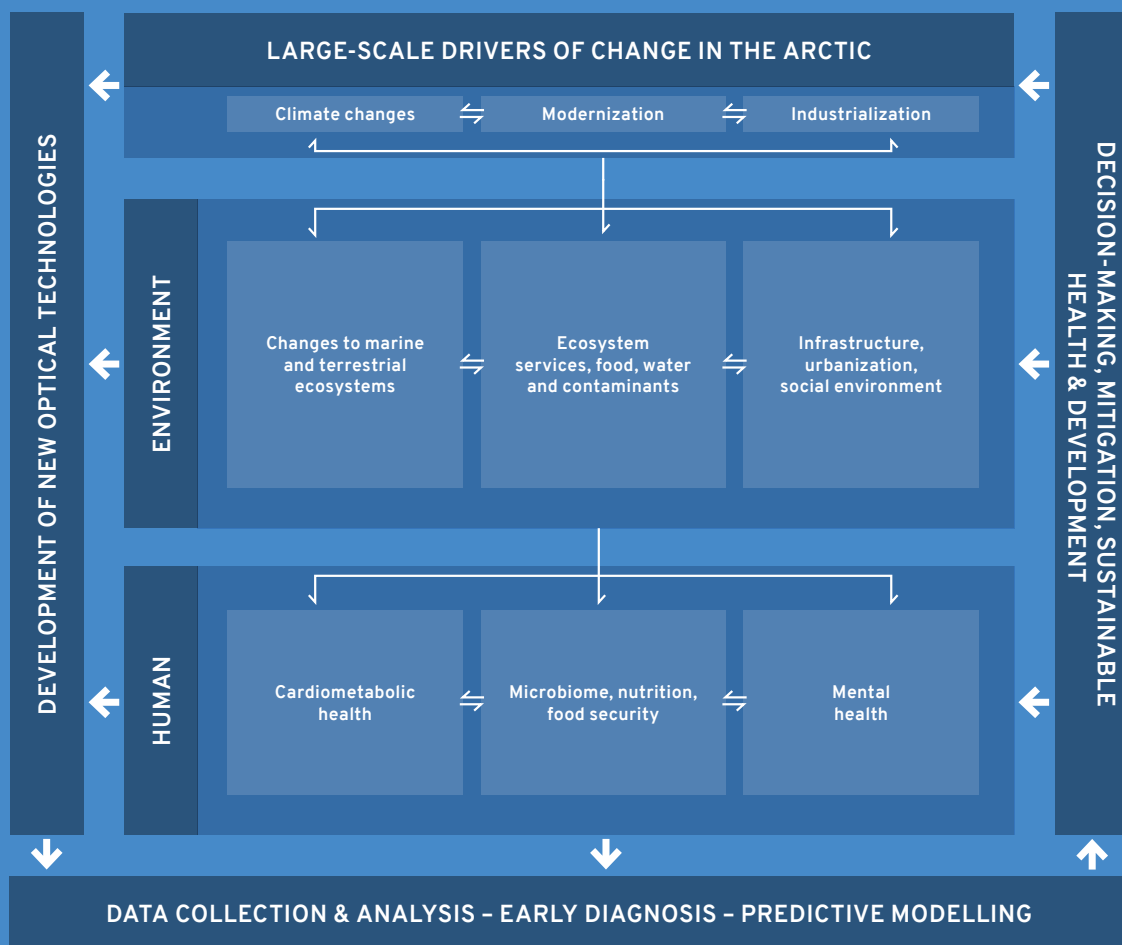
**Yves De Koninck**  
Scientific Co-Director, Sentinel North  
Director, CERVO Brain Research Centre



**Marcel Babin**  
Scientific Co-Director, Sentinel North  
Laureate of the CERC in Remote Sensing of Canada's New Arctic Frontier

## Conceptual Framework

In the face of accelerating climate change and socioeconomic development in the Arctic and sub-Arctic, the Sentinel North research program helps generate the knowledge needed to monitor and prepare for environmental changes at multiple levels—from microbes to ecosystems—using better technologies, predictive models, and intervention strategies oriented toward sustainable health and development.

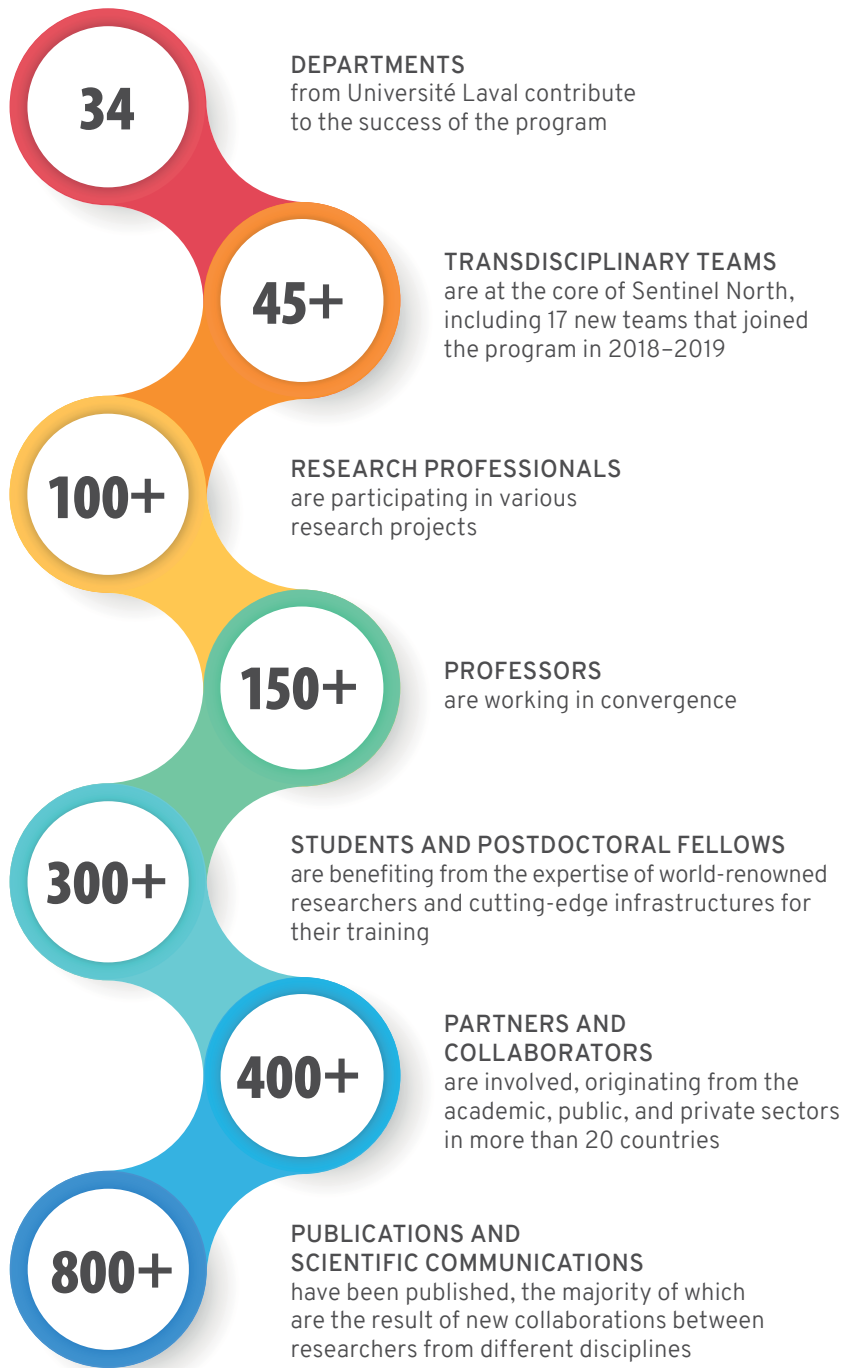




## Sentinel North at a Glance

### Environment, health, and innovation as cornerstones

Sentinel North aims to mobilize Université Laval's rich and diverse research community and lower barriers between disciplines to improve our understanding of the northern environment and its impact on humans and their health.





Researchers are working with a vast network of collaborators to better understand extreme weather events.



# Research

## WHERE ENVIRONMENT, HEALTH, AND OPTICS/ PHOTONICS INTERSECT

The Sentinel North research program encourages the development of collaborative teams and research projects with an emphasis on discovery, transdisciplinarity, innovation, teamwork, national and international partnerships, and technology transfer. It builds on the convergence of research areas in which Université Laval is already recognized as a national and international leader, notably through the attribution of four Canada Excellence Research Chairs in the fields of northern and Arctic science, optics/photonics, cardiometabolic health and the microbiome, and neuroscience.

## A focus on transdisciplinary and innovative research

4

Canada Excellence Research Chairs (CERCs)

Drawing on Université Laval's four Canada Excellence Research Chairs, Sentinel North's research program focuses on convergence, thereby encouraging research collaborations and the merging of expertise for the purpose of understanding northern issues.

Associated with the CERCs, the 4 Joint International Research Units established in 2017 bring together the expertise of renowned researchers from France, Brazil, Switzerland, and Italy.

4

Joint International Research Units

21

projects under 3 research themes

Following the first call for proposals in 2017, 21 transdisciplinary projects under 3 research themes were launched as part of Sentinel North's core research program.

### 2018-2019

The 10 Sentinel North Research Chairs, **6 of which are newly funded**, promote a better understanding of the environment and its impact on humans.

10

Sentinel North Research Chairs

11

international collaborative projects

In the spirit of international and transdisciplinary collaboration, Sentinel North joined forces with **2 other universities** (Université Côte d'Azur and UiT The Arctic University of Norway) on 11 new research projects in **2018-2019**.

## Joint International Research Units

The Joint International Research Units allow Sentinel North to draw on exceptional international teams in pursuit of its research and technology development objectives.

Takuvik Joint International Research Unit (French National Centre for Scientific Research, France), associated with the CERC in Remote Sensing of Canada's New Arctic Frontier (Chairholder: Marcel Babin)

Québec-Brazil Photonics Research Joint International Research Unit (Sao Paulo State University, Brazil), associated with the CERC in Photonic Innovations (Chairholder: Younès Messaddeq)

Joint International Research Unit in Child Neural Development and Psychiatry (Université de Lausanne, Switzerland), associated with the CERC in Neurophotonics (Chairholder: Pierre Marquet)

Joint International Research Unit for Chemical and Biomolecular Research of the Microbiome and Its Impacts on Metabolic Health and Nutrition (National Research Council, Italy), associated with the CERC in the Microbiome-Endocannabinoidome Axis in Metabolic Health (Chairholder: Vincenzo Di Marzo)



### TECHNOLOGY MATURATION FUND

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Since April 2018, Sentinel North's researchers have had access to a Maturation Fund that supports projects with strong commercialization potential. Funding is intended to support the steps to help a technology reach a level of maturity that will allow an operating license to be granted to an industrial partner or allow consideration of the creation of a start-up company. Eight innovations are currently being supported, including a microchamber for *in-situ* culture of cells and microorganisms, materials for solar cells with high conversion efficiency, a medium infrared laser source for remote gas detection, and an electrode-based smart fabric made with flexible fibres for real-time detection of electrophysiological activity.



## RESEARCH THEME 1

# Complex systems: Structure, function and interrelationships in the North

Steering Committee: Frédéric Maps, Biology;  
Leslie Ann Rusch, Electrical and Computer Engineering;  
René Therrien, Geology and Geological Engineering

Coordination: Vani Mohit

The North, with its multiple interconnected networks, is a vast and complex system confronted by rapid climatic, ecological, economic, and social changes. The theme's main goal is to develop a better understanding of the internal logic of northern complex systems, which depends in part on mutual interactions.

About 40 researchers and collaborators from Université Laval and their partners work in this theme's 5 projects. They explore northern systems at every level—from the microscopic (microbiota) to the mesoscopic (biodiversity, infrastructure) and macroscopic (permafrost, ecosystems, society)—using powerful numerical models and a new generation of optical sensors with multiple networking capabilities.

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Research Theme 1 uses powerful digital models and innovative technologies to decode the northern environment.

1.1 Network analysis of umbrella and indicator species: Assessing the integrity of northern ecosystems

Principal investigator: Daniel Fortin, Biology

1.2 The resilience of complex networks: Identifying critical indicators for efficient targeted interventions

Principal investigators: Patrick Desrosiers, Physics, Physical and Optical Engineering; Simon Hardy, Computer Science and Software Engineering

1.3 Characterization and modelling of the key interrelationships of northern water systems under climatic, geosystemic, and societal pressures

Principal investigator: René Therrien, Geology and Geological Engineering

1.4 Photonic ultimate sensing (PULSE) and monitoring of permafrost environments

Principal investigators: Sophie LaRochelle, Electrical and Computer Engineering; Richard Fortier, Geology and Geological Engineering

1.5 Pitutsimaniq, networked sensor sentinels for real-time surveillance of infrastructures and ecosystems

Principal investigators: Michel Allard, Geography; Leslie Ann Rusch, Electrical and Computer Engineering



WATER QUALITY  
ACCORDING TO  
CLIMATE CYCLES

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Under the supervision of professors Alexander Culley, Manuel Rodriguez and Steve Charrette, postdoctoral fellows Perrine Cruaud and Adrien Vigneron examined the annual cycle of microbial communities in seasonally ice-covered freshwater ecosystems. This team, which contributes to project 1.3 and includes experts in microbiology, ecology and water engineering, correlated variations in bacterial communities to seasonal changes in various environmental parameters (temperature, rainfall, snow cover, etc.), which could have potential consequences on water quality.

Results from this research project were published in 2019 in *Limnology and Oceanography*: “Annual bacterial community cycle in a seasonally ice-covered river reflects environmental and climactic conditions.”



## RESEARCH THEME 2

# Light as a driver, environment, and information carrier in natural environments and human health

Steering Committee: Philippe Archambault, Biology;  
Claude Demers, Architecture; Réal Vallée, Physics,  
Physical and Optical Engineering

Coordination: Jérôme Lapointe

At high latitudes, major seasonal variations in photoperiod and snow and ice cover cause significant variability in the availability and quality of light affecting northern ecosystems and societies.

The objective of this research theme is to study the propagation of light through different substrates, its interaction with matter, and its influence on physiology and biorhythms.

With 50 members from Université Laval and dozens of collaborators, the theme's 8 projects use the design and application of new optical sensors and technologies to study biochemical and geochemical processes, the detection of climatically active compounds, and sustainable energy production.

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Light is an essential vector of energy and is both the object and instrument of study for Research Theme 2.



### 2.1 Optimizing biophilia in extreme climates through architecture

Principal investigators: Claude Demers, Architecture; Marc Hébert, Ophthalmology and Otorhinolaryngology

### 2.2 Innovative optical systems to track winter life in the cryosphere

Principal investigator: Gilles Gauthier, Biology

### 2.3 The use of diatom microalgae for improving the treatment of the light-driven dysfunctions of the biological clock in Arctic human populations

Principal investigator: Johann Lavaud, Biology

### 2.4 A better understanding of light-matter interactions

Principal investigator: Pierre Marquet, Psychiatry and Neuroscience

### 2.5 Printed solar cells for small remote instruments

Principal investigator: Mario Leclerc, Chemistry

### 2.6 Beacons Of Northern Dynamics (BOND) – Developing light-based sensing technologies to monitor climate active gases in a mutating Arctic

Principal investigator: Réal Vallée, Physics, Physical Engineering and Optics

### 2.7 Observing Arctic substrates: Unveiling ice, water column, and benthic physical and biological properties using laser remote sensing from autonomous underwater vehicles and unmanned aerial vehicles

Principal investigators: Philippe Archambault, Biology; Michel Piché, Physics, Physical Engineering and Optics

### 2.8 Development, implementation, and use of miniature portable technologies for the prevention, assessment, and treatment of chronic diseases in northern areas

Principal investigator: Laurent Bouyer, Rehabilitation



## USING BIOPHILIC ARCHITECTURE TO BENEFIT NORTHERN COMMUNITIES

The built environment in the North has traditionally been adapted to significant variations in the availability of natural light. However, the buildings that local residents and new northern workers occupy today largely ignore biophilia—humans’ innate attraction to light.

Under the direction of Claude Demers and Marc Hébert, Mojtaba Parsaee, a PhD student in architecture, is proposing an innovative solution to this challenge, one that combines architecture, ophthalmology and electrical and computer engineering. His project involves designing facades that adapt to light conditions in order to maximize the energy efficiency of buildings—and promote the health of their occupants—in the extreme cold of the North.

In 2019, Parsaee *et al.* published the article “A photobiological approach to biophilic design in extreme climates” in the international scientific journal *Building and Environment*.



### RESEARCH THEME 3

## Microbiomes: sentinels of the northern environment and human health

Steering Committee: Pierre Ayotte, Social and Preventive Medicine; Denis Boudreau, Chemistry; André Murette, Medicine; Warwick F. Vincent, Biology

Coordination: Philippe St-Pierre

Microbiomes are predominant in the atmosphere, hydrosphere, cryosphere, soils, fauna, and humans. With the core objective of determining the roles of microbiomes in the northern human-environment ecosystem, this team of 75 researchers and collaborators from Université Laval and their partners will develop and deploy new photonic sensors and new sampling and analysis methods for a wide range of microbiological data to monitor ecosystems, nutrition, and human health in the North.

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Research Theme 3 examines the influence of food quality on the health and microbiome of northern residents.

### 3.1 Sentinel microbiomes for Arctic ecosystem health

Principal investigators: Daniel Côté, Physics, Physical Engineering and Optics; Warwick F. Vincent, Biology

### 3.2 Comprehensive environmental monitoring in the North: From molecules to microorganisms

Principal investigator: Jacques Corbeil, Molecular Medicine

### 3.3 BriGHT (Bridging Global change, Inuit Health and the Transforming Arctic Ocean)

Principal investigators: Jean-Éric Tremblay, Biology; Mélanie Lemire, Social and Preventive Medicine

### 3.4 Enabling tools for the monitoring of food quality in the northern environment

Principal investigators: Dominic Larivière, Chemistry; Jean Ruel, Mechanical Engineering

### 3.5 Impact of environmental conditions on airway microbiota and respiratory health in the North

Principal investigators: François Maltais, Medicine; Marc Ouellette, Microbiology, Infectious Disease and Immunology

### 3.6 The gut microbiome: Sentinel of the northern environment and Inuit mental health

Principal investigators: Richard Bélanger, Pediatrics; Gina Muckle, Psychology

### 3.7 Optogenetics investigation of microbiota influence on brain development and epigenetics

Principal investigators: Paul De Koninck and Sylvain Moineau, Biochemistry, Microbiology, and Bioinformatics

### 3.8 Deciphering host-microbial interactions for cardiometabolic and mental health disorders with novel multimodal light-based sensing tools

Principal investigators: Denis Boudreau, Chemistry; André Murette, Medicine



## ACCESS TO NORTHERN INFRASTRUCTURE FUND

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The Access to Northern Infrastructure Fund was created to help mitigate the high costs of conducting research in the North. In 2018–2019, it funded 40 hours of aircraft flights, 81 researcher-days at sea on the Canadian research icebreaker CCGS *Amundsen* and access to land-based northern research stations for a total of 566 researcher-days in the field.



A chemistry team works with researchers and students in biophotonics, engineering physics, and mechanical engineering. Left to right: Audrey Laberge-Carignan, Dominic Larivière, Mathieu Lamarre, Audrey Picard-Lafond, Adolfo Javier Sepúlveda San Martín, Denis Boudreau, and Nicolas Fontaine.



## TRANSDISCIPLINARITY FOR THE BENEFIT OF THE NORTH

Under the supervision of chemistry professors Denis Boudreau and Dominic Larivière, Audrey Picard-Lafond, a PhD student in chemistry contributing to project 3.4, is developing a fluorescent nanotool that will allow northern populations to identify contaminants in traditional foods without the use of a laboratory.

A recipient of the Ryan Harris Graduate Student Award from the Chemical Institute of Canada and a Vanier Canada Graduate Scholarship, Audrey joined Sentinel North because she wanted to contribute to a project that focused on health and the environment with a direct link to northern communities. Her nanotool uses a molecule that emits light in the presence of mercury, which greatly simplifies and accelerates the detection of contaminants compared to traditional laboratory tests.

*“Having access to qualified mentors to carry out a concrete project is an incredible benefit of being part of the Sentinel North community. Not only does it allow the project itself to progress at a good pace, but the interactions that come with it enrich my network and give me access to many experts that I can rely on in the future. This is a significant advantage over a single-discipline project and program.”*

- Audrey Picard-Lafond, Student, Chemistry, ULaval

*“The transdisciplinarity that Sentinel North promotes means that I can discuss topics or problems with researchers who have very different experiences and skills from mine. However, we share common objectives: learning a new vocabulary, developing a common language (taming acronyms!), learning to trust each other, understanding the issues in areas that would otherwise remain opaque to us, and combining all these skills to develop a new understanding of the subject that we simply couldn't obtain in any other way.”*

- Denis Boudreau, Chemistry, ULaval



## TECHNOLOGICAL INSTRUMENT DEVELOPMENT PLATFORM

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The Technological Instrument Development Platform, one of Sentinel North's core services, was launched in 2017 to meet researchers' and students' needs. The platform team provides unique assistance with the development, production, integration, qualification, launch, and operation of products, such as sensors, that are adapted to the extreme climate of the North. Working closely with researchers and students from 15 Sentinel North projects, the team has developed 6 prototypes and is currently working on 7 others, in addition to several new custom technologies.

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A team of researchers is examining the ecophysiological mechanisms that allow phytoplankton species to live in extreme conditions.



## New Sentinel North Research Chairs



In the past year, **six new professors** have been recruited through Sentinel North's Research Chair program, joining the four existing chairholders to enhance Sentinel North's transdisciplinary research program and strengthen Université Laval's capacity in strategic research areas.

### Mathematical Modelling of Complex Systems and Networks

Antoine Allard, Science and Engineering

With this chair, the objective is to develop the next generation of mathematical tools to better understand and model complex systems of all kinds, from the brain to ecosystems, and thus better understand the changing North. These tools will be used, for example, to study the spread of infectious diseases in northern communities.

### Light to Probe Life and the Environment - in partnership with the CERVO Foundation, the CERVO Research Centre, Pfizer and Université Laval's Faculty of Medicine

Antoine Godin, Psychiatry and Neurosciences

The goal of this chair is to develop non-invasive light-based tools to deepen our understanding of the way living tissues are organized, and how that organization affects various pathologies. These non-invasive portable technologies will promote medical research and diagnosis in remote areas.

### Economics and Brain Health - in partnership with the CERVO Foundation, the Capitale-Nationale Centre intégré universitaire de santé et de services sociaux (CIUSSS) and Université Laval's Faculty of Social Sciences

Maripier Isabelle, Economics

The work conducted as part of this chair will allow us to understand the dynamics and links between the evolution of income inequality, the organization of healthcare systems, and brain health. In particular, the chair aims to use this knowledge to help develop strategies that promote the well-being, inclusion, and social mobility of different populations, including northern communities.

### Molecular Neurobiology of Mood Disorders - in partnership with the CERVO Foundation and Pfizer

Benoit Labonté, Psychiatry and Neurosciences

The network science approach to decipher the interactions between genes in the brains of men and women with mood disorders will help us to understand, among other things, how environmental factors affect human beings and their health.



Projects focus on the relationships between health and the environment, in collaboration with northern communities and organizations.

### Impact of Animal Migrations on Arctic Ecosystems

Pierre Legagneux, Biology

This chair aims to understand the complex interconnections in Arctic ecosystems and examine the consequences of new connections created by migratory movements, particularly bird migrations between the North and other parts of the globe.

Ecosystemic Approaches to Health - in partnership with the Northern Contaminants Program of the Ministry of Crown-Indigenous Relations and Northern Affairs Canada, Indigenous Services Canada and Air Inuit

Mélanie Lemire, Social and Preventive Medicine

This interdisciplinary research chair focuses on the health and resilience of indigenous peoples living in northern coastal regions. The research is conducted in close collaboration with these communities. Studying the complex effects of environmental change on health and well-being will aid in the development of relevant preventive actions for indigenous and coastal populations.

### Chairs launched in 2017-2018

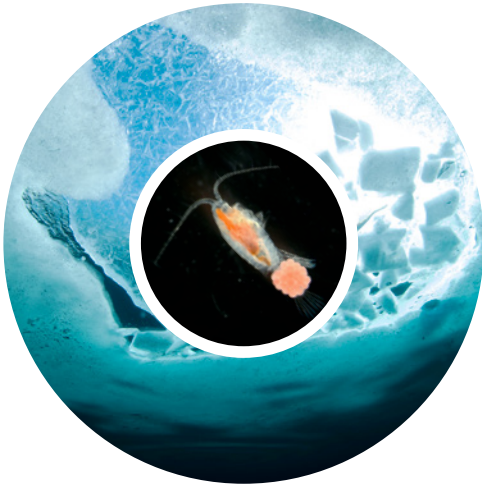
Aquatic Environmental Geochemistry  
Raoul-Marie Couture, Science and Engineering

Relations with Inuit Societies  
Caroline Hervé, Social Sciences

Neurobiology of Stress and Resilience  
Caroline Ménard, Medicine

Surveillance of Avian Influenza Viruses in Migratory Birds in Northern Canada  
Gary Wong, Medicine

## International collaborative projects



The population dynamics of copepods in the North give us insight into changes in northern marine ecosystems.

### UiT The Arctic University of Norway

As the main Arctic research universities in their respective countries, Université Laval (ULaval) and UiT The Arctic University of Norway (UiT), in Norway, have brought their complementary expertise into 6 new collaborative projects.

**UiT** / THE ARCTIC UNIVERSITY  
OF NORWAY

#### Screening for Emerging Arctic health Risks to Circumpolar Human populations (SEARCH)

Principal investigators:

Pierre Ayotte – ULaval (Preventive and social medicine)  
Torkjel M. Sandanger – UiT

#### The characterization of underneath sea-ice light field variability in the Arctic Ocean using underwater and aerial autonomous vehicles

Principal investigators:

Marcel Babin – ULaval (Biology)  
Jørgen Berge – UiT

#### CalAct: The impact of light and temperature on Calanus activity patterns in the Arctic

Principal investigators:

Louis Fortier – ULaval (Biology)  
Malin Daase – UiT

#### Can we envision net-zero energy buildings in the High North? A Canada/Norway comparative study with prefabrication solutions for highly energy efficient buildings.

Principal investigators:

Louis Gosselin – ULaval (Mechanical engineering)  
Raymond Riise – UiT

#### The role of circadian clocks in seasonal synchrony in the Arctic

Principal investigators:

Johann Lavaud – ULaval (Biology)  
David Hazlerigg – UiT

#### Calanus redness index from artificial intelligence applications to image analysis (CARDINAL): creating the link between satellite and individual-scale imagery for ecosystem-based management of a keystone species in subarctic seas

Principal investigators:

Frédéric Maps – ULaval (Biology)  
Sunnje Basedow – UiT



## Université Côte d'Azur

Through the Sentinel North strategy, Université Laval has partnered with the IDEX program at Université Côte d'Azur (UCA) to develop 5 innovative research projects on which researchers from these universities are working in convergence.



Preliminary results from Sentinel North have shown that nordicity clearly impacts the metabolism and chemical diversity of plants, leading to new essential oils.

Development of photonic devices to generate mid-infrared laser pulses suitable for remote gas spectroscopy

**Principal investigators:**  
Martin Bernier – ULaval  
(Physic, physical engineering and optics)  
Bernard Dussardier - UCA

Frame shift mutation-induced ATI influence on the microbiome

**Principal investigators:**  
Arnaud Droit – ULaval (Molecular medicine)  
Guillaume Sandoz – UCA

Artificial intelligence application for to the identification of functional traits of zooplankton from high-resolution images (ARTIFACTZ)

**Principal investigators:**  
Frédéric Maps – ULaval (Biology)  
Lionel Guidi – UCA

Pinealocyte-derived melatonin: a chronobiotic hormone that modulates the effects of photoperiod on energy homeostasis and metabolic dysfunctions

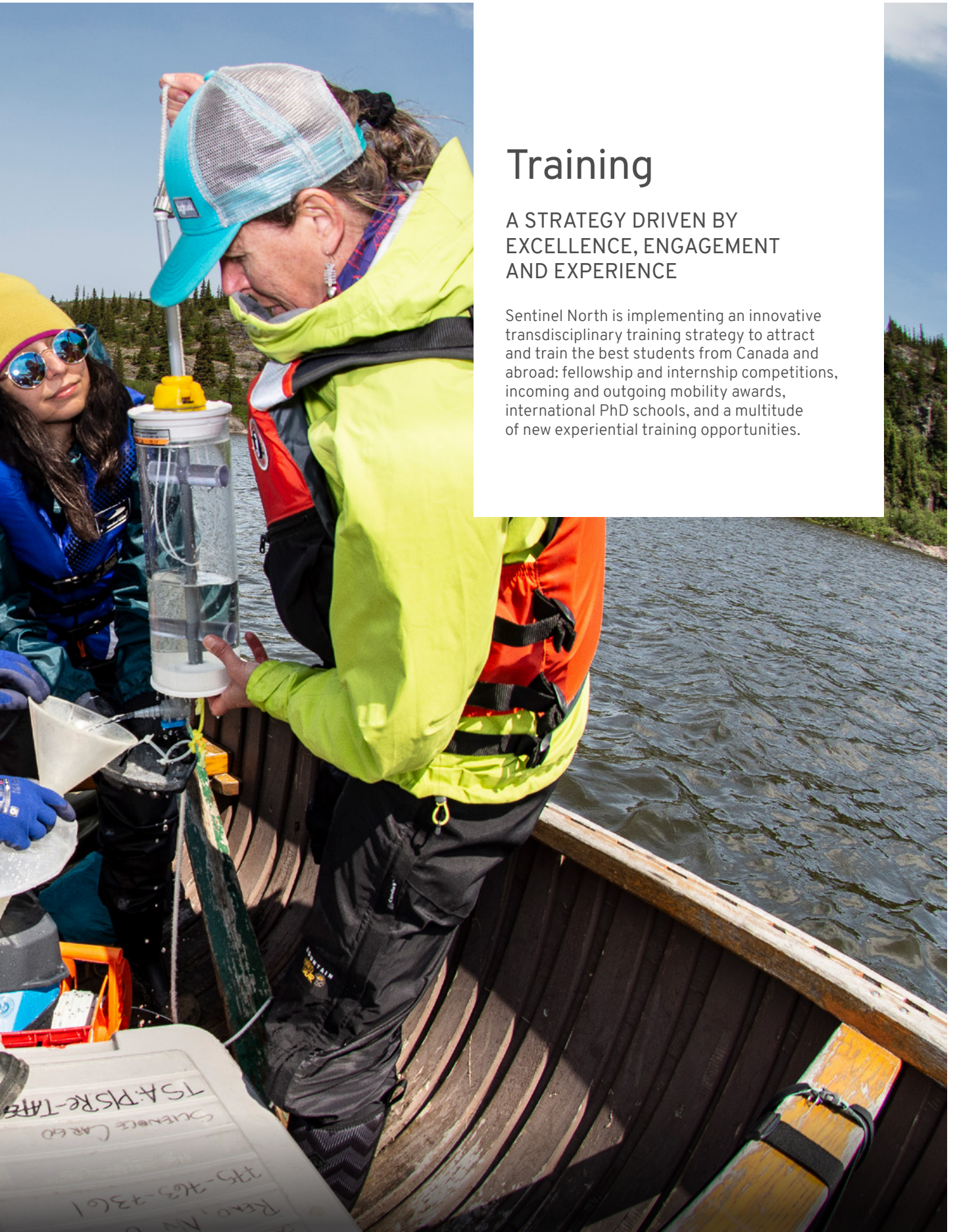
**Principal investigators:**  
Denis Richard – ULaval (Medicine)  
Carole Rovère – UCA

Characterization of essential oils and new natural products from the North

**Principal investigators:**  
Normand Voyer – ULaval (Chemistry)  
Stéphane Boudreau – ULaval (Biology)  
Xavier Fernandez - UCA



The training activities offered by Sentinel North promote the technological, experiential and cultural aspects of northern research.



## Training

A STRATEGY DRIVEN BY  
EXCELLENCE, ENGAGEMENT  
AND EXPERIENCE

Sentinel North is implementing an innovative transdisciplinary training strategy to attract and train the best students from Canada and abroad: fellowship and internship competitions, incoming and outgoing mobility awards, international PhD schools, and a multitude of new experiential training opportunities.

60 +

**excellence** scholarships and internships have been awarded since the scholarship program was launched in 2017

## Fostering excellence

Excellence scholarships and internships encourage the best candidates to undertake or pursue research activities within Sentinel North projects and in a transdisciplinary environment. **In 2018–2019, two competitions resulted in the recruitment of 24 masters and PhD students and 10 postdoctoral fellows.**

## Propelling the best students forward

Through its incoming and outgoing mobility grants and its access fund for short-term training, Sentinel North promotes the sharing of knowledge and experience beyond borders. **In 2018–2019, the financial support provided by these grants helped 28 foreign and Université Laval students and postdoctoral fellows access high-calibre PhD schools, training, and internships in internationally renowned laboratories.**

65 +

**mobility** and short-term **training** scholarships have allowed students and postdoctoral fellows to enrich their careers since 2017

150+

students, postdoctoral fellows and research assistants have participated in **international PhD schools** since the training program was created in 2017

## Providing unique experiential training opportunities

The program's training strategy promotes the development of future skills such as complex thinking, problem solving, creativity, adaptability, communication, and social responsibility. Through dozens of workshops and international PhD schools, it seeks to train the next generation of scientists so that they are fully equipped to become world leaders in their field. **In 2018–2019, 77 students, postdoctoral fellows, and research assistants from 15 countries participated in international PhD schools, supported by 39 renowned mentors.**

**Bootcamp: from development to deployment of an optical tool in a northern environment**

February 26–28, 2018  
Montmorency Forest  
Quebec, Canada

The main objective of the bootcamp was to develop a flat light detection tool for use in northern environments. As a joint initiative of the CREATE-SMAART and Sentinel North programs, this bootcamp was an opportunity for students to interact with preeminent scientists in a transdisciplinary and highly technological context.

**Complex Networks Winter Workshop**

December 15–21, 2018  
Old Québec  
Quebec, Canada

This intensive workshop, a collaboration between the Complex Systems Center at the University of Vermont, the Networks Science Institute at Northeastern University, and Sentinel North, included lectures on open problems and recent advances in the field of complex networks.

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Participants from 20 institutions across 9 countries had the opportunity to learn about complex social, ecological, and technological networks in a transdisciplinary learning environment.





Through experiential training at sea and on Arctic ice, participants developed a better understanding of the ways that extreme environments challenge the deployment of new technologies.

### Shedding light on arctic marine ecosystem services

July 12 to 24, 2018  
Baffin Bay  
Nunavut, Canada

Aiming to explore the links between light, marine ecosystem services, and health in the North, this international PhD school allowed participants to apply their expertise in optics and photonics, biology, Arctic marine ecology, physics, biochemistry, remote sensing, and human health aboard the Canadian research icebreaker CCGS *Amundsen*. Several major partners have contributed to the success of this school: Amundsen Science, the Municipality of Qikiqtarjuaq, CNRS-Takuvik, University of Maine, the Alfred Wegener Institute and the Villefranche Oceanographic Laboratory (LOV).

*“The opportunities for sharing and discussion were one of the most important aspects of the IPS. These opportunities were made all the more valuable because the school brings together international optics engineers and oceanographers, who do not share the same knowledge, vocabulary or way of working. It was a great opportunity to open our minds and learn a lot more.”*

- Gwenaëlle Gremion, PhD student in oceanography, UQAR-Ismer



The Sentinel North Student Association (AÉSN) aims to improve the educational experience of Université Laval's students by promoting a transdisciplinary learning ecosystem and providing networking opportunities between students, researchers, and partners. Through participation in the development and dissemination of Sentinel North activities, the AÉSN contributes to the success of the training strategy.

In 2018–2019, the association's executive committee held several events that allowed Sentinel North students from multiple disciplines to meet and discuss their projects. The speed networking event organized by the AÉSN during the 2018 Sentinel North Scientific Meeting was an opportunity for students to explore the variety of options available to them by talking with partners from the private and public sectors.

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Training initiatives encourage collaboration and social involvement, and open doors to a multitude of future opportunities.





Collaborations between northern communities and researchers help research projects achieve results for a more sustainable North.

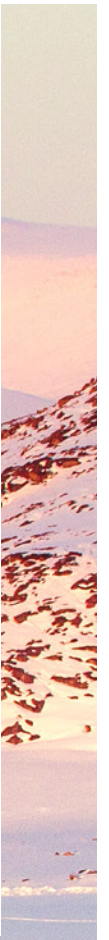


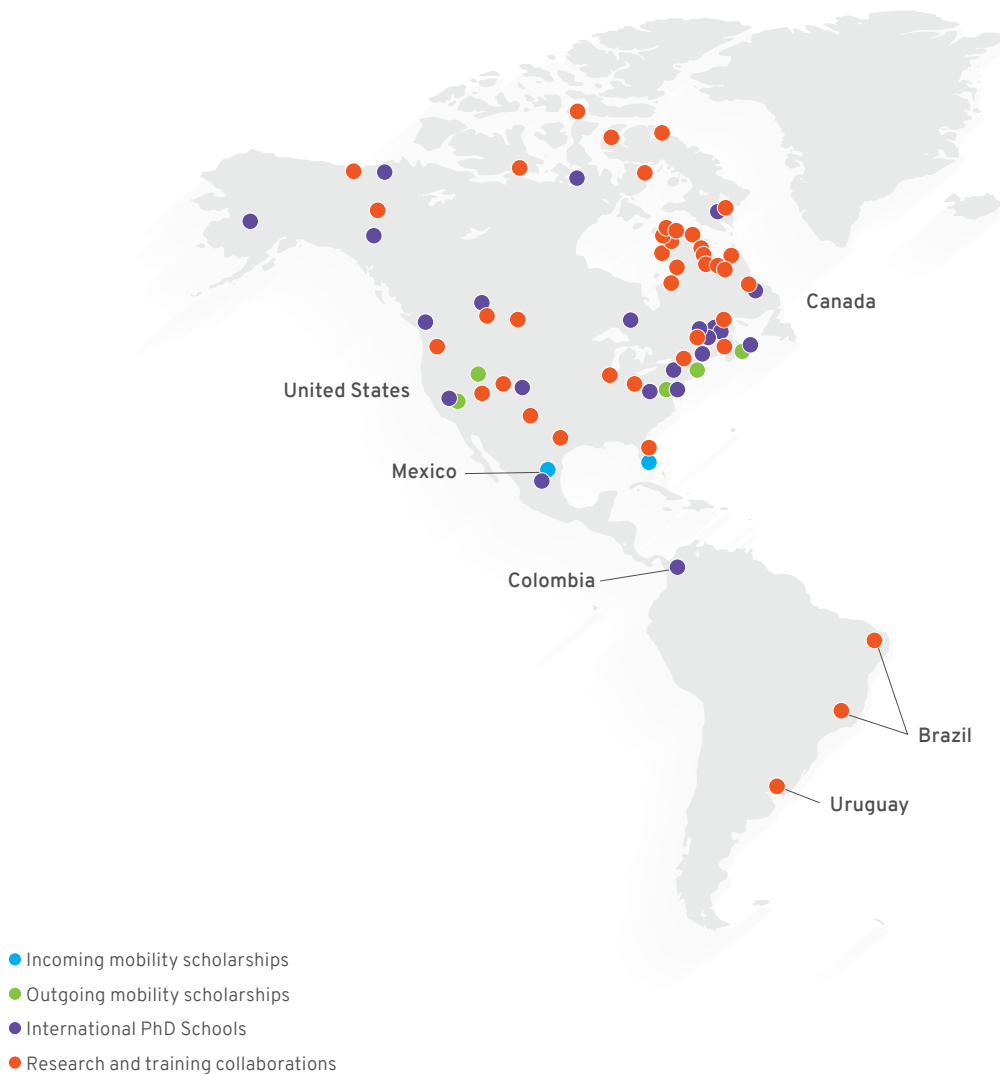


# Partnerships and Collaborations

## SYNERGISTIC RELATIONS IN RESEARCH AND TRAINING

Sentinel North's partnership and collaboration strategy is based on a vast network of northern, academic, public, and private collaborators backed by numerous research centres and groups. Research and training partnerships are based on the desire of renowned institutions and researchers to work together on innovative joint projects with the aim of building long-term collaborative relationships.





## Collaborations and partnerships for research and training

Over the years, Sentinel North has developed more than 400 collaborations and partnerships with Canadian and international organizations, including indigenous and northern organizations. By joining forces with Sentinel North, these collaborators and partners advance research, promote access to infrastructure, and provide additional expertise for developing new technologies and training highly qualified scientists.

## Training without borders

The incoming and outgoing mobility scholarships and training opportunities offered in 2018–2019 allowed students from 15 countries to further their professional development through opportunities such as research internships and international PhD schools.



Note: The list of researchers, collaborators and partners is available in the “The Sentinel North Community” section.

## International projects

In addition to the existing Joint International Research Units with centres and universities in France, Brazil, Switzerland, and Italy, Sentinel North funded 11 new international collaborative projects in 2018–2019. These projects have strengthened the links between Université Laval, UiT The Arctic University of Norway, and Université Côte d’Azur in Nice.





## Communication and Outreach

### MOBILIZING TO DISSEMINATE AND PROMOTE KNOWLEDGE

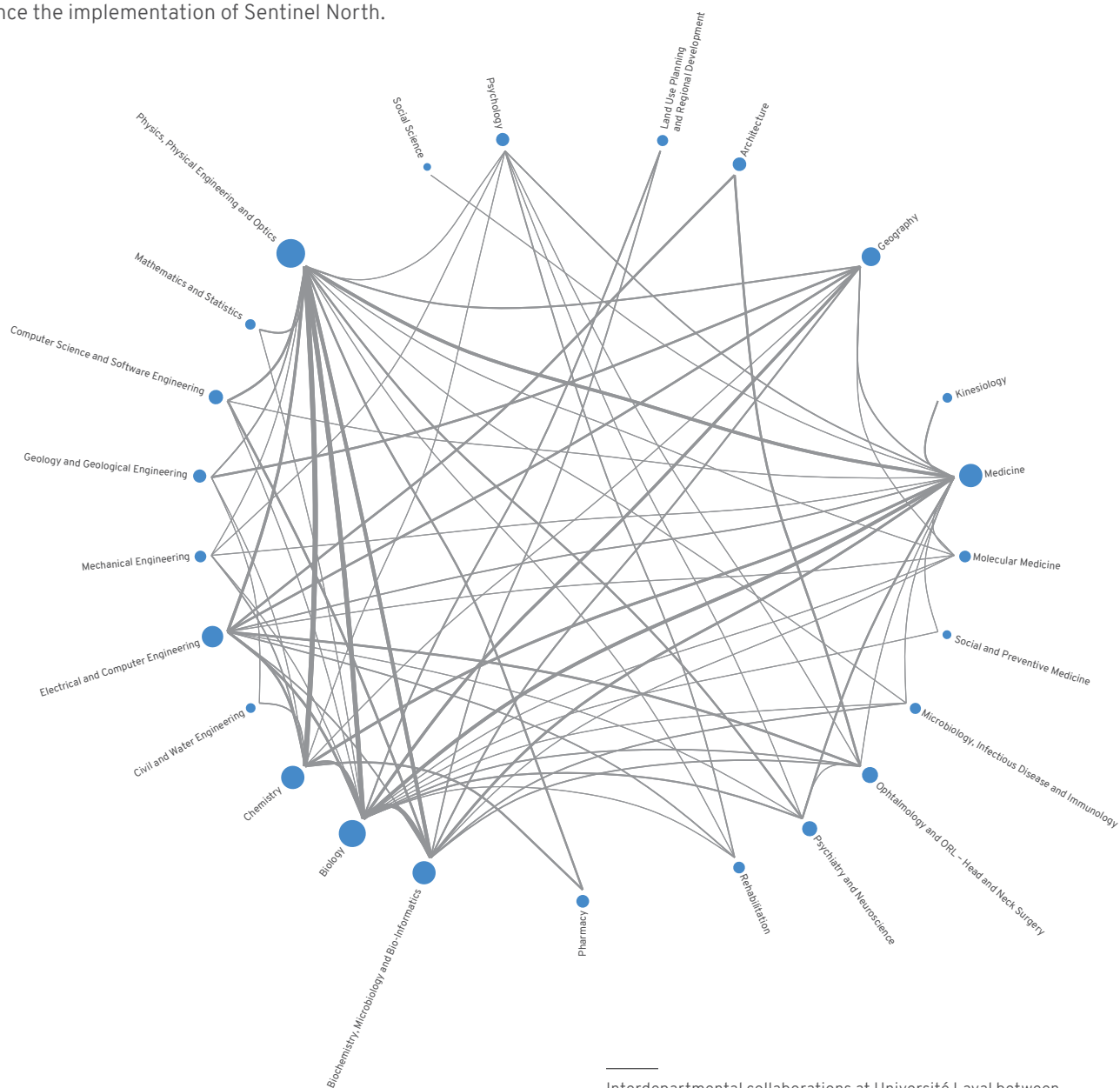
Sentinel North's communication initiatives are part of a strategic plan to highlight transdisciplinary and innovative research and training, as well as Université Laval's institutional strategy. The success of the program's outreach and knowledge dissemination is the result of the contributions of an engaged community, publications by Sentinel North's researchers, and numerous national and international activities.

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The Sentinel North Scientific Meeting is an opportunity to share research advances to improve our understanding of the northern environment and the ways it affects people and their health.

## Transdisciplinarity at the heart of research

2018–2019 was particularly significant for the dissemination of research—more than 700 new scientific publications and communications were published. The co-authors of these publications reflect the diversity of disciplines involved and the increase in interdepartmental collaborations since the implementation of Sentinel North.



Interdepartmental collaborations at Université Laval between the co-authors of Sentinel North's 800 publications and scientific communications (with and without peer review). The thickness of the links and the diameter of the nodes are proportional to the number of publications and co-authors in each department, respectively.



## Health benefits from Arctic berries

In project 3.8, *Deciphering host-microbial interactions for cardiometabolic and mental health disorders with novel multimodal light-based sensing tools*, a transdisciplinary team, including Sentinel North researchers in pharmacy, phytology, social and preventive medicine, and nutrition, studied Arctic berries. Their results have shown the potential benefits of polyphenolic extracts from five types of Arctic berries and their place in health programs to help reduce chronic inflammation related to obesity and metabolic disorders (Ahnê *et al.*, 2018).

A tropical disease could be countered by the novel properties of a northern substance.

## The molecular treasures of the Far North

The Sentinel North research team comprised of Normand Voyer (Chemistry) and Dave Richard (Medicine) chemically synthesized the natural mortiamide molecules in *Mortierella* lichen, which were discovered in 2017 by a group of researchers in Frobisher Bay. These molecules have shown to be effective against the parasite *Plasmodium falciparum*, which is responsible for 50% of malaria cases worldwide (Bérubé *et al.*, 2019).



Arctic wild berries, which are traditionally consumed in the North, are full of benefits.

## An event that promotes knowledge transfer

More than 350 students, researchers, and collaborators attended the 2018 Sentinel North Scientific Meeting, which was held from August 27–30 in Québec City. Hosting nearly 170 oral and poster presentations and multiple networking activities, the event allowed participants to share their research and results, as well as build relationships with their international and Canadian collaborators.



(Left) Eugénie Brouillet, Vice Rector, Research and Innovation.  
(Right) Scientific poster sessions at the 2018 Sentinel North Scientific Meeting.



Researchers, students, and partners are at the heart of the Sentinel North program.





# The Sentinel North Community

## A NETWORK FOR INNOVATION

The Sentinel North program includes hundreds of participants from Université Laval who work with their partners from northern organizations, federal and provincial agencies, and the private sector to improve our understanding of the northern environment and its impact on humans and their health. This vast network of stakeholders developed innovative research projects and implemented numerous Sentinel North training, knowledge translation, partnership, and research support programs.



## Université Laval Researchers and Collaborators

### ANIMAL SCIENCES

Bailey, Janice  
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### BIOCHEMISTRY, MICROBIOLOGY, AND BIO-INFORMATICS

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Frenette, Michel  
Hardy, Simon  
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Moineau, Sylvain  
Paquet, Marie-Ève  
Trudel, Luc

### BIOLOGY

Archambault, Philippe  
Babin, Marcel  
Bernatchez, Louis  
Boudreau, Stéphane  
Côté, Steeve  
Derome, Nicolas  
Fortier, Louis  
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Gauthier, Gilles  
Johnson, Ladd  
Landry, Christian

Lavaud, Johann  
Legagneux, Pierre  
Levasseur, Maurice  
Lovejoy, Connie  
Maps, Frédéric  
Massé, Guillaume  
Moore, Jean-Sébastien  
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### CHEMISTRY

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Couture, Raoul-Marie  
Dominé, Florent  
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Larivière, Dominic  
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ECONOMICS

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### CIVIL AND WATER ENGINEERING

Ancil, François  
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### COMPUTER SCIENCE AND SOFTWARE ENGINEERING

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### ELECTRICAL AND COMPUTER ENGINEERING

Bélanger, Louis N.  
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### FOOD SCIENCES

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### GEOGRAPHY

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### GEOLOGY AND GEOLOGICAL ENGINEERING

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Molson, John  
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### GEOMATICS

Badard, Thierry  
Pouliot, Jacynthe

### KINESIOLOGY

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Tremblay, Angelo

### LAND USE PLANNING AND REGIONAL DEVELOPMENT

Cloutier, Geneviève  
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### MANAGEMENT

Garand, Denis J.

### MATHEMATICS AND STATISTICS

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**MECHANICAL ENGINEERING**

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**MEDICINE**

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**MICROBIOLOGY, INFECTIOUS DISEASE, AND IMMUNOLOGY**

Bergeron, Michel  
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**MOLECULAR BIOLOGY, MEDICAL BIOCHEMISTRY, AND PATHOLOGY**

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**MOLECULAR MEDICINE**

Corbeil, Jacques  
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**NURSING**

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**NUTRITION**

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**OPHTHALMOLOGY AND ORL-HEAD AND NECK SURGERY**

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**PHARMACY**

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## URUGUAY

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## Interinstitutional Research Centres and Groups - Université Laval

Aluminium Research Centre  
ArcticNet Network of Centres of Excellence  
Big Data Research Centre  
Centre for Interdisciplinary Research in Rehabilitation and Social Integration  
Centre for Forest Research  
Centre for Northern Studies  
Centre for Research in Geomatics  
Centre for Research in Regional Planning and Development  
Centre in Green Chemistry and Catalysis  
Centre intégré universitaire de santé et de services sociaux de la Capitale-Nationale  
Centre interdisciplinaire en modélisation mathématique de l'Université Laval  
CentrEau  
CERVO Brain Research Centre  
CHU de Québec Research Centre  
Infectious Disease Research Centre  
Institut Hydro-Québec en environnement, développement et société  
Institut nationale de santé publique du Québec  
Institut nordique du Québec

Institute for Health and Social Policy, McGill University  
Institute of Integrative Biology and Systems  
Institute of Nutrition and Functional Foods  
Interdisciplinary Research Group on Suburbs  
Joint International Research Unit for Chemical and Biomolecular Research on the Microbiome and Its Impact on Metabolic Health and Nutrition (ULaval – CNR, Italy)  
Joint International Research Unit in Neurodevelopment and Child Psychiatry (ULaval – University of Lausanne, Switzerland)  
Joint International Research Unit Québec-Brazil Photonics Research (ULaval – UNESP, Brazil)  
Machine Learning Research Group  
Neuroscience Thematic Research Centre  
Oral Ecology Research Group  
Physical Ambiances Research Group  
Québec Centre for Functional Materials  
Quebec Heart and Lung Institute Research Centre  
Quebec Mental Health Institute  
Québec Network for Research on Protein Function, Engineering, and Applications  
Québec-Océan  
Ressources aquatiques Québec  
Takuvik Joint International Research Unit (ULaval – CNRS, France)

## Partners

### ACADEMIC AND RESEARCH

#### **AUSTRALIA**

Matrix Mathematical Research Institute

#### **BRAZIL**

São Paulo State University

São Paulo State University - Food Research Centre-FORC

Universidade estadual Paulista

#### **CANADA**

Aurora College

Centre for Northern Studies

CERVO Research Centre

Dalhousie University

Université de Sherbrooke (INTER)

Université du Québec à Chicoutimi

#### **FRANCE**

National Centre for Scientific Research

Institut polaire français (IPEV)

Université Côte d'Azur

University of Bordeaux

#### **GERMANY**

Alfred Wegener Institute

#### **JAPAN**

National Institute of Polar Research

#### **NORWAY**

UiT - The Arctic University of Norway

#### **SWITZERLAND**

Centre Hospitalier Universitaire Vaudois,

Université de Lausanne

#### **UNITED STATES**

Florida Atlantic University

Stanford University

University of California, San Diego

University of Maine

University of Vermont

University of Washington

Woods Hole Oceanographic Institution

## PUBLIC

### **CANADA**

Aurora Research Institute

Canadian Ice Service

Canadian Space Agency

Centre de recherche industrielle du Québec

Centre intégré universitaire de santé et de services sociaux de la Capitale-Nationale

Department of Indigenous Services Canada (uOttawa)

Fisheries and Oceans Canada

Infrastructure Canada

International Brain Research Organization

Inuvialuit Regional Corporation

Kativik

Kativik Municipal Housing Bureau

Ministère de l'Économie et de l'Innovation

Ministère de l'Éducation et de l'Enseignement Supérieur

Ministère de l'Énergie et des Ressources naturelles

Ministère de la Santé et des Services sociaux

Ministère des Forêts, de la Faune et des Parcs

Ministère des Transports, de la Mobilité durable et de l'Électrification des transports du Québec

Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques

Municipality of Cambridge Bay

Municipality of Kangiqsualujjuaq

National Research Council Canada

Natural Resources Canada

Natural Resources Canada

Nunavik Hunting Fishing Trapping Association

Nunavik Parks

Nunavik Regional Board of Health and Social Services

Nunavut Department of health

Nunavut Research Institute

Parks Canada

Polar Continental Shelf Program

Polar Knowledge Canada

Public Safety Canada

Quebec Pain Research Network

Québec Research Funds



Réseau provincial de recherche  
en adaptation-réadaptation  
Société d'habitation du Québec  
Société du Plan Nord  
Transport Canada  
Ville de Québec

**FRANCE**

Centre National d'Études Spatiales  
European Commission - H2020

**NORWAY**

Norwegian Institute for water research - Norforsk

**UNITED KINGDOM**

Natural History Museum London

**UNITED STATES**

NASA

**SWEDEN**

Swedish Research Council  
Switzerland  
Synapsy

**PRIVATE**

**CANADA**

Agilent Technologies  
Air Inuit  
BD Biosciences  
Bliq Photonique  
Coopérative forestière Ferland-Boilleau  
CorActive  
Doric Lenses  
Explora Technologies  
FlowJEM  
Franatech  
Fruit d'Or  
Gas Plume Imaging Canada  
Kongsberg Maritime  
Leica  
LogR Systems inc.  
Matrix Solutions inc.  
Mine Raglan  
Peaxy

Pfizer  
Photons Canada (Canadian photonic industry  
consortium CPIC)  
Quebec consortium for industrial bioprocess  
research and innovation  
Realtech  
Reformar  
Satlantic-SeaBird Scientific  
Scientifica LLC  
SiliCycle  
SyntBioLab Inc.  
TeraXion  
Thorlabs  
VELUX

**GERMANY**

Airbus Defence and space

**NORWAY**

Akvaplan Niva

**UNITED STATES**

BeamSea LLC  
IFOS Inc.

**OTHER INSTITUTIONS**

Amundsen Science, Canada  
Fondation CERVO, Canada  
Fondation de l'Université Laval, Canada  
Fondation de Préfargier, Sweden  
Fondation Institut universitaire de cardiologie  
et de pneumologie de Québec, Canada  
National Optics Institute, Canada  
Quebec Photonic Network, Canada  
São Paulo Research Foundation (FAPESP), Brazil

## Participating Research Chairs

### CANADA EXCELLENCE RESEARCH CHAIRS (CERCS)

- CERC in Photonic Innovations (Younès Messaddeq)
- CERC in Remote Sensing of Canada's New Arctic Frontier (Marcel Babin)
- CERC in the Microbiome-Endocannabinoidome Axis in Metabolic Health (Vincenzo Di Marzo)
- CERC on Neurophotronics (Pierre Marquet)

### CANADA RESEARCH CHAIRS (CRCS)

- CRC in Advanced Photonic Technologies for Communications (Sophie LaRochelle)
- CRC in Antimicrobial Resistance (Marc Ouellette)
- CRC in Aquatic Ecosystem Studies (Warwick F. Vincent)
- CRC in Aquatic Environments and Water Quality (Antoniades Dermot)
- CRC in Arctic Marine Ecosystems' Response to Global Warming (Louis Fortier)
- CRC in Bacteriophages (Sylvain Moineau)
- CRC in Biophotonics (Daniel Côté)
- CRC in Chronic Pain and Related Brain Disorders (Yves De Koninck)
- CRC in Communications Systems Enabling the Cloud (Leslie Ann Rusch)
- CRC in Electroactive and Photoactive Polymers (Mario Leclerc)
- CRC in Evolutionary Cell and Systems Biology (Christian Landry)
- CRC in Genetic Conservation of Aquatic Resources (Louis Bernatchez)
- CRC in Genomics Applied to Nutrition and Metabolic Health (Marie-Claude Vohl)
- CRC in Lactic Cultures Biotechnology for Dairy and Probiotic Industries (Denis Roy)
- CRC in Liquid Crystals and Behavioral Biophotonics (Tigran Galstian)

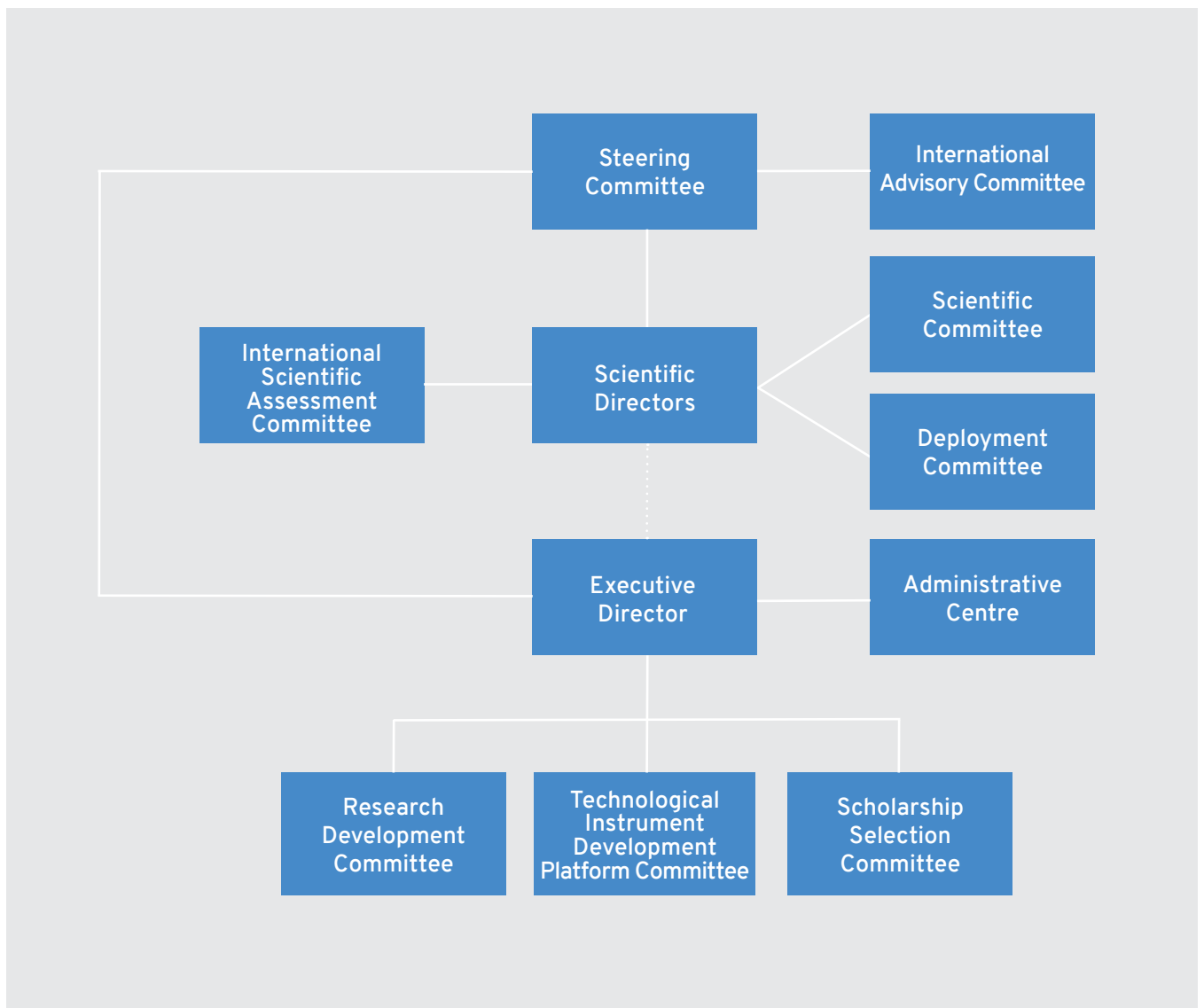
- CRC in Medical Genomics (Jacques Corbeil)
- CRC in Multipolar Infrared Vision (Xavier Maldaque)
- CRC in Physical Activity, Nutrition and Energy Balance (Angelo Tremblay)
- CRC in Quantitative Hydrogeology of Fractured Porous Media (John Molson)
- CRC in Silicon Photonics (Wei Shi)
- CRC in Smart Biomedical Microsystems (Benoit Gosselin)
- CRC in Statistical Sampling and Data Analysis (Louis-Paul Rivest)

### PARTNERSHIP RESEARCH CHAIRS

- International Chair in Cardiometabolic Risk (Jean-Pierre Després)
- L'Oréal Research and Innovation Chair in Digital Biology (Arnaud Droit) NSERC/Creaform Industrial Research Chair on 3-D Scanning: 3-D Creation (Denis Laurendeau)
- NSERC Industrial Research Chair in Heavy Load, Climate, and Pavement Interaction (i3c) (Guy Doré) NSERC/Diana Food Industrial Research Chair on the Effects of Polyphenol Prebiotics from Fruits and Vegetables (Phenobio) (Yves Desjardins)
- NSERC Industrial Research Chair in Integrated Resource Management of Anticosti Island (Steeve Côté)
- NSERC Industrial Research Chair in Optical Design (Simon Thibault) NSERC Industrial Research Chair in Monitoring and Management of Drinking Water Quality (Manuel J. Rodriguez-Pinzon)
- NSERC-Coractive-TeraXion-LaserAX-TLCL Industrial Research Chair in Femtosecond Photo-Inscribed Photonic Components and Devices (Réal Vallée)
- NSERC/Alcoa/Hydro-Québec Industrial Research Chair on Energy Efficiency and the Advanced Modelling of Aluminum Electrolysis Cells (MACE3) (Louis Gosselin)
- Research Chair on Obesity (Denis Richard)
- Research Chair on the Pathogenesis of Insulin Resistance and Cardiovascular Disease (André Marette)

## Governance

Sentinel North's governance and management structure is designed to provide the resources and vision the program needs to achieve its strategic objectives and ensure leadership, sound management, and scientific coordination at every level.



## STEERING COMMITTEE

The Steering Committee is responsible for implementing Sentinel North's strategy. It ensures the program makes progress towards its objectives, performance indicators, and deliverables. It makes the final decisions on the recommendations made by the scientific directors, the executive director, and all Sentinel North committees.

Marcel Babin, Scientific Co-Director, Sentinel North and Chairholder, CERC on Remote Sensing in Canada's New Arctic Frontier

Régnald Bergeron, Vice Rector, External and International Affairs and Health

Eugénie Brouillet (chair), Vice Rector, Research and Innovation

André Darveau, Vice Rector, Administration

Yves De Koninck, Scientific Co-Director, Sentinel North and Director, CERVO Brain Research Centre

Jean-Claude Dufour, Dean, Faculty of Agriculture and Food Sciences

Martin Fortier (non-voting), Executive Director, Sentinel North, and Assistant to the Vice Rector, Research and Innovation

François Gélinau, Dean, Faculty of Social Sciences

Julien Poitras, Dean, Faculty of Medicine

André Zaccarin, Dean, Faculty of Science and Engineering

## SCIENTIFIC DIRECTORS

The two scientific directors are appointed by the Steering Committee to provide the leadership necessary for the vitality of the program, the active participation of its members, and the relevance and scientific quality of its activities. They work with the Steering Committee and receive input from the Scientific and Deployment Committees to establish a strategic development plan and scientific program in keeping with the program's objectives.

## EXECUTIVE DIRECTOR

The Executive Director oversees operations and day-to-day activities. They work with the Steering Committee and Scientific Directors to develop and implement Sentinel North's strategic and operational plan. The executive director liaises with funding agencies, government, industry, and other non-governmental organizations.

## INTERNATIONAL ADVISORY COMMITTEE

The International Advisory Committee provides high-level advice to the Steering Committee and scientific directors regarding the program's strategic and scientific thrusts. The advice is used to conduct comparative analyses in accordance with international standards and to address conflicting interests within the network structure.

## SCIENTIFIC COMMITTEE

The Scientific Committee provides advice and makes recommendations to the Steering Committee through the Scientific Directors with regard to Sentinel North's scientific priorities and calls for projects.

#### **DEPLOYMENT COMMITTEE**

The Deployment Committee provides advice and makes recommendations to the Steering Committee through the Scientific Directors on the deployment and status of research, collaboration, training, partnership, and networking activities within the program.

#### **INTERNATIONAL SCIENTIFIC ASSESSMENT COMMITTEE**

The International Scientific Assessment Committee provides assessments, monitors the progress of funded projects, and makes recommendations to the Steering Committee through the Scientific Directors for funding applications received through Sentinel North's calls for projects. The committee is composed of scientists and international stakeholders external to Université Laval.

#### **RESEARCH DEVELOPMENT COMMITTEE**

The Research Development Committee helps identify discoveries with application and commercialization potential as part of Sentinel North's research activities. It guides the implementation of knowledge mobilization and transfer activities that maximize the use of research results by users.

#### **TECHNOLOGICAL INSTRUMENT DEVELOPMENT PLATFORM COMMITTEE**

The Technological Instrument Development Platform Management Committee oversees the platform's activities, reviews the operating budget and the strategic and operational objectives proposed by the coordinator, and ensures that the platform has the appropriate resources to achieve its goals.

#### **SCHOLARSHIP SELECTION COMMITTEE**

The role of the Scholarship Selection Committee is to select the recipients of Sentinel North graduate scholarships and postdoctoral fellowships.

#### **ADMINISTRATIVE CENTRE**

Michèle Desgagnés, Secretary

Martin Fortier, Executive Director

Sophie Gallais, Operation Coordinator

Marie-France Gévry, Training Program Coordinator

Keith Lévesque, Assistant Director

Ahmed Lidam, Finance Coordinator

Béatrice Saint-Cricq, Partnerships and Technology Transfer

Jérôme St-Charles, Communications Officer and Webmaster

Daphné Trottier, Communications Officer

#### **SENTINEL NORTH STUDENT ASSOCIATION (AÉSN) – EXECUTIVE COMMITTEE**

Yasmine Alikacem, Research Theme 2 Representative

Marc-Antoine Bansept, Vice-President - Events

Béatrice Choi, Treasurer

Nicolas Fontaine, Research Theme 3 Representative

Antoine Gervais, Research Theme 1 Representative

Audrey Laberge-Carignan, Vice-President – Communications

Christophe Perron, Secretary

Audrey Picard-Lafond, President

PHOTO CREDITS

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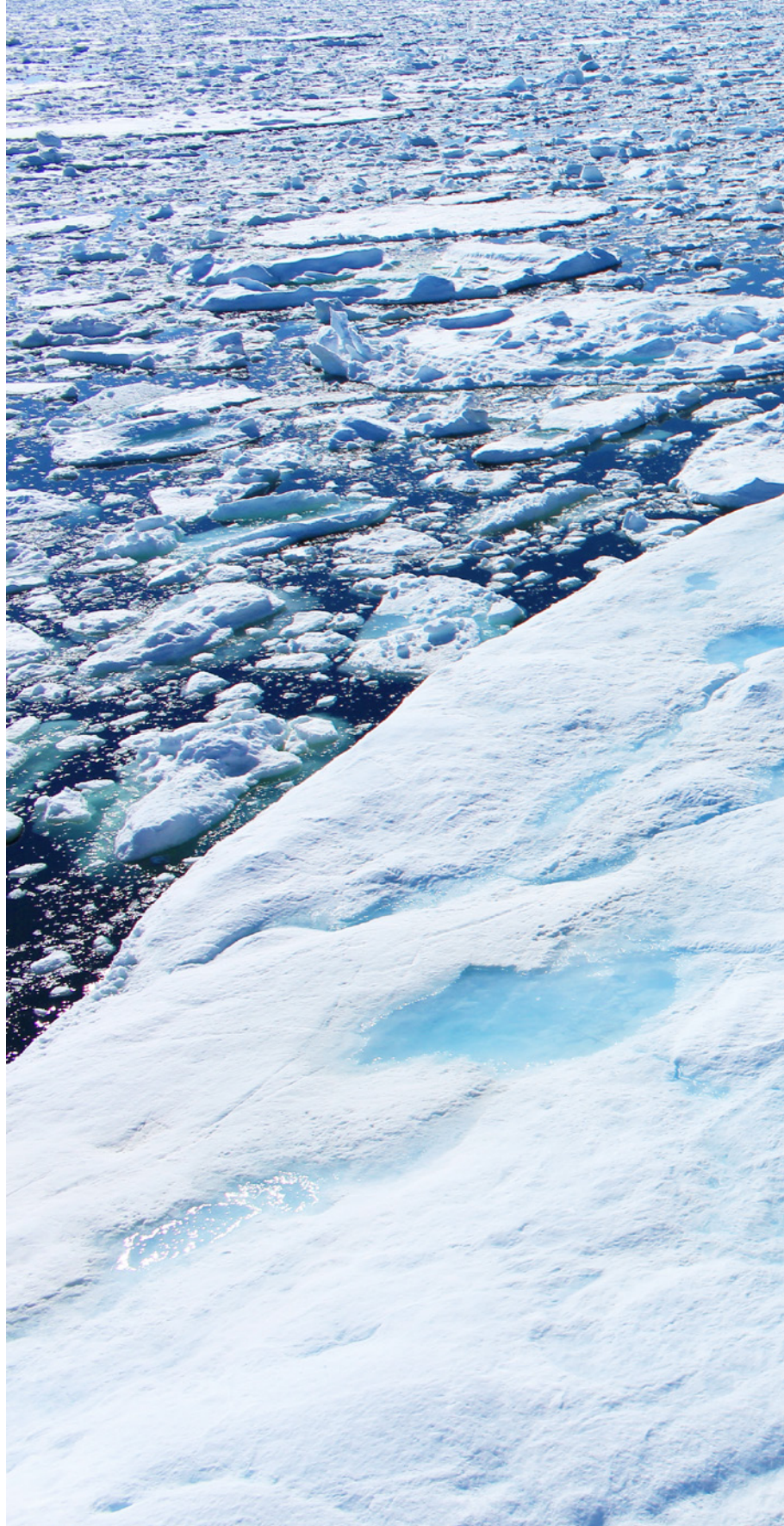




## CREDITS

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