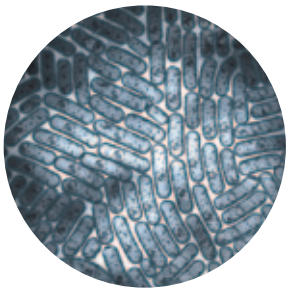
Connecting the Best Minds
for a Better World.

2014–2015 Annual Performance Report

CIFAR



INTEGRATED MICROBIAL BIODIVERSITY

Explores the diverse microbial world that surrounds and permeates human life. Program members are transforming our understanding of biodiversity, and changing approaches to medicine and health, environmental sustainability, and evolutionary biology itself.

AT A GLANCE

Founded: 2007

Most recent renewal: 2012

Program Director: Patrick Keeling, University of British Columbia

Fellows and advisors*: 31

Institutions represented: 19, in 4 countries

Fields and subfields represented: *Microbiology; evolutionary biology; bioinformatics; biochemistry & molecular biology; cell biology; marine & freshwater biology; oceanography; ecology; genetics; taxonomy; mycology; virology; zoology*

** Listed in Appendix C: Researchers, pages 79-80*

PROGRESS REPORT

The program in Integrated Microbial Biodiversity continued its work studying microbial life. Members organized a prestigious U.S. National Academy of Sciences Sackler Colloquium, co-sponsored by CIFAR, examining symbiosis and the origins of cellular complexity[47] (page 40). Fellows also collaborated on a paper in *Nature* showing that a single-celled dinoflagellate developed a complex sub-cellular eye similar to multi-cellular mammalian eyes, using normal cell parts re-purposed for a new function[48] (page 39).

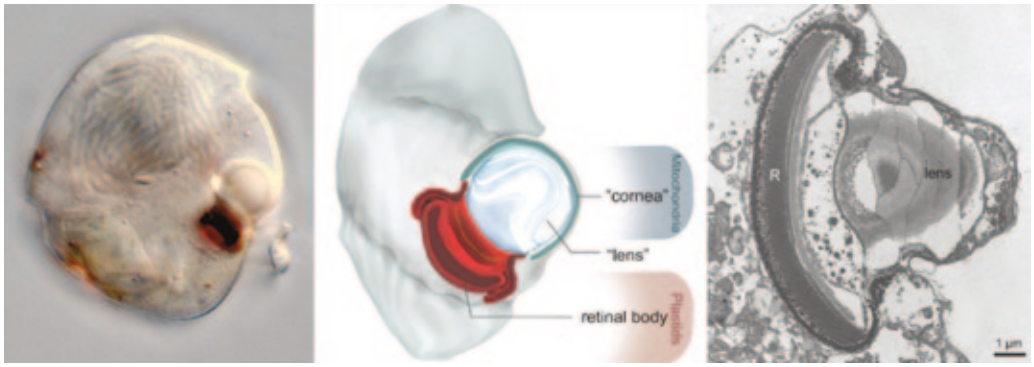
Other joint work between fellows led to a review in *Science* that painted a more complex and accurate picture of the way marine microbial interactions affect nutrient flow and carbon cycling in the world's oceans, and how that influences global climate change.[49] Three fellows presented a related AAAS symposium on the role of microbes in ocean ecosystems.[50] Seven fellows and their trainees conducted a field-based interaction in conjunction with Caribbean Research & Management of Biodiversity (CARMABI) in Curaçao. Participants worked together to collect and identify microbial samples, and exchange materials, methods and expertise. The close interaction laid the groundwork for numerous future collaborative projects.

Program Meeting:

- **May 26-29, 2015, Victoria, B.C.:** Discussions focused on a wide range of subjects related to microbial diversity and evolution, including new research in comparative genomics, the evolution of host-microbe interactions and of cell differentiation. Poster sessions provided an opportunity for trainees to present and gain feedback on their latest research projects.

Focus

CONVERGENT EVOLUTION OF AN "EYE" IN SINGLE-CELLED PLANKTON



Light micrograph (left), illustration (centre) and transmission electron micrograph (right) showing the eye-like structure in warnowiid *dinoflagellates.*

Eye-like structures have evolved independently many times in animals and algae, with varying abilities to detect the intensity of light, its direction or objects. This process, known as convergent evolution, helps scientists understand how life adapts and evolves in response to environments.

In a paper published in *Nature*, a team of collaborators, including CIFAR Senior Fellows **Brian Leander**, **Patrick Keeling**, **Curtis Suttle** (all University of British Columbia) and lead author and Ph.D. student, Greg Gavelis, showed that the eye-like structure of a single-celled marine plankton called *warnowiids* contains many of the components of a complex eye.

They sequenced the genomes of *warnowiids*, which are predatory microbes, and analyzed how their eyes are built using powerful new methods in electron microscopy that offer unprecedented detail about uncultivated organisms. They found a collection of sub-cellular organelles that look very much like the lens, cornea, iris and retina of multicellular eyes that can detect objects, such as those that humans and other larger animals have. The organelles consist of mitochondria and a network of interconnected plastids, which photosynthetic plants use to harvest energy from light.

Scientists are still investigating exactly how *warnowiids* use the eye-like structure, but hypotheses suggest they may help these predators detect the position of their prey in the plankton, consisting of different kinds of microbes, including other dinoflagellates like itself.

Focus

SACKLER COLLOQUIUM: SYMBIOSES BECOMING PERMANENT

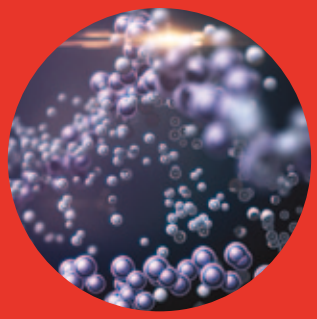
An Arthur M. Sackler Colloquium of the U.S. National Academy of Sciences was curated by CIFAR Senior Fellow and Program Director **Patrick Keeling** (University of British Columbia), CIFAR Fellow **John McCutcheon** (University of Montana) and CIFAR Advisor **W. Ford Doolittle** (Dalhousie University). The high-profile, competitively awarded opportunity was co-sponsored by CIFAR and held in Irvine, California in 2014.

Entitled *Symbioses becoming permanent: The origins and evolutionary trajectories of organelles*, the meeting brought together world leaders in two research fields: the biology of symbiotic interactions and the origins of organelles, the specialized compartments found within complex cells. While scientists have long accepted that mitochondria and chloroplasts evolved from symbiotic relationships between microorganisms, enormous gaps remain in understanding just how this happened. Research in both endosymbiosis and organelle biology has progressed significantly, but separately; the colloquium's goal was to reunite these fields through detailed and multi-level comparisons of different symbiotic and organelle systems, searching for commonalities previously overlooked.

The invited presenters, including seven CIFAR fellows and advisors, repeatedly uncovered characteristics that unify endosymbionts and organelles, including some fundamental genetic processes. Insights from the wide-ranging talks will be published in more than twenty papers in a forthcoming special issue of the *Proceedings of the National Academy of Sciences*, edited by the colloquium organizers. The collective work is expected to spark new lines of thinking and discovery about how symbiotic interactions work and evolve.

ENABLERS: HOW WE ACHIEVE OUR IMPACT

2. Broaden CIFAR's Global Reach



Among CIFAR's unique strengths are the depth and breadth of its global research community. Seeking to become recognized as one of the world's leading organizations dedicated to fostering high-calibre global research networks, CIFAR is connecting and leveraging Canada's brightest minds with their global counterparts and strengthening an international culture and approach to its operations.

Today, CIFAR fellows and advisors are based in 17 countries, with a balance of researchers based inside and outside of Canada. At the same time, new international research partnerships with strategically aligned organizations in America, Europe and Asia are expanding the definition of CIFAR's global nature.

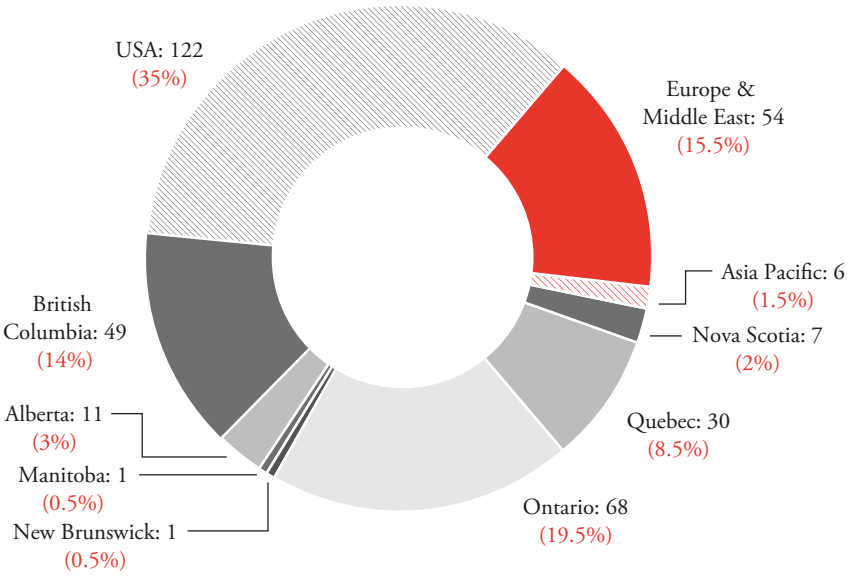
2014/2015 OBJECTIVE: CIFAR will continue to solidify its role as a leading Canadian-based organization that creates and sustains global research networks, connecting Canada's and the world's best.

SUMMARY OF KEY OUTCOMES:

- Engaged in discussions promoting CIFAR's research networks and Canada's research strength with nearly 50 institutions in 12 countries.
- Held six CIFAR program interaction meetings, two specially focused workshops and one summer school in partnership with internationally recognized nodes of expertise in Korea, China, Germany, United Kingdom, Sweden, the United States and Canada. Of these events, six were convened outside of Canada.
- Increased the number of CIFAR researchers based in Europe by nearly 40 per cent.
- Expanded the participation of international guests at CIFAR program meetings by 80 per cent over the previous year.

Distribution of CIFAR Researchers by Region

For the year ending June 30, 2015

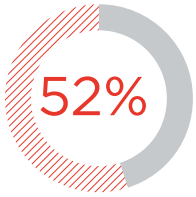


NUMBER OF COUNTRIES WHERE CIFAR FELLOWS AND ADVISORS ARE LOCATED (INCLUDING CANADA)

REPRESENTING

27
INSTITUTIONS IN CANADA AND

88
INTERNATIONALLY



OF FELLOWS AND ADVISORS ARE BASED OUTSIDE OF CANADA

229
INTERNATIONAL GUESTS
*from **17 countries** attended program meetings – an **80% increase** in international guests over the previous year*

CIFAR FELLOWS COLLABORATE WITH OTHER RESEARCHERS IN

49
COUNTRIES

CIFAR RESEARCHERS BY GEOGRAPHIC LOCATION

- CIFAR researchers' countries of residence
- Other countries in which CIFAR researchers have collaborators
- ( ) Number of CIFAR researchers, if more than one

CANADA (167)

British Columbia (49)
UBC (41)
Simon Fraser U. (5)
U. of Victoria (3)

Alberta (11)
U. of Alberta (4)
U. of Calgary (6)
U. of Lethbridge

Manitoba
U. of Winnipeg

New Brunswick
U. of New Brunswick

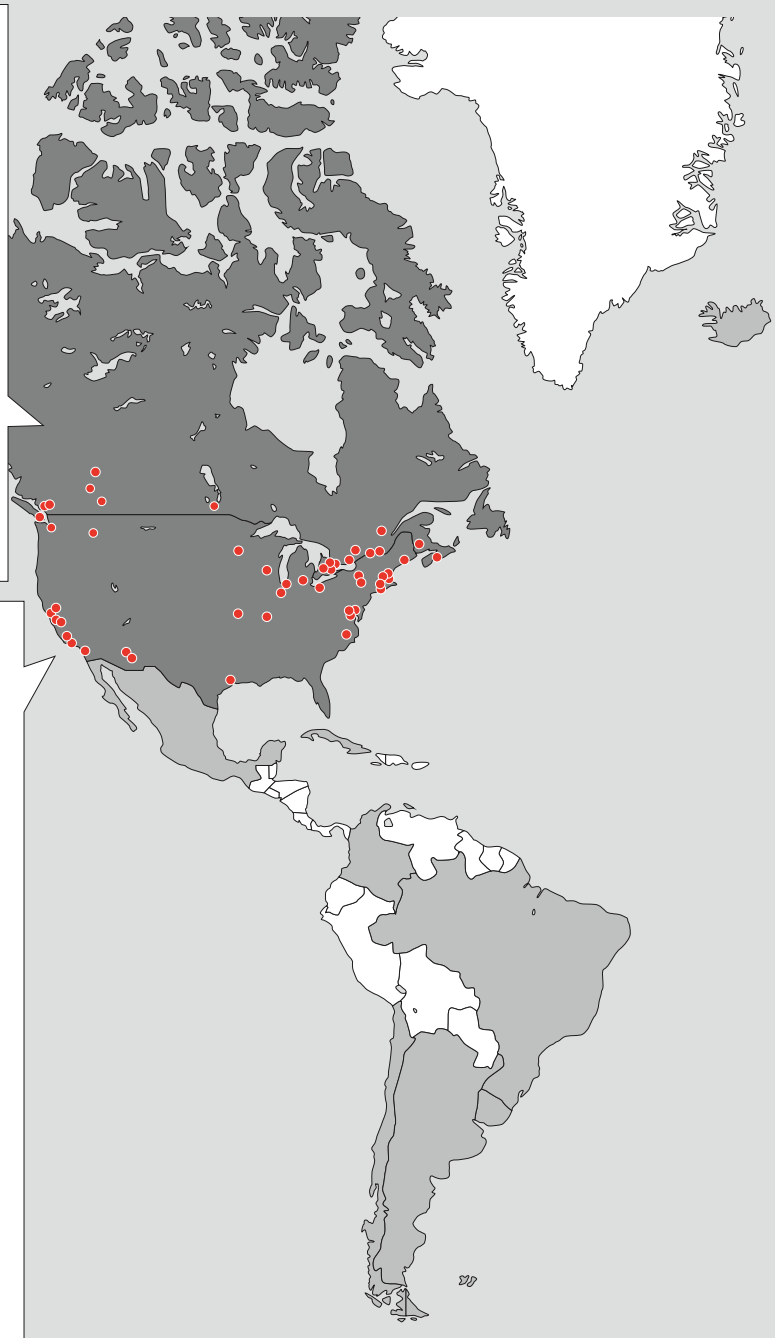
Nova Scotia (7)
Dalhousie U. (7)

Ontario (68)
Carleton U.
U. of Guelph (3)
The Hospital for Sick Children (2)
McMaster U. (6)
Perimeter Institute (3)
Queen's U. (4)
U. of Ottawa (2)
U. of Toronto (32)
Statistics Canada
U. of Waterloo (12)
Western U. (2)

Quebec (30)
Concordia U.
U. Laval
McGill U. (12)
U. of Montreal (7)
U. of Quebec at Montreal
U. of Quebec at Chicoutimi
U. of Sherbrooke (7)

UNITED STATES OF AMERICA (122)

Arizona State U.
Brookhaven National Lab
UC Berkeley (9)
UC San Diego (2)
UC San Francisco (2)
UC Santa Barbara (3)
California Inst. of Technology (3)
California Life Company
Case Western Reserve U.
U. of Chicago (4)
Columbia U.
Cornell U.
Duke U. (2)
Google
Harvard U. (14)
U. of Hawaii
U. of Illinois at Urbana-Champaign
IBM Corporation
Institute for Advanced Study (2)
The Jackson Lab
Johns Hopkins U. (2)
U. of Kansas
Massachusetts Inst. of Technology (6)
U. of Maryland (4)
Microsoft Research
U. of Minnesota (2)
U. of Montana
Monterey Bay Aquarium Research Institute
National Radio Astronomy Observatory
National Institutes of Health (2)
New York U. (4)
Northwestern U. (2)
Princeton U. (13)
Rice U.
Rutgers U.
Salk Inst. for Biological Studies
San Diego State U. (2)
Stanford U. (17)
Tufts U.
U. of Washington (3)
Washington U. (2)
U. of Wisconsin, Madison
The World Bank



EUROPE & MIDDLE EAST (54)

Austria
U. of Innsbruck

Belgium
U. libre de Bruxelles

Czech Republic
Czech Academy of Sciences

Finland
U. of Helsinki

France (9)
Collège de France
École Polytechnique
Inria (2)
Institut Pasteur (2)
Laboratoire National des Champs Magnétiques Intenses
Musée du quai Branly
Sciences Po

Germany (12)
Ludwig-Maximilians U.
Max Planck Institute – Astrophysics
Max Planck Institute – Biochemistry
Max Planck Institute – Chemical Physics of Solids
Max Planck Institute – Intelligent Systems
Max Planck Institute – Psychiatry
Max Planck Institute – Solid State Research (3)
Max Planck Institute – Structure & Dynamics of Matter
RWTH Aachen U.
TU Dresden

Israel
Hebrew U. of Jerusalem

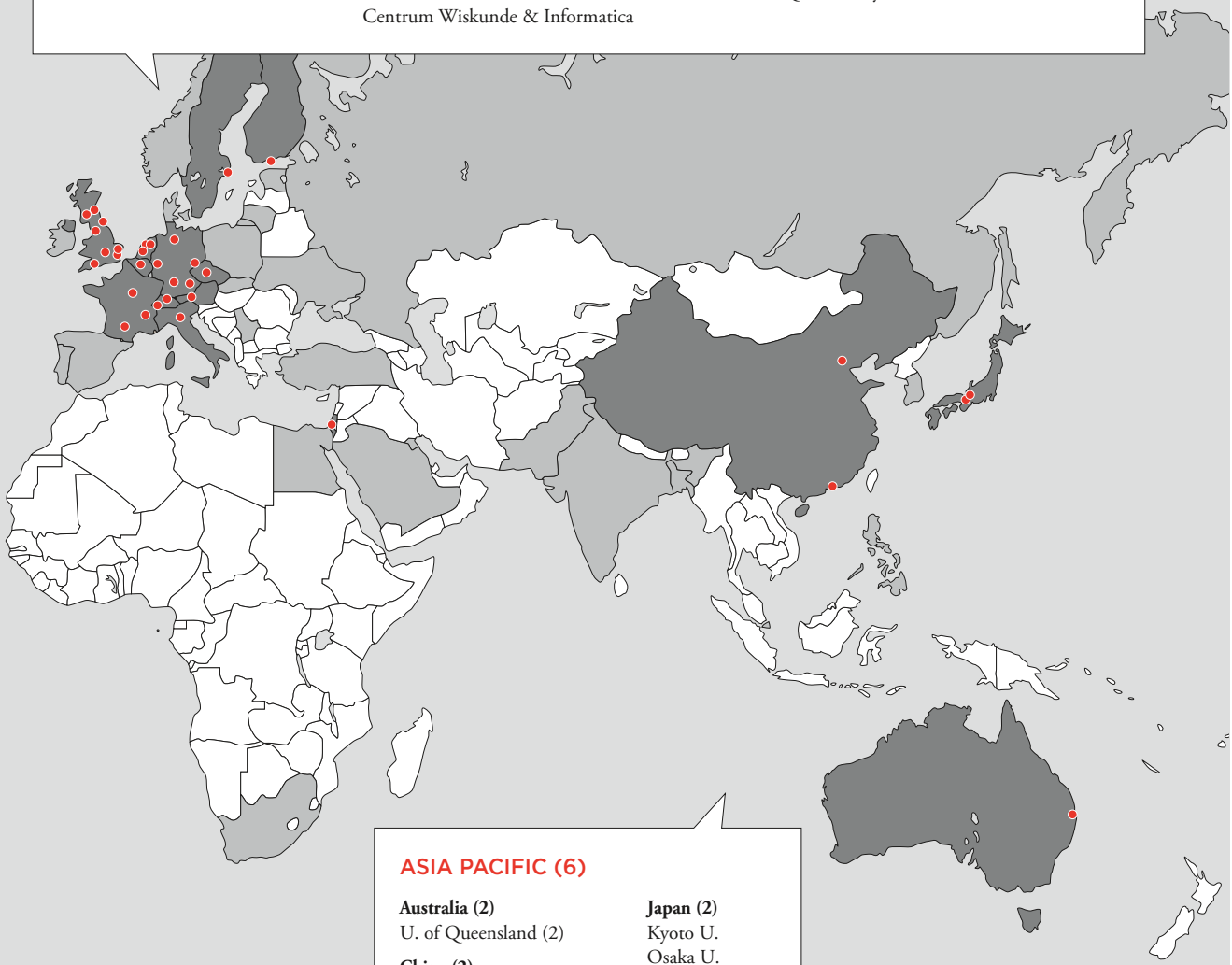
Italy
Bocconi U.

Netherlands (4)
U. of Amsterdam
Centrum Wiskunde & Informatica
Leiden U.
Vrije U. Amsterdam

Sweden
Stockholm U.

Switzerland (3)
École polytechnique fédérale de Lausanne
ETH Zurich (2)

United Kingdom (19)
U. of Cambridge (5)
U. of Durham
U. of Edinburgh (2)
U. of Exeter
U. of Glasgow
King's College London (2)
London School of Economics
U. of Manchester
U. of Oxford (4)
Queen Mary, U. of London



ASIA PACIFIC (6)

Australia (2)
U. of Queensland (2)

China (2)
Chinese Academy of Sciences
U. of Hong Kong

Japan (2)
Kyoto U.
Osaka U.

APPENDIX A:

Major Awards and Honours Received

January 2014 to June 2015

CIFAR fellows and advisors received **78 major Canadian and international awards and honours** in 2014 and 2015. As a further indicator of excellence, 40 per cent of senior program members and 66 per cent of advisory committee members attained the top one per cent of citations in their field worldwide as of 2014/2015. Details are reported on pages 8-9.

AWARDS

AWARD	CIFAR FELLOW OR ADVISOR	CIFAR PROGRAM
Alexander von Humboldt Research Award (Germany)	• Eugene Demler (Harvard University) • Steven Kivelson (Stanford University)	• Quantum Materials • Quantum Materials
Alfred P. Sloan Research Fellowship (USA)	• Alyson Santoro (University of Maryland)	• Integrated Microbial Biodiversity
BBVA Foundation Frontiers of Knowledge Award (Spain)	• Elhanan Helpman (Harvard University)	• Institutions, Organizations & Growth
Beckman-Argyros Award in Vision Research (USA)	• Krzysztof Palczewski (Case Western Reserve University)	• Molecular Architecture of Life
Brockhouse Medal for Outstanding Contributions to Condensed Matter and Materials Physics (Canadian Association of Physicists)	• Ian Affleck (University of British Columbia)	• Quantum Materials
Canada Gairdner Wightman Award (Gairdner Foundation)	• Janet Rossant (Hospital for Sick Children, Toronto)	• Humans & the Microbiome
Dannie Heineman Prize for Astrophysics (American Institute of Physics & American Astronomical Society)	• David Spergel (Princeton University)	• Cosmology & Gravity
Distinguished Contributions to Interdisciplinary Understanding of Child Development (Society for Research in Child Development - USA)	• W. Thomas Boyce (University of California, San Francisco)	• Child & Brain Development
Distinguished Investigator Award (International Behavioural and Neural Genetics Society)	• Marla Sokolowski (University of Toronto)	• Child & Brain Development
Dunlap Award for Innovation in Astronomical Research Tools (Canadian Astronomical Society)	• Matthew Dobbs (McGill University)	• Cosmology & Gravity
Edward Novitski Prize (Genetics Society of America)	• Charles Boone (University of Toronto)	• Genetic Networks
Friedenwald Award (Association for Research in Vision and Ophthalmology - USA)	• Krzysztof Palczewski (Case Western Reserve University)	• Molecular Architecture of Life

Ontario

Gustavo J. Bobonis, Fellow	University of Toronto
Daniel Trefler, Senior Fellow	University of Toronto

International

Daron Acemoglu, Senior Fellow	Massachusetts Institute of Technology, USA
Philippe Aghion, Senior Fellow	Harvard University, USA
George Akerlof[1], Senior Fellow and Nobel Laureate	Georgetown University, USA
Roland Bénabou[1], Associate Fellow	Princeton University, USA
Timothy Besley, *Gluskin-Granovsky Fellow*	London School of Economics and Political Science, UK
Daniel Diermeier, Senior Fellow	University of Chicago, USA
James Fearon, Senior Fellow	Stanford University, USA
Thomas Fujiwara, Global Scholar	Princeton University, USA
Avner Greif, Senior Fellow	Stanford University, USA
Elhanan Helpman, CIFAR Distinguished Fellow and Founding Program Director	Harvard University, USA
Matthew Jackson, Senior Fellow	Stanford University, USA
Ruixue Jia, Global Scholar	University of California, San Diego, USA
Torsten Persson, Senior Fellow and Program Director	Stockholm University, Sweden
Guido Tabellini, Senior Fellow	Università Bocconi, Italy

[1] *cross-appointed to CIFAR's program in Social Interactions, Identity & Well-Being*

Advisory Committee Members:

International

Robert Boyd	Arizona State University, USA
Joel Mokyr, Chair	Northwestern University, USA
Roger Myerson, Nobel Laureate	University of Chicago. USA
Kenneth Shepsle	Harvard University, USA

INTEGRATED MICROBIAL BIODIVERSITY

Alberta

Yan Boucher, Fellow	University of Alberta

British Columbia

Maya Bhatia, Global Scholar	University of British Columbia
Steven Hallam, Fellow	University of British Columbia
Patrick Keeling, Senior Fellow and Program Director	University of British Columbia
Brian S. Leander, Senior Fellow	University of British Columbia
Steve J. Perlman, Fellow	University of Victoria
Curtis A. Suttle, Senior Fellow	University of British Columbia
Laura Wegener Parfrey, Associate Fellow	University of British Columbia

New Brunswick

Adrián Reyes-Prieto, Fellow	University of New Brunswick

Nova Scotia

John Archibald, Senior Fellow	Dalhousie University
Andrew Roger, Senior Fellow	Dalhousie University
Alastair Simpson, Senior Fellow	Dalhousie University
Claudio Slamovits, Fellow	Dalhousie University

Ontario

Nicolas Corradi, Fellow	University of Ottawa

Quebec

David Walsh, Associate Fellow	Concordia University

International

Michael E. Grigg, Fellow	National Institutes of Health, USA
Jan Janouškovec, Global Scholar	San Diego State University, USA
Nicole King, Senior Fellow	University of California, Berkeley, USA
Julius Lukeš, Senior Fellow	Czech Academy of Sciences and University of South Bohemia, Czech Republic
John McCutcheon, Fellow	University of Montana, USA
Thomas A. Richards, Fellow	University of Exeter, UK
Forest Rohwer, Senior Fellow	San Diego State University, USA
Alyson Santoro, Associate Fellow	University of Maryland, USA
Alexandra Zoe Worden, Senior Fellow	Monterey Bay Aquarium Research Institute, USA

Advisory Committee Members:

Canada

W. Ford Doolittle, CIFAR Distinguished Fellow	Dalhousie University
Michael W. Gray, Chair	Dalhousie University

International

E. Virginia Armbrust	University of Washington, USA
Thomas Cavalier-Smith	University of Oxford, UK
Ursula Goodenough	Washington University in St. Louis, USA
Joseph Heitman	Duke University, USA
John W. Taylor	University of California, Berkeley, USA

MOLECULAR ARCHITECTURE OF LIFE

Ontario

Oliver P. Ernst, Senior Fellow and Program Co-Director	University of Toronto
Lewis E. Kay, Senior Fellow	University of Toronto

Quebec

Paul W. Wiseman, Senior Fellow	McGill University

International

Wolfgang Baumeister, Senior Fellow	Max Planck Institute of Biochemistry, Germany
R. J. Dwayne Miller, Senior Fellow and Program Co-Director	Max Planck Institute for the Structure and Dynamics of Matter, Germany
Krzysztof Palczewski, Senior Fellow	Case Western Reserve University, USA

Advisory Committee Members:

International

Robert H. Austin	Princeton University, USA
Daniel Müller	ETH Zurich, Switzerland
Brian Kobilka, Nobel Laureate	Stanford University, USA
David Stuart, Chair	University of Oxford, UK

NEURAL COMPUTATION & ADAPTIVE PERCEPTION

Ontario

David J. Fleet, Senior Fellow	University of Toronto
Brendan J. Frey[1], Senior Fellow	University of Toronto
Ruslan Salakhutdinov, Fellow	University of Toronto
Richard Zemel, Senior Fellow	University of Toronto

Quebec

Yoshua Bengio, Senior Fellow and Program Co-Director	Université de Montréal
Jörg Bornschein, Global Scholar	Université de Montréal
Aaron Courville, Fellow	Université de Montréal
Hugo Larochelle, Fellow	Université de Sherbrooke
Roland Memisevic, Fellow	Université de Montréal
Pascal Vincent, Associate Fellow	Université de Montréal