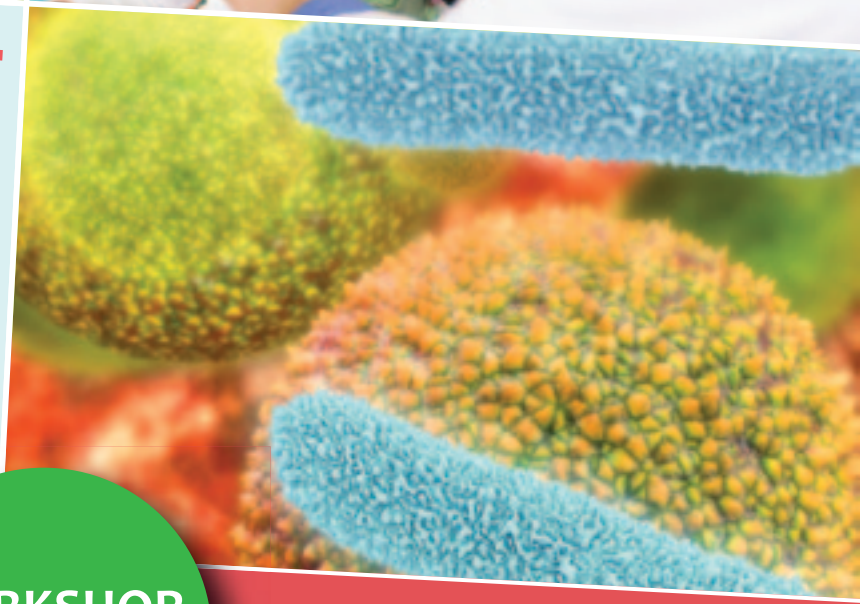
CIHR IRSC

# CANADIAN MICROBIOME WORKSHOP 2014 :
# From Research to Applications



## WORKSHOP REPORT

Westin Bayshore Hotel, Vancouver - February 12-14, 2014

Canadian Institutes of Health Research
Instituts de recherche en santé du Canada
Canada

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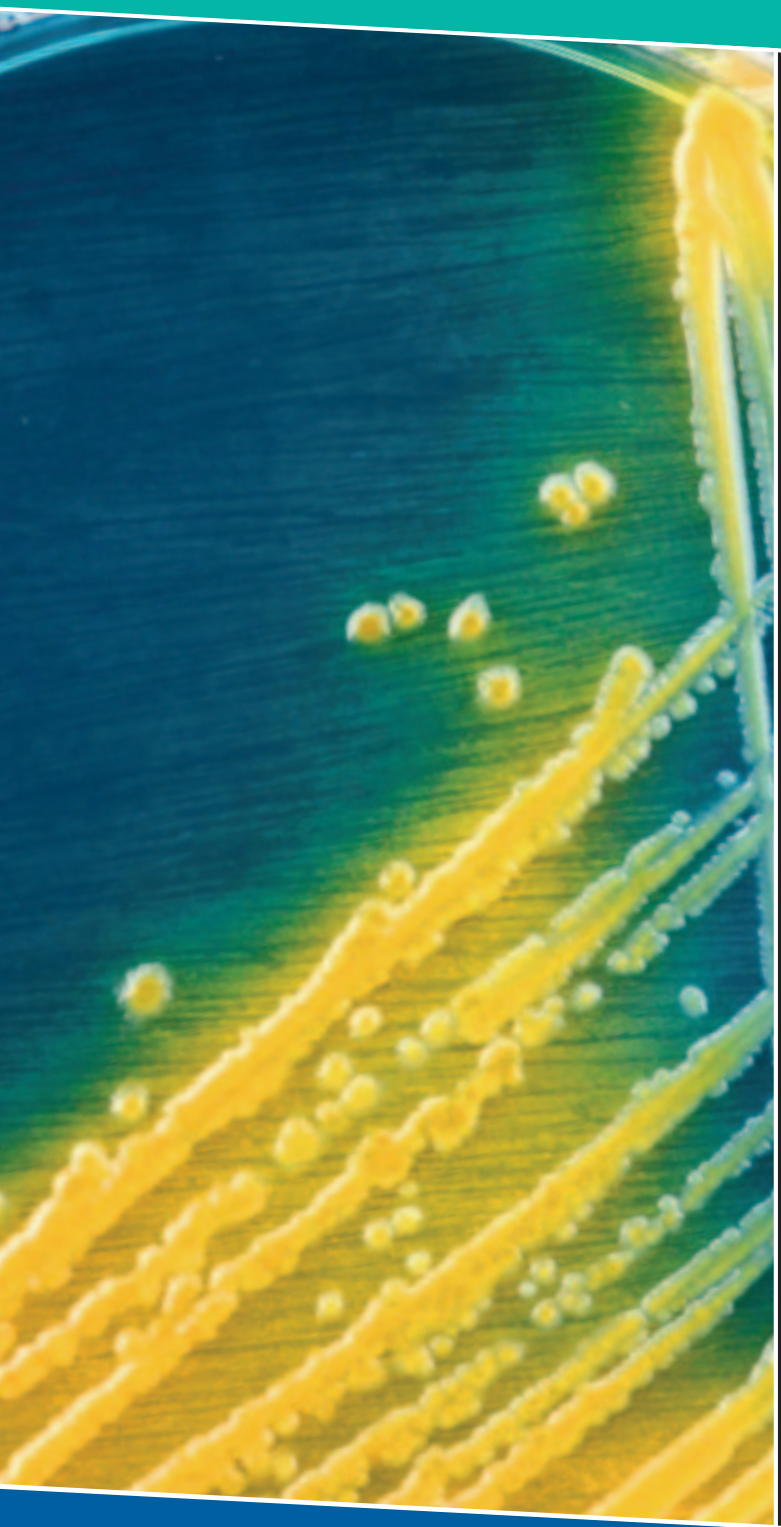

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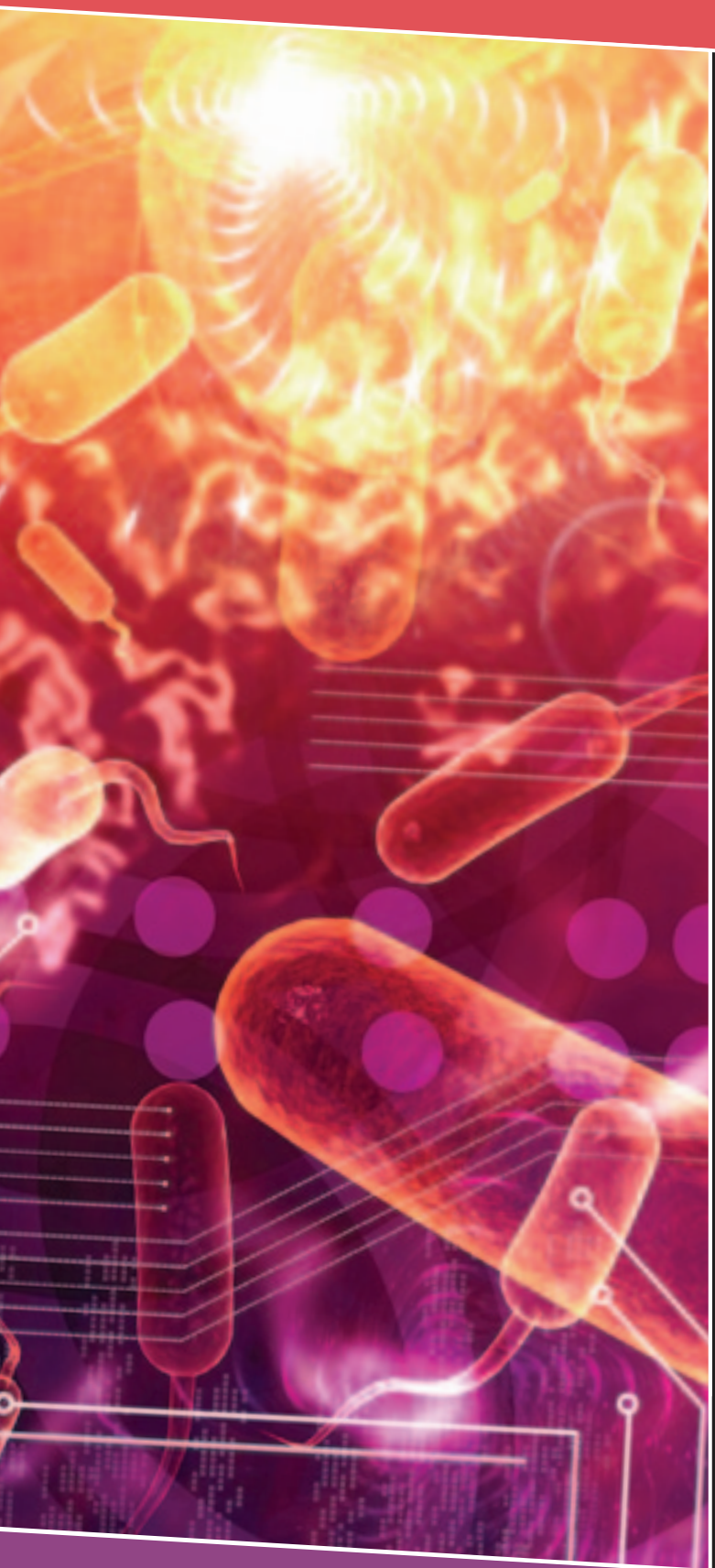


# EXECUTIVE SUMMARY

## BACKGROUND

The human microbiome, which is comprised of the trillions of microorganisms that inhabit the human body, has recently captured major scientific and public interest and spawned a rapidly evolving field of research probing the relationships between the microbiome and human health and disease. Projects undertaken under the auspices of the International Human Microbiome Consortium (IHMC) have generated vast amounts of sequencing data and provided insights into the structure and function of microbial communities. As a founding member of the IHMC, and a major contributor to this international effort, Canada, through the Canadian Institutes of Health Research (CIHR), is committed to exploring opportunities to translate these research outcomes into preventative or therapeutic clinical interventions.

Through the Canadian Microbiome Initiative, the CIHR Institute of Infection and Immunity and partners have invested more than $17 million in microbiome research. These funds have supported networking workshops, catalyst grants, large team grants, a journalism workshop, and a Café Scientifique.

«The Canadian Microbiome Workshop 2014: From Research to Application» was organized to foster new collaborations among the Canadian microbiome community, international leaders, and industry representatives, and to discuss a framework for future research in Canada. The workshop was comprised of a combination of presentations, small breakout sessions and plenary discussions.

**Table 1 / Partners Supporting the Canadian Microbiome Initiative (CMI)**

| | |
|---|---|
| CIHR Institute of Circulatory and Respiratory Health | Genome British Columbia |
| CIHR Institute of Gender and Health | Crohn's and Colitis Foundation of Canada |
| CIHR Institute of Nutrition, Metabolism and Diabetes | Canadian Cystic Fibrosis Foundation |
| CIHR HIV/AIDS Research Initiative | CIHR Ethics Office |

## THE INTERNATIONAL PERSPECTIVE

**George Weinstock, from the Jackson Laboratory for Genomic Medicine, US**, spoke of the first phase of the Human Microbiome Project (HMP1), which generated vast amounts of sequencing data from a reference set of microbial genomes collected from many different body sites. Advances in sequencing technologies, and data storage and handling, have helped rapidly move the field to a point where it is now possible to probe the associations between microbial diversity and human health.

**Dusko Ehrlich, from the Microbial Genetics Unit in Jouy en Josa, France; and Kings College in London, UK** spoke of the achievements of the EU-based MetaHIT Project. This Project was designed to probe the associations between the gut microflora and a number of chronic diseases, including type 2 diabetes, obesity, and cardiovascular disease. The data reveals an association between low bacterial diversity, or richness, in the gut and poor health outcomes, suggesting that measures of gut microbial diversity could have a future in both diagnostics and the design of interventions. A pressing need for standardization of sample collection and processing, DNA sequencing, and bioinformatics was emphasized.

**Lita Proctor from the NIH Human Genome Research Institute, US** spoke of the second phase of HMP (HMP2), which will focus on cause and effect relationships between the microbiome and host health status. This two-year project will create a dataset of biological properties for the microbiome and the host in: pre-term birth; inflammatory bowel disease; and diabetes. The presentation highlighted the pros and cons of increasing scientific, public, and media interest in the microbiome, as well as the power of the microbiome field in uniting scientific disciplines and health areas.

## THE INDUSTRY PERSPECTIVE

The industry panel was comprised of: James Brown, GlaxoSmithKline; Nilufer Seth, Pfizer; Humphrey Gardner, AstraZeneca; Jackie Papkoff, Johnson & Johnson; Mohan Iyer, Second Genome; and Karimah Es Sabar, Centre for Drug Research and Development. Panel members each gave a short synopsis of their organization's involvement in the microbi-

ome field and expressed enthusiasm for exploring opportunities for academic/industry collaborations in areas of mutual interest.

## WORKSHOP OUTCOMES

The workshop engaged the 108 participants in animated discussions throughout the three days, some of which led to the development of plans for new collaborations. The momentum generated spurred the development of a number of action items. A core group of 14 participants volunteered to lead small working groups focused on specific topics that would build on existing Canadian strengths and align with international efforts. Additional volunteers will be recruited as required. Topics for action included:

### Coordinating infrastructures

- Sharing resources (e.g. germ free animal facilities, Robo-gut);
- Coordination and harmonization of existing cohorts, including sampling for microbiome studies;
- Centralized biobanks of bacterial strains and samples such as stool, saliva and urine.

### Consolidating networking and collaboration

- Forming a Canadian Microbiome Network with a website to host research updates; a repository of tools; job postings; training and career development opportunities; and webcasts.
- Organizing focused workshops on specific topics to support knowledge exchange; resource sharing; and collaboration, and to bridge the gap between researchers, funders and the public.

### Sustainable Funding

- Capitalizing on public and media interest to advocate for targeted funding that transcends the boundaries between the three tri-council funding agencies and extends beyond the health field.
- Exploring existing funding sources, e.g. CIHR, NGOs, the Networks of Centres of Excellence Program.
- Exploring opportunities to leverage funds through international collaborations and academic/industry partnerships.

## CONCLUSION

The CIHR Institutes of Infection and Immunity; Nutrition, Metabolism and Diabetes; and partners will work with the Canadian microbiome research community to assist them in their efforts to build on the existing Canadian strengths in microbiome research and to continue the momentum generated by the workshop as a result of the enthusiasm and commitment of workshop participants.

# DAY 1 FEBRUARY 12th

## WORKSHOP OBJECTIVES

The **Canadian Microbiome Workshop 2014: From Research to Applications** brought together members of the Canadian microbiome research community with international experts and representatives of funding bodies and end-user organizations. Participants were drawn from diverse but complementary fields, including microbiology, immunology, technology development, genome sequencing, metabolomics, proteomics, bioinformatics and computational methods, regulatory processes, and ethics. The Participant List can be found in **Appendix 1**. The objectives of the workshop were to:

- Promote networking among the Canadian microbiome research community;
- Foster national and international collaboration;
- Assess progress in the microbiome field and consider potential "next steps"; and
- Engage industry and other "end-user" representatives to explore the application of research discoveries in the microbiome field.

## WORKSHOP FORMAT

The workshop took place over three days, beginning with a networking lunch on Wednesday, February 12th and ending at 11.30 am on Friday, February 14th. The format was a mix of presentations, small breakout group discussions and open plenary sessions. The Agenda can be found in **Appendix 2.**

## Introduction and Background

**Philip Sherman[1], Scientific Director, CIHR Institute of Nutrition, Metabolism and Diabetes (INMD); and**

**Marc Ouellette[2] – Scientific Director, CIHR Institute of Infection and Immunity (III)**

The human body hosts trillions of microbes, including bacteria, viruses, bacteriophages, fungi and protozoa that far outnumber the number of human cells. These microbes reside on the surface and within the human body and collectively constitute the human microbiome.

Advances in the field of metagenomics and the emergence of next generation sequencing (NGS) technologies have provided powerful tools for the analysis of microbial communities, including those that cannot be easily cultured in the laboratory, accelerating our ability to probe the structure and function of microbial communities. Now, increasingly viewed as a new human organ, the microbiome has been associated with both health and a growing number of human diseases and conditions, including irritable bowel syndrome, chronic inflammatory bowel disease, obesity, diabetes, asthma, arthritis, cardiovascular disease, and autism. As interest in this relatively new field has grown so too has the number of grant applications, publications, and patents. At CIHR, alone, investment in microbiome research increased 15-fold between 2007 and 2012 and more and more CIHR Institutes have expressed interest in the field as reflected by the fact that 12 of the 13 Institutes of CIHR were represented at this workshop, including nine Scientific Directors.

The Canadian Microbiome Initiative (CMI) was launched in 2007 under the leadership of III's inaugural Scientific Director, Bhagirath Singh, securing a place for Canada as a founding member of the International Human Microbiome Consortium (IHMC). Since the first planning meeting, which also took place in Vancouver in September 2007, III and partners have launched two strategic initiatives: the first a Catalyst Grant competition which funded 12 one-year pilot projects for a total investment of $1.2 million; and the second a Team Grant competition, through which seven large teams were funded for an investment of $15.5 million over five years. In addition to the current workshop, the Institute has hosted two previous workshops, initially to consult with the broader research community on the scope and breadth of the CMI and then to bring together the seven funded teams early in their programs to promote networking and collaboration. Additional activities include external meeting support, a press conference, a journalism workshop and a Café Scientifique, for a total investment in the Canadian Microbiome Initiative of more than $17 million, making Canada the third largest funder in the IHMC (after the US and the EU).

Throughout all these activities and initiatives, III has been supported by many partners, including: the CIHR Institutes of Circulatory and Respiratory Health; Gender and Health; and Nutrition, Metabolism and Diabetes, as well as the CIHR HIV/AIDS Research Initiative and the CIHR Ethics Office. External partners supporting the initiative include Genome BC, Crohn's and Colitis Canada and Cystic Fibrosis Canada. Now, at the mid-point of the Team Grant program, it was timely to bring representatives of the whole Canadian microbiome community together to consider next steps, with a focus on moving from research to applications.

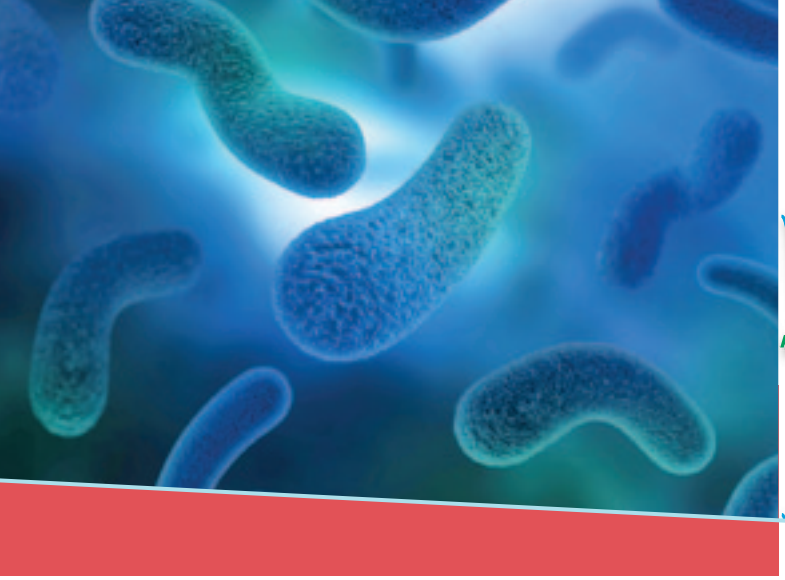
## The International Perspective

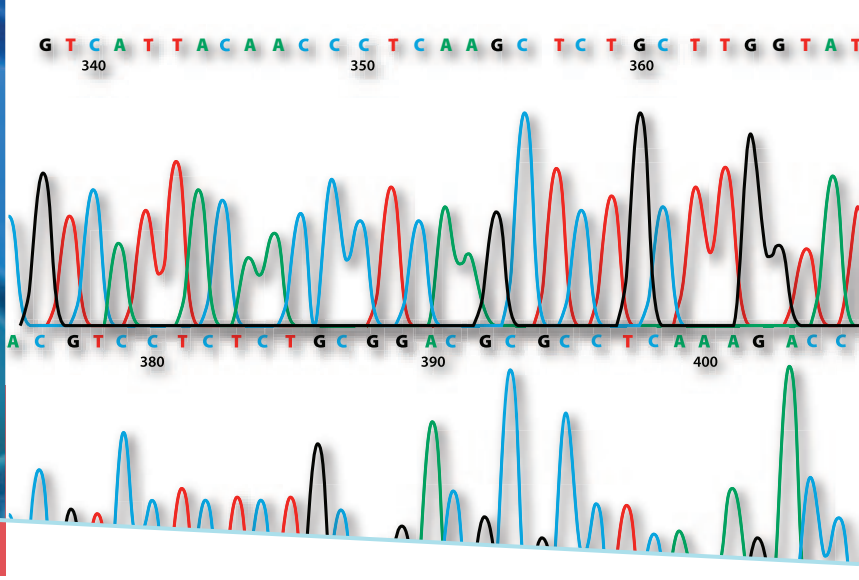
Moderated by: David Charest, Director, Sector Development, Genome BC; Marc Ouellette, Scientific Director of the CIHR Institute of Infection and Immunity; and Philip Sherman, Scientific Director of the CIHR Institute of Nutrition, Metabolism and Diabetes

**Sequencing the Human Microbiome: Achievements, challenges and next steps**

**George Weinstock, Jackson Laboratory for Genomic Medicine, Farmington, CT**

Funded by the Common Fund at the US National Institutes of Health (NIH), the Human Microbiome Project (HMP) began in 2007 as a logical sequel to the Human Genome Project. As attention turned to the microbial communities inhabiting the human






body and their potential impact on human health and disease, HMP researchers began sequencing a reference set of microbial genomes as well as microbial communities in samples collected from 18 body sites generally located in nasal passages, oral cavities, skin, gastrointestinal tract and urogenital tract. Using NGS techniques, hundreds of microbial genomes have now been sequenced and catalogued, over 10,000 metagenomic samples have been analyzed, and the number of microbiome projects has grown to include MetaHIT, HMP2, a variety of medium sized initiatives, and a number of demonstration projects. In the last five years an enormous amount of data have been generated by these projects, providing a basis from which to explore the inter-relationships within the microbiome, as well as the associations between microbiome diversity and human health.

Since the early days of Sanger sequencing, when both 16S rRNA gene and whole gene sequencing were expensive and low throughput (96-384 16S rRNA sequences per sample), a whole new generation of technologies have become available that enable faster, more cost-effective, deep sequencing with more (approx. 5000) 16S rRNA sequences and up to 100 million whole genome shotgun sequences per sample. Overall, full-length sequencing provides 92% accuracy in predicting taxa at the species level and 94% at the genus level, with 88-92% accuracy if only three variable regions are sequenced. The constant evolution of new sequencing technologies has raised concerns about bias both within and between different methods. Examples of commonly used sequencing technologies include:

- **Classic 16S rRNA technology** that performs Sanger sequencing for 9 hypervariable regions (full length sequencing)
- **454 pyrosequencing** (400bp reads) which gives good taxonomic information from only 2-4 hypervariable regions and is the standard for large-scale sequencing projects (cheaper, faster, high throughput)
- **Illumina sequencing** (100 - 300bp)which is lower resolution but generates hundreds of thousands of sequences from one hypervariable region.
- **PacBio sequencing** which can now do full length sequencing of the 16S gene, lower in cost than Sanger but higher throughput, although it is more expensive than Illumina and not as high throughput. Accuracy is high, though, at more than 99% sequence identity to reference sequences
- **Shotgun sequencing** of microbial communities which, although more expensive, enables analysis of strain variation, eukaryotic microbes and viruses, as well as community gene content.

The outcome of several successful years of microbial sequencing has been the generation of vast amounts of data and the need for new storage and software solutions such as mBLAST, which has both increased sensitivity and is orders of magnitude faster than

the original algorithm. Despite progress, however, computational challenges remain and are likely to increase as more and more data are generated at an ever-increasing pace.

Despite the technological challenges, the HMP has paved the way for a new field of research exploring the intricate relationships that exist between host and the microbiome. Research shows that, although microbiota composition varies between body sites and from person to person, after the first few years of life, an individual's microbiome remains relatively stable over time and it is possible to tell people apart based on their bacterial genomes. Although we can now answer precise questions about microbial diversity and associations with human health, the challenge is to prove a link between association and causality. Several pilot projects underway as part of the HMP are showing promise in this area, including:

- Acne project – probing the association between specific bacterial strains and acne. One particular strain, *Propionibacterium acnes*, the dominant bacterium on skin, has certain ribotypes (substrains) only found in acne lesions and thus may be causal. Conversely, a *P. acnes* ribotype found only in normal skin and not in acne lesions may be exerting a protective effect.

- Hospital acquired diarrhea – metagenomics enables the accurate identification of *C. difficile*, but also commonly reveals the presence of other bacteria such as *Campylobacter* and *Salmonella*, augmenting the results from the clinical microbiology laboratory and providing additional information to clinicians.

- Bacteremia in infants – regular collection of diapers and sampling of stool bacteria identified pathogenic microbes before the clinical development of bacteremia symptoms, opening the door to risk identification and early interventions in colonized infants.

- Pneumococcus vaccination and the pediatric nasopharyngeal microbiome – a collaboration with researchers in the Gambia to understand what makes a type of bacteria that causes pneumonia so deadly and how a vaccine can affect the microbial population that colonizes infants. Longitudinal sampling shows microbiome variation over time with a shift in strains from those present in vaccines to those absent.

Going forward, the challenge will be to move from sequencing and microbial characterization to applications in health and the demonstration of causal relationships in disease. Some major successes such as the proposed use of fecal transplants for treatment of recalcitrant *C. difficile* infections are needed to establish the translational impact and clinical utility of microbiome research.

**EU MetaHIT Project - Achievements, challenges and next steps**

**Dusko Ehrlich, Research Director, Microbial Genetics Unit, INRA, Jouy-en-Josa, France; King's College, London, UK**

The MetaHIT project, financed by the European Commission under the 7th FP program, was comprised of 13 partners from academia and industry drawn from 8 EU countries. The project operated from 2008-2012, supported by a total financial investment of more than € 21,2 million (Can$32.3M). MetaHit's primary goal was to explore the role of the human intestinal microbiota in disease, specifically inflammatory bowel disease (IBD) and obesity.

The human intestinal microbiome has an estimated mass of up to 3kg and serves as an interface between food and the gut epithelium as well as being in direct contact with both the underlying immune and neuronal cells. Some view the gut microbiome as a neglected organ that plays a major, as yet un-

defined, role in both health and disease. In contrast to the steady decline in infectious diseases in the industrialized world, there has been a steady increase in chronic diseases such as Crohn's disease, multiple sclerosis, asthma and diabetes since the 1950's. A central theme for the MetaHIT project was to explore whether characterization of the gut microflora could predict the risk of chronic disease, leading to the development of preventative interventions.

The MetaHIT approach was based on the construction of a pipeline that included:

- Creation of an extensive reference catalogue of microbial genes present in the human intestine
- Development of bioinformatics tools to store, organize and interpret this information
- Development of tools to determine which genes in the reference catalogue are present in different individuals and at what frequency
- Recruitment of cohorts of individuals, some sick and some healthy, to determine which genes they carry
- Development of methods to study the function of bacterial genes associated with disease to understand the underlying mechanisms and host-microbe interactions.

To date, 10 million genes have been catalogued from stool samples of 1267 healthy individuals in the EU, US and Japan. Genes have been clustered into MetaGenomicUnits (MGUs) producing 741 large MGUs (>700 genes) that correspond to bacterial species; and 6,640 small MGUs. In addition, 257 high quality genomes have been constructed. The data show that all the genes of a certain species have the same frequency in an individual; the abundance of species varies greatly between individuals; and genes that co-vary in abundance belong to the same species. Of interest is the fact that while the identification of rare genes is increasing, common genes have now plateaued, suggesting that common genes may be the most useful for studying disease.

Studies have shown that human metagenomic markers perform better than human genome markers in discriminating between lean and obese people and that, when gut microbes are stratified by enterotype, the correlation is even better. Similarly, microbiome markers are more discriminatory for type 2 diabetes and for liver cirrhosis, suggesting that metagenome markers may be a useful diagnostic tool for other chronic diseases.

In general, bacterial richness increases during the first three years of life, then plateaus, and eventually declines slightly in old age. However, ulcerative colitis patients have significantly fewer gut bacterial-derived genes than their healthy counterparts. Similarly, low bacterial richness correlates with an increase in metabolic and pro-inflammatory traits. Overall, the data suggest that low bacterial richness in an individual predisposes to increased adiposity, insulin resistance, dyslipidemia, inflammation, type 2 diabetes, cardiovascular disease and even certain cancers that may represent a specific risk phenotype. The unanswered question is: why is this gut microbial diversity lost? A twin study on 240 healthy Dutch twins and spouses, suggests that multiple factors are at play.

Microbial perturbations are probably ecologically mediated rather than a consequence of pathogenic infection, raising the possibility of microbiome modulation through dietary modifications. A 2012 dietary intervention study of 49 overweight and obese individuals in France demonstrated that gene richness in low gene count individuals increased while on a high protein, low glycemic index, high fiber, calorie restricted diet for six weeks - followed by maintenance for a further six weeks. The response was even more marked in people who began the study with high gene richness, a further indication that low richness could be a predictor of poor health outcomes.

Finally, a Danish study on overweight and obese individuals demonstrated that low richness individuals on average gained more weight than their high richness gut microbiota counterparts over a nine-year period. High levels of certain MetaGenomic Species (MGSs) are associated with lower weight gain during the study, indicating a potentially protective role for these MGSs. The fact that these MGSs were predominately butyrate producers suggests a role for short-chain fatty acids as a health promoter in the gut.

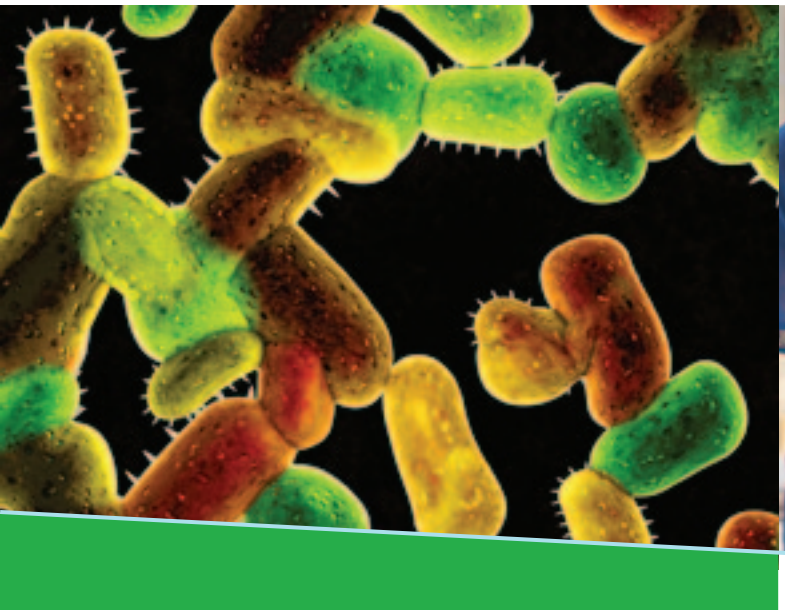
The results from MetaHIT indicate that a low diversity microbiome carries a health risk that could be used as a diagnostic leading to interventions to alleviate such a risk. This could have a major impact on public health. One key requirement to move the field forward is standardization which is critical when comparing results among studies reporting levels of bacterial diversity to ensure that associations and correlations do not merely reflect differences in sample collection and processing; DNA sequencing; and bioinformatics.

MetaHIT has led to MetaGenoPolis (MGP), a demonstration project funded by the French Investissement d'avenir to explore the impact of the human gut microbiota on health and disease. MGP will integrate technology and expertise with a focus on nutrition and medical interventions. MGP is a partnership between the MICALIS Institute of INRA, IHU ICAN (Institut de Cardiométabolisme et Nutrition) hosted by the Pitié Salpêtrière University Hospital, and Institut Catholique de Lyon. MGP is also supported by industry partners Enterome Bioscience, Pfizer and Danone Research Institute for a total investment for 2012-2019 of more than 80M€ (Can$122M). Goals for the future include the creation of an international network of structures for microbiome investigations to accelerate discovery, and the development of a richness assessment kit by the end of 2014.

**The NIH Microbiome Project - A Funder›s perspective: Achievements, challenges and opportunities**

**Lita Proctor, Coordinator, Human Microbiome Project, National Human Genome Research Institute, NIH**

The formal 2008 launch of the first phase of Human Microbiome Project (HMP1), established the US NIH as a founding member of the International Human Microbiome Consortium (IHMC), along with the European Union (MetaHIT), Canada (CIHR) and several other countries. HMP1 was supported by the NIH Common Fund as a catalytic community resource project, tasked with building research capacity and providing tools, resources, repositories, and data for



the international microbiome research community. The primary objective of HMP1 was to characterize the microbiome populations in five major regions of the body (skin, oral, nasal, GI tract, and urogenital tract) and establish public repositories for sequence, strain and clinical phenotype data. Samples were collected from a healthy cohort of 300 adults and each body region was verified to be clinically free of overt disease prior to sampling. The goal was to conduct large-scale, high throughput assays to analyze the makeup of the human microbiome and develop bioinformatics and computational tools to analyze the complex sequence data. Repositories included a catalogue of 3000 microbial reference strains and their genome sequences, as well as a biobank of nucleic acid extracts from the healthy cohort subjects. A series of demonstration projects on diseases of the skin, the gastrointestinal and the urogenital tracts were also begun to probe microbiota associations with human disease.

HMP1 showed that each individual hosts between 250 and 500 bacterial species and two million unique bacterial genes. As there is variation in the microbial diversity between individuals, it was estimated that in the US population, there is a global pool of up to 10,000 bacterial species and eight million unique bacterial genes - the genetic "blueprint" of the human metagenome. Moving forward, it will be necessary to collect other microbiome data including its biological properties in order to understand the connections between the microbiome and human health.

The completion of HMP1 in 2012 spurred a series of planning meetings to consider the scope for a second phase - HMP2. It was decided that HMP2, building on the data produced in HMP1, would focus primarily on creating a rich dataset of biological data for the microbiome and the host, including transcripts, proteins and metabolites, which would allow the research community to evaluate cause and effect relationships between the microbiome and host health status. These kinds of data are costly and time consuming to collect. Therefore, HMP2 (2014-16), though smaller in scale is supporting three sites focused on creating a dataset of biological properties, both for the microbiome and the host, in three well-defined cohorts which are key examples of microbiome-associated conditions: preterm birth, IBD, and diabetes. More information about HMP can be found at: http://commonfund.nih.gov/hmp/ .

The whole idea of the human microbiome has captured the interest and imagination, not just of scientists, but also of the general public. In a world conditioned to think that bacteria cause infections and are "bad for our health", there has been a paradigm shift in thinking and the media has seized the opportunity to promote the benefits of a "healthy microbiome". While the attention generated is good for promoting microbiome research, especially in the minds of politicians and funding bodies, there is a risk that the public and media acclaim is actually advancing at a greater speed than the science can support, raising the concern of "over-hyping"

the microbiome to the ultimate detriment of the field. Since the beginning of HMP in 2008, there has been a many fold increase in the number of journal articles (scientific and non-scientific), media events and advertisements (TV, press, radio), patents, and new biotech company start-ups related to the microbiome. While controlling media and industry efforts to raise public awareness of the potential of fecal transplants to cure *C. difficile* infections or the health-promoting effects of probiotics, for example, can be challenging, the reality is that all this attention has also resulted in an increased appetite to support research through non-traditional sources, such as crowd-sourced funding and philanthropic donations. In addition, the public appears happy to participate in studies, providing much needed samples to support the research. Overall, all this activity is a sign of healthy growth in a relatively new field – one which holds the promise of important advances in the diagnosis and treatment of a number of chronic diseases.

A similar transformation has taken place within the NIH, which has seen a dramatic increase in the number of Institutes entering the microbiome field since the launch of HMP in 2008. NIH is comprised of 27 Institutes, Centers and Offices (ICOs) which in fiscal years 2007 and 2008 were collectively investing roughly $7 million per year to support microbiome research, essentially from just five participating ICOs. Initially HMP did not increase the number of participating ICOs, although it did increase funding through a "big science" approach. However, by 2011-2012 there had been a dramatic shift that saw the increase of participating ICOs jump from five to sixteen with a total NIH investment, outside of HMP, of $125 million. This increase reflects the breadth of microbiome research and the potential importance of the microbiome to health. The biggest increases in research areas were seen in microbiology, immunology, food science technology and nutrition, gastroenterology and hepatology[1].

As links emerged across the spectrum of human health, more and more ICOs saw themselves as part of the field, even if they had not traditionally been engaged in host-microbiota research. NIH has now created a Microbiome Working Group to manage broad interest in the microbiome and coordinate research across the organization, including a common website and shared funding opportunities. With an estimated close to half a billion dollars invested worldwide in microbiome research, including industry supported research, there is a growing need for international collaboration and a common regulatory framework.

In July 2013, NIH hosted a three-day meeting to take stock of this emerging field: Human Microbiome Science - Vision for the Future. It included nine thematic sessions, 36 keynote and invited speakers, 50 posters, and a daily open floor discussion moderated by Ed Yong (a science journalist for National Geographic). Francis Collins, NIH Director, Jesse Goodman, Chief Scientist for the US Food and Drug Administration and Roberto Barbero, with the Obama Administration's Office of Science and Technology Policy spoke at this conference. Roughly 270 participants attended this meeting, including representatives from 16 ICOs and scientists from around the world, with another 250 joining via a webcast. Outcomes included a Commentary (in review) in the journal Science, a meeting report (in review) in the journal Microbiome and a recommendation for the inclusion of microbiome sampling in the US National Children's Study – a cohort of 100,000 Americans who will be studied from birth to 21 years of age. This last point led to a plea to better coordinate international efforts particularly with respect to the inclusion of microbiome sampling in ongoing or new cohort studies, including Canadian cohorts.

## The Industry Perspective

Moderated by: Paul Lasko, Scientific Director of the CIHR Institute of Genetics; and Stephen Robbins, Scientific Director of the CIHR Institute of Cancer Research.

*1 Nature Biotechnology, vol. 31, #4, 2013, pp. 309-315.*

## GlaxoSmithKline

### James R. Brown, Director, Computational Biology – Infectious Diseases and Microbiome

GlaxoSmithKline (GSK) is a science-led global healthcare company that researches and develops a broad range of innovative products in three primary areas of Pharmaceuticals, Vaccines and Consumer Healthcare. GSK has a significant global presence with commercial operations in more than 150 countries, a network of 86 manufacturing sites in 36 countries, and large R&D centers in the UK, USA, Spain, Belgium and China. Research is vitally important to the success of GSK, and £3.4 billion ($6.3B) was invested in 2013 in the search to develop new medicines, vaccines and innovative consumer products. GSK is one of the few healthcare companies researching medicines and vaccines for the World Health Organization's three priority diseases - HIV/AIDS, tuberculosis and malaria.

Historically, there has been little interaction between infectious and chronic disease research, but it is now recognized that there are microbial targets for chronic disease and host targets for infectious disease. This "meeting of the minds" has found a perfect home in the microbiome field and numerous therapeutic areas now include microbiome projects. GSK interests in the microbiome and host-pathogen interactions span several therapeutic areas with a main focus on respiratory diseases, metabolic diseases, immune and inflammatory diseases, and infectious diseases, as well as synthetic biochemistry and drug metabolism. Internally, GSK has several relevant technology platforms such as computational biology, NGS, drug development and pharmacokinetics, metabolomics, medicinal chemistry and screening. In October 2013, GSK held a science day focused on the microbiome and driven by therapeutic areas, which helped develop GSK's strategic interests and goals in the microbiome.

GSK has been actively engaging the wider external scientific community in recognition that, in the drug discovery continuum, collaborations with academia have a large role to play in the discovery of new targets ready for uptake by industry. Several different models for engagement are possible, including in- kind contributions of compounds and drug development expertise, and developing young talent. There are now many examples of successful public/private partnerships and pre-competitive consortia, which could be applied to the microbiome area. For example, collaborations involving the combined expertise in microbiome systems in academia and the pharmaceutical industry's vast array of tools, including narrow-spectrum antibiotics, human receptor agonists/antagonists, vaccines and biologicals.

## Pfizer

### Nilufer Seth, Principal Scientist, Immunoregulation Group

Pfizer applies science and resources to bring therapies to people that extend and significantly improve their lives, setting the standard for quality, safety and value in the discovery, development and manufacture of health care products. Pfizer's global portfolio includes medicines and vaccines as well as many of the world's best-known consumer health care products. Pfizer's Host-Microbiome Group is focused

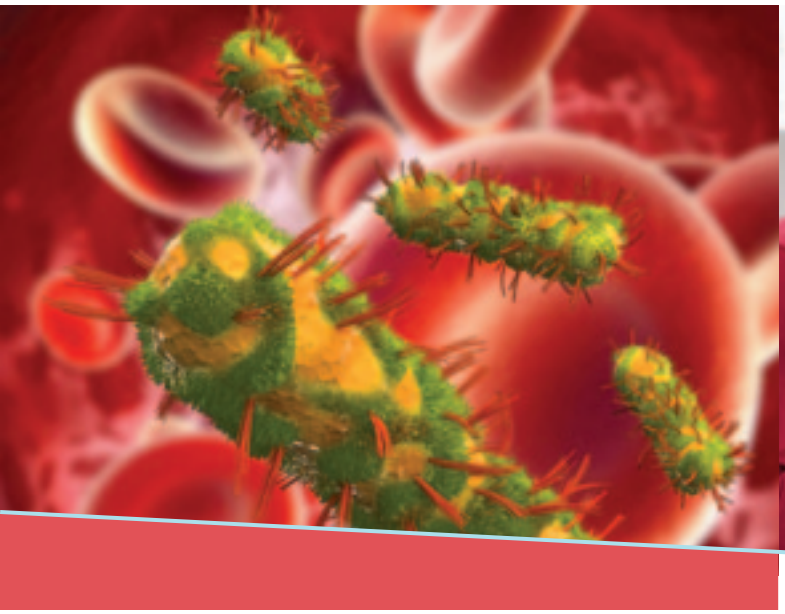
on the study of interventions for inflammatory and autoimmune diseases that harness strategies and pathways used by the human intestinal microbiota to maintain immune homeostasis.

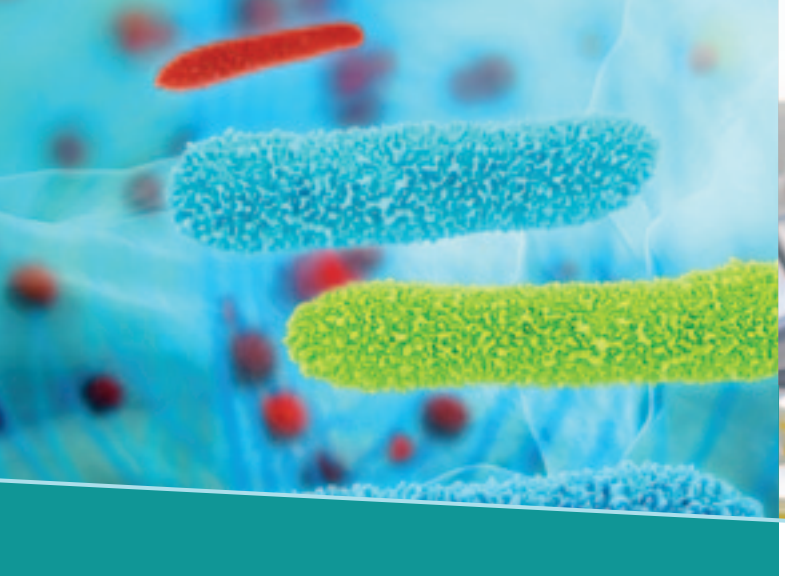
Although microbial dysbiosis is observed in many diseases, the challenge is to determine the nature of the associations and discriminate between cause and effect. Pfizer's Host-Microbiome Interactions Group is interested in the relationship between diet, microbiota, and host mucosal epithelial and immune responses - particularly the effects on innate and adaptive immune pathways, and believes that harnessing the microbiome will be a key strategy for restoring immune homeostasis. The goal is to develop therapeutic drugs based on bacteria, bacterial products, and modulated pathways as part of a strategy that includes single strains, mixed strains, or engineered bacteria, as well as immunomodulatory bacterial and engineered/optimized products. To achieve this goal, the Group is involved in both internal programs targeting short chain fatty acid receptors and Toll-like receptors, as well as multiple external partnerships. A central aim is to catalyze the creation of an external network of programs that are enabled by Pfizer drug development capabilities.

## AstraZeneca

**Humphrey Gardner, Vice-President, Translational Medicine**

AstraZeneca (AZ) has a primary focus in cardiovascular, respiratory, inflammatory, and metabolic diseases as well as oncology. In the long term, opportunities abound in the modulation of the microbiome in the treatment of a multitude of inflammatory diseases as well as metabolic, respiratory, and CNS diseases. In the AZ infection group the main focus is the development of new, highly targeted antibacterials. A good understanding of the resistome – the microbiome's potentially transferable gene pool enabling antibacterial resistance – is a key component of the strategy in developing new antibiotics. To this end AZ works *in silico* looking for correlations between the presence of novel resistance genes and resistance, as well as taking advantage of tools developed, through the Quebec Consortium for Drug Discovery (CQDM) support, by colleagues at Laval University in Quebec City.





In disease areas such as colitis, great progress has been made exploring microbiome relationships, with the strong suggestion that loss of microbiome diversity is a fundamental prerequisite to a variety of inflammatory disease states. As a pharmaceutical development organization, AZ is eager to see and develop evidence of causality enabling development of stable formulations of molecules, macromolecular complexes, or organisms, which might be used in the treatment of well-characterized disease states. AZ will collaborate with academic groups to develop such evidence where preliminary data are compelling, and will leverage resources in areas of particular strength, such as high throughput screening, to contribute to discovery.

## Johnson & Johnson

**Jackie Papkoff, Vice-President, Immunology Scientific Innovation, J&J California Innovation Centre**

The Johnson & Johnson Family of Companies (J&J) is the world's most comprehensive and broadly based manufacturer of health care products, as well as a provider of related services for the consumer, pharmaceutical and medical devices and diagnostics markets. The J&J Innovation Centers were launched in 2013 in London, Boston, San Francisco and Shanghai (2014) to identify and foster innovation across the pharmaceutical, medical devices, diagnostics and consumer product ecosystem. These Centers invest in transformational opportunities from inception through clinical proof of concept and cultivate and sustain meaningful relationships with the academic, biotech and business communities. The driver for partnering is novel, rigorous science that is aligned with J&J strategic objectives, with a focus on research and development with partners having shared scientific values and common clinical objectives. The Centers serve as a "one-stop shop" for researchers, partners and small incubator companies - offering advice, sponsorship and mentorship as required.

Janssen Immunology, within the pharmaceutical division of J&J, is focused on immune-mediated diseases including rheumatoid arthritis, inflammatory bowel diseases, psoriasis and respiratory conditions such as severe asthma and chronic obstructive pulmonary disease. Through partnerships Janssen Immunology is probing causative relationships between microbiome and host in an effort to define actionable therapeutic mechanisms and targets. An additional interest is to determine whether microbes or their products can achieve therapeutic efficacy with a

profile similar to conventional therapeutics for autoimmunity. As a science, the microbiome field is in its infancy but it has the potential to yield innovative medical solutions through the discovery of disease triggers, novel targets, and new drugs.

## Second Genome

### Mohan Iyer, Scientific Vice-President, Corporate Development

Second Genome brings microbiome science to the discovery and development of therapeutic products. The company has established a pipeline of microbiome modulators that impact infection, immunity and metabolic diseases. Their development pipeline is fueled by novel technologies for identifying, screening and scientifically validating product candidates and microbial biomarkers. Second Genome's technologies have been rigorously validated through partnerships with leading pharmaceutical and nutrition companies, as well as academic and governmental research institutions.

Beginning as a small start-up company in San Francisco, Second Genome took a calculated risk in entering the microbiome field before the increase in public and mainstream research interest. The company started with proprietary technologies, but has evolved to include sequencing, metagenomics and metabolomics, with a focus on the standardization of processes. It is now focused on microbiome therapeutics with a causal mechanism of action. In order to show causation, it will be necessary to move beyond 'omics' to bring microbes back into assays in an intelligent way through screens specifically tailored for the microbiome. Tailored in vivo models are also key. Second Genome is particularly interested in well-pedigreed clinical samples (suitable for microbiome profiling) as well as mechanism-based microbiome technologies that may not yet be ready for the large pharmaceutical companies but show early promise in the laboratory, and is keen to explore partnerships with academics who have new tools and novel ideas.

## The Center for Drug Research and Development

### Karimah Es Sabar, President and CEO

The Center for Drug Research and Development (CDRD) (http://www.cdrd.ca/ ) is a fully-integrated national drug development and commercialization center, providing expertise and infrastructure to enable researchers from leading health research institutions to advance promising early-stage drug candidates. CDRD is the only centre of its kind in Canada with the full expertise and infrastructure to source, evaluate, develop and commercialize both small molecules and biologic innovative technologies in virtually any therapeutic area. CDRD was specifically created to streamline promising discoveries stemming from publically funded academic health research and transform them into commercially viable opportunities for the private sector. To date, CDRD has:

- Leveraged public and private sector funding to create a state-of-the-art drug development and commercialization platform with the infrastruc-

ture, scientific and business expertise, and professional project management skills to develop innovative health technologies through the pre-clinical stage;

- Established Innovation Funds with some of the world's top pharmaceutical companies including Pfizer, Johnson & Johnson, and GlaxoSmithKline;

- Undertaken over 136 research projects representing 99 novel technologies; launched a new start-up company; and out licensed three novel therapies with five additional technologies moving towards the commercial arm; and

- Provided project management services based on industry best practices, and rigorous milestone-based project plans.

Created only six years ago, CDRD is affiliated with all major universities in Canada and its success is based, in large part, on strong partnerships with industry and foundations. CDRD now has 43 affiliated partnerships across Canada and internationally, and is part of a global alliance of leading drug discovery and development centers to develop shared best practices. CDRD de-risks and accelerates the translation of discoveries, with a focus on pre-clinical activities that draw on the best of Canadian technology. CDRD is currently supporting several projects on antibiotics and antibiotic resistance of potential relevance to the microbiome field and is open to additional proposals that align with the CDRD mandate.

## Question and Answer Period

The industry panel presentations, were followed by a question and answer period during which participants raised many questions, including:

- **What is the industry position on antibiotic resistance given the fact that the microbiome carries antibiotic resistance genes that could be transferred between organisms?** – GSK actively researches in this area with a focus on gram-negative bacteria and has partnerships with the UK and the US. The challenge is that, although there are many targets, it is hard to find compounds that are effective, safe and overcome clinical resistance. GSK is open to new ideas.

- **What is the future for probiotics?** – AZ considers that delivering live bacteria is currently outside their scope; J&J haven't ruled out live bacteria and their consumer product and immunology divisions are working in this area; GSK are exploring potential innovations, such as bacteria that could deliver therapeutic compounds to the gut. However, there are intellectual property (IP) issues and environmental considerations to overcome when introducing live bacteria into a population.

- **Are we missing a new paradigm in terms of the interactions, rather than a simple cause and effect, between the microbiome and inflammation? Should industry be focusing on screening molecules to reduce pro-inflammatory bacteria and restoring the normal balance? –** It maybe time to move from a broad-based to a narrower, single strain approach, although proprietary issues would need to be overcome. This could occur through a consortium of companies or open-access public/private partnerships, although currently no funds are specifically earmarked for this line of investigation.

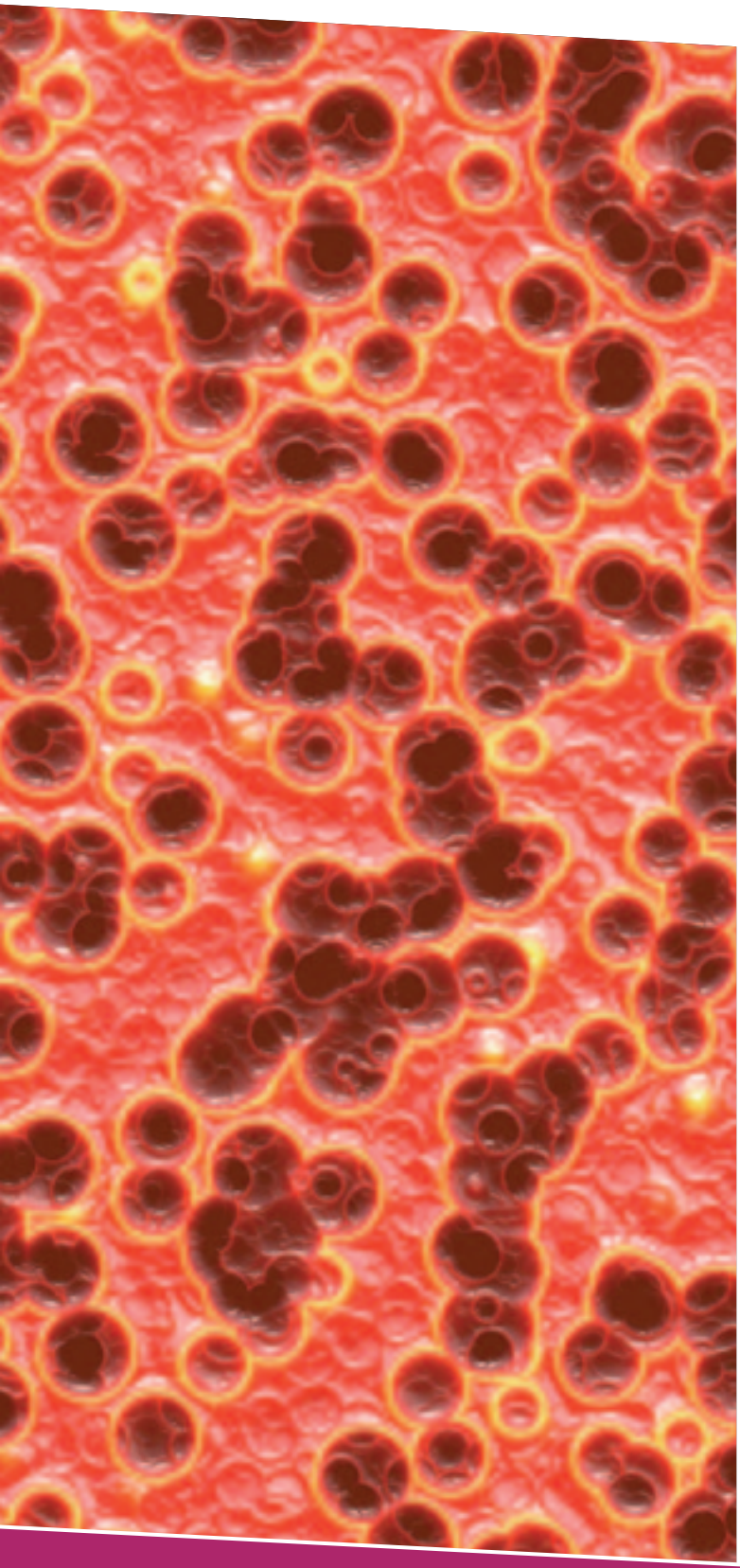
- **How do we overcome IP issues, as it is hard to patent bacteria or their products? –** CDRD can help through de-risking early translational research in collaboration with industry, foundations and regulatory bodies; Second Genome pointed to the implications of a US Supreme Court ruling from the 1920s, when the Funk Brothers Seed Company failed to get a patent on strains of bacteria that fix nitrogen in leguminous plants. However, despite the challenges in patenting specific bacteria, formulations and certain other aspects associated with bacteria could potentially be protected.

- **Is research taking place to develop a technology capable of removing specific microbes from a microbial community?** – GSK screens many microbial compounds, but not for this specific use. Removing a specific microbe from a com-

munity would require the development of new tools, especially as many microbes are strict anaerobes; Second Genome is investigating the concept of functional silencers rather than full removal of a specific microbe, as well as the role of pre-biotics to selectively promote microbial growth; J&J raised the question that perhaps rather than removing certain microbes the focus should be on changing the composition of the microbial community. Perhaps the host immune system could be manipulated to modulate the composition of the microbiome.

- **Are there ongoing studies investigating the effects of the microbiome on *in vivo* drug metabolism causing alterations in toxicity and efficacy?** – AZ and GSK have both done studies to look at this by examining metabolites in stool samples. This raises the possibility that the effects of the microbiome on drugs might be one reason for the variability in drug responses. Second Genome has studied a panel of 100 commonly ingested compounds, including medications, coffee, chocolate and wine, to examine how the microbiota was affected. They obtained interesting data on drugs such as metformin and fluoxetine (Prozac), both of which cause significant microbial perturbations. All panel members agreed that much more research is needed in this area as medications for chronic disease are rarely screened for activity against the microbiome, even though the implications of such effects could be significant. Also, further studies are needed on the role of the microbiome as an aid to patient selection in drug responsiveness studies.

Additional comments included: building new platforms such as the Robo-gut developed by Emma Allen-Vercoe at the University of Guelph; studies on the immunomodulatory properties of the entire microbe rather than just the cell wall; exploring the host response and the downstream effects of small molecules produced by microbes; studies on the microbiota/gut/brain axis; and the need for more studies on the functional implications of microbes present at body sites other than the gut.



# DAY 2 FEBRUARY 13th

## Breakout Sessions

Day 2 was comprised of a series of two breakout sessions, report backs, and plenary discussions, during which workshop participants were encouraged to network and interact as much as possible. To facilitate this process, participants were assigned to specific tables for Breakout Session 1, ensuring a multi-disciplinary, multi sector composition at each table. For Breakout Session 2, many participants were re-assigned to different tables to promote further networking. The breakout sessions focused on three broad questions: **What do we have? What do we need? How do we get it?**

## Breakout Session 1

Groups were chaired by either a CIHR Scientific Director or a Team Lead from one of the seven teams funded under the CMI. The session began with round table introductions at each table that extended beyond names and locations to include areas of expertise and opinions on the most promising and exciting areas of research in their respective fields. Participants were asked to address the following questions:

### Tables 1-4 – What do we have?

- What are the current Canadian strengths and in which areas do we have the greatest capacity?
- What infrastructure/resources already exist? What do we still need? How can we better share existing resources?

## Public Interest

One overarching strength that was identified, although certainly nor restricted to Canada, was the widespread scientific and pubic interest in the microbiome, a factor that has contributed to the rapid growth of the field and the strong financial investment in microbiome research in recent years. This interest had been fuelled by the ubiquitous nature of the microbiome and the promise that microbiome manipulations could one day improve human health across a wide spectrum of common diseases and conditions.

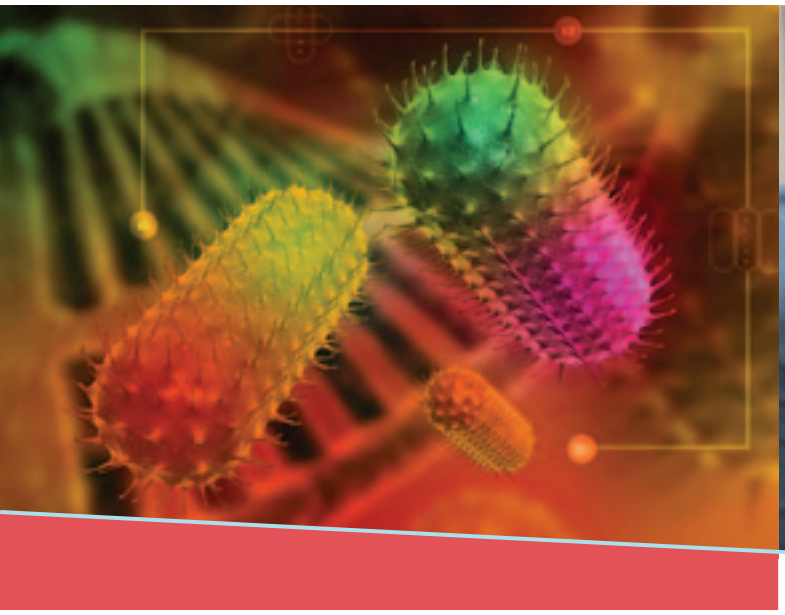
## Research capacity

Canada is fortunate to have a strong legacy in basic microbiology research, with many well-established centers across the country. Canada's strength in this area was consolidated through the Canadian Bacterial Disease Network (CBDN) funded through the Networks of Centre of Excellence (NCE) program from 1989-2005. This strong research base has generated expertise in bacterial culture conditions, such that we can now dissect the microbiome into its component strains and reconstitute it by design. In addition, Canada has recognized strengths in immunology and immunomodulation; mechanisms of disease pathogenesis; food and dairy science; vaccine production, formulation and delivery; and environmental microbiology research. In fact there are many researchers studying microbial ecology (communities, niches, etc.) who do not consider themselves as microbiome researchers, but who could be "brought into the fold".

With respect to the microbiome, Canada has a cadre of world-class researchers with particular strengths in microbiome studies in the lung and gut, including a track record in the use of fecal transplants for the treatment of recalcitrant *C. difficile* infections. The inclusion of Canada as a founding member of the IHMC and the support provided by CIHR through the CMI has created a strong, networked Canadian microbiome community that has benefited from the support of organizations such as Genome BC, the Crohn's and Colitis Foundation of Canada, and the Canadian Cystic Fibrosis Foundation.

## Clinical Capacity

The Canadian health care system was identified as a potential strength. Provincial health systems offer an opportunity that other countries do not have, in that researchers can have access to large databases with integrated clinical data linked to administrative and drug databases. Canada also has relatively strong clinical trials capacity that is supported by a good regulatory environment. For example, in Canada, several probiotics have been approved for use in adults with irritable bowel syndrome.



## Cohort Studies

Canada is home to a number of specialized cohort studies, including the Genes-Environment-Microbes (GEM) study for healthy first-degree relatives of newly diagnosed IBD patients; the Canadian Healthy Infant Longitudinal Development Study (CHILD), the Alberta Pregnancy Outcomes and Nutrition (APrON) cohort study; and the NCE: Allergies, Genes and Environment (AllerGen) as well as national cohorts such as the Canadian Partnership for Tomorrow project and the Canadian Longitudinal Study on Aging (CLSA). Many of these cohorts are linked to biobanking infrastructure and some are supporting microbiome research through the collection of stool and saliva samples.

One potential important niche area for Canada is the study of unique populations, (e.g. s First Nations populations with their high incidence of chronic diseases such as diabetes and increased resistance to IBD); geographically constrained cohorts (e.g. Saguenay-Lac-Saint-Jean region in Quebec); and recent immigrants. As Canada has a high incidence of IBD and multiple sclerosis relative the rest of the world, these represent priority areas for further research.

## Infrastructure

Canada is home to a thriving genomics community housed in universities and major, internationally recognized, genome centers across the country. In addition to sequencing capabilities, the Canadian research community excels in the areas of computational science, statistical analyses, bioinformatics, proteomics and metabolomics, and modeling and is home to supercomputing resources such as Compute Canada – a leader in the creation of powerful High Performance Computing (HPC) platforms for research. This platform integrates resources at six partner consortia across the country to create a national computational resource that researchers at any Canadian university can access.

Canada has other unique resources, such as the Robo-gut, housed at the University of Guelph. The, now famous, Robo-gut has revolutionized our ability to study bacterial communities, especially anaerobes or other previously "unculturable" bacteria. In addition, gnotobiotic and mono-colonized mice at McMaster University's germ free facility are a vital resource for the microbiome community, particularly in functional studies.

## Collaborative Canadian Culture

Canadians have a long history of successful team science, through the CIHR Large Team Grant Program and the NCE program as well as smaller grass-roots networks and collaborations. Specific examples in the microbiome field include: the Microbiome and Disease Tolerance Centre based at McGill, announced in February 2014, that connects three universities (McGill, Montreal and McMaster) and has similarities to

HMP2 in that the goal is to use HMP1 data to dissect immune/non-immunoregulatory mechanisms in the context of human disease; The Canadian Research & Development Centre for Probiotics in London, Ontario, which was established in 2001 through funding by the Ontario Research and Development Challenge Fund, to bring together experts in Canada who specialize in probiotics and their application; the Institute of Nutrition and Functional Foods at Laval University and the Centre for Dairy Science, also at Laval; the Richardson Centre for Functional Foods and Nutraceuticals at the University of Manitoba in Winnipeg; the Canadian Network of Oral Health Research in Halifax; and the NCE: Advancing Canadian Wastewater Assets, which could provide an opportunity to study sewage as a monitoring system for human health and a warning system for the presence of pathogens. Methods used in environmental ecology to enumerate microbial species could be used in human microbiome studies.

**Tables 5-8 – What do we need?**

- What are the underserved areas in Canada, (e.g. gender differences, oral microbiome)? Where are the collaborative opportunities? How can we work better with the funds we have?
- What are the greatest challenges in human microbiome research in Canada and how could they be overcome?

Paradoxically, many of the Canadian strengths listed above were also described as weaknesses. For example, Canada is very proud of its germ-free facility at McMaster, but adequate sustainable funding remains a challenge. In order to increase accessibility, while reducing the cost, it was suggested that the current facility should be expanded and made national in scope. The challenge is identifying a source of funds to support this as it falls outside of the current CIHR mandate.

Likewise, although public interest and media attention are generally considered beneficial, there is the danger that if the microbiome and its potential impact on human health is "over-hyped, the field will lose credibility to the detriment of future progress. It will be important to maintain a balance and ensure that the "press" does not get ahead of the science, and that the risks and benefits are effectively communicated to end-users.

**Cohort Studies**

Although Canada has a number of excellent cohort studies, they are not well coordinated and most do not have guaranteed sustainable funding. In addition, many of these cohorts that could be collecting the kinds of samples and information necessary for microbiome research are not currently doing so. Improved national coordination and access would facilitate functional microbiome studies, and it would be relatively inexpensive to add additional sample collection to existing cohorts. Coordination of Canadian cohorts is a priority for CIHR with both internal and external discussions currently in progress to determine how this might best be achieved. The possibility of "piggy backing" microbiome studies onto these cohorts is a topic that could be raised during such discussions. In fact microbiome studies could be incorporated into a number of existing initiatives, including the CIHR Roadmap Signature Initiatives on Inflammation and Chronic Disease; and the Canadian Epigenetics, or in the new initiative on Environment and Health. It was suggested that an additional cohort – a twin registry study would be a very valuable resource for Canadian researchers studying the microbiome.

Participants with an interest in cohort studies in First Nation communities were cautioned that living conditions, such as economic conditions and diet, can vary greatly from one community to another, even within the same province. Researchers would be well advised to consult with provincial and national heath authorities if they wish to connect with individual First Nation communities.

## Technology Challenges and Solutions

Massive amounts of data are being generated by genomics research across all life science sectors. The lack of efficient tools and methodologies available to effectively mine, rapidly access and efficiently analyze vast quantities of genomic information and integrate it with other data sets is a major challenge for research communities, including the microbiome community. Genome Canada, NSERC, CIHR, and CFI recently partnered on an initiative to support a national bioinformatics platform. The results of that competition should be made public in the near future. Also, Genome Canada and CIHR have partnered on a bioinformatics and computational biology initiative, so steps are underway to address the problem of data management and analysis.

For the microbiome community, international standards are needed that establish standard operating procedures for sample collection, nucleic acid extraction, sequencing, and analysis. Even there, however, there is progress, as the IHMC will soon publish standards for the international community. The next challenge will be moving from data collection and analysis to translation and application. It was suggested that a series of small focused workshops in specific areas such as model systems, or sample collection would prove helpful in improving standardization of methods and protocols.

## Research Directions

One of the main weaknesses identified at the workshop was the current superficial level of resolution and the need for a finer, population level detailing clonal dynamics, which also moves beyond microbial communities to the species level. There is a need to drill deeper for a more granular view to enhance current understanding of how the microbiome interacts with the host so as to be able to integrate phenotype with health outcomes. At the same time there is a need for a better understanding of host genomics and the impact of the host on the microbiome. For example, healthy individuals asymptomatically carry up to 80 potentially "pathogenic" bacterial strains. What triggers these commensals to become pathogens?

There was a call for more hypothesis-driven research to optimize experimental design in studies trying to establish causality. A big challenge identified was the difficulty of doing functional studies in humans, especially as there are limitations to current animal model systems. There was also recognition that more diverse microbiome sampling is required that looks beyond the gut (oral, nasopharynx, brain), and also explores gender differences, which could be very significant.

## Training

There was broad agreement that training and career development are major issues and that there is a need for interdisciplinary training and co-op programs that span the field and take better advantage of industry internships and post-doctoral programs – perhaps through a joint CIHR/industry recruiting program, or links to MITACS. Canada also needs more clinician-scientists and better interactions between microbiome researchers and clinicians, as clinicians can help inform the research questions that can be applied clinically. In addition, researchers need more training on how to deal with IP issues when moving their ideas forward to market, as well as a better understanding of regulatory processes.

## Collaboration and Networking

There was widespread agreement that the Canadian microbiome community needs a national network – a one-stop shop for the field, that would serve as a central hub and include a website to host job-postings, funding opportunities, and that would be a central information repository for the community. Such a network would bring together different disciplines, such as microbiology, immunology, food science, environmental science and technology development as well as facilitate better linkages between basic researchers and clinicians.

The network would also be well placed to forge international and industry collaborations and would provide a forum for communicating information on "what has worked and what hasn't", especially in

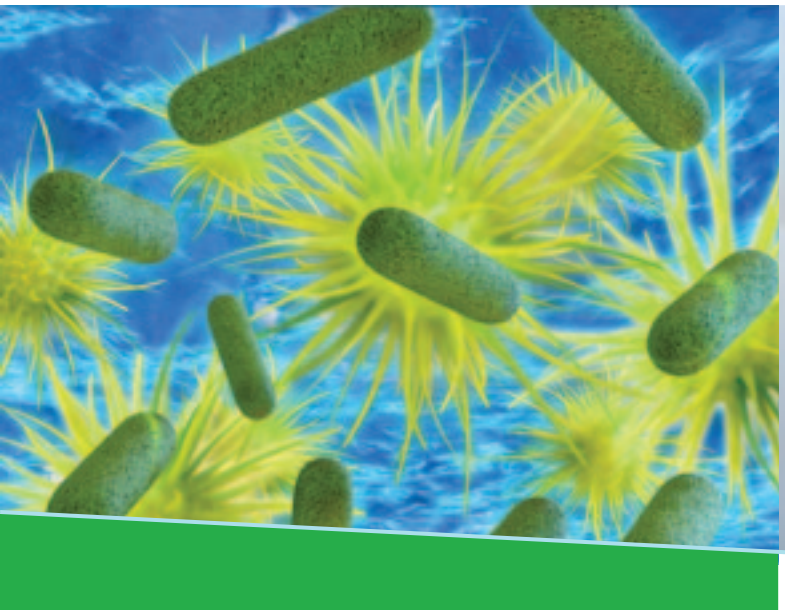
clinical studies. It was agreed that networks don't have to be expensive but, rather, can depend on the vitality and commitment of the members and the availability of research resources to serve the network. A Canadian Microbiome network could hold annual meetings for a broad field of experts, perhaps linked to annual Association meetings such as the Canadian Society for Microbiology (CSM) and Canadian Society of Immunology (CSI).

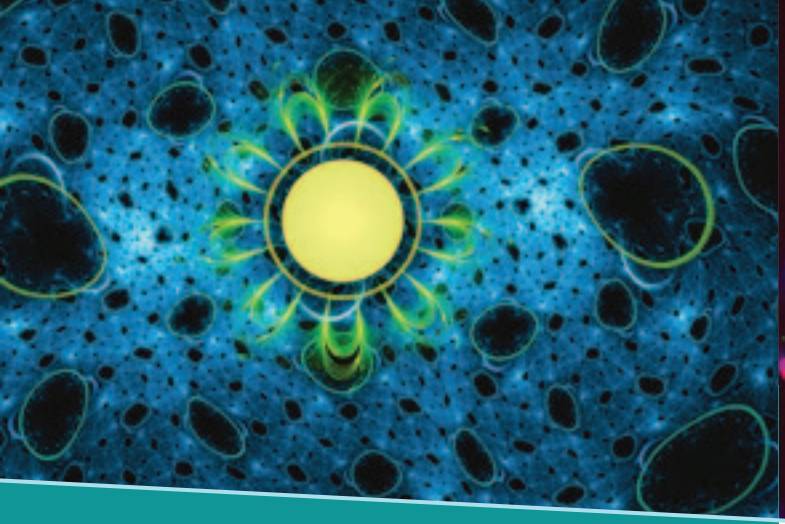
## Research Funding

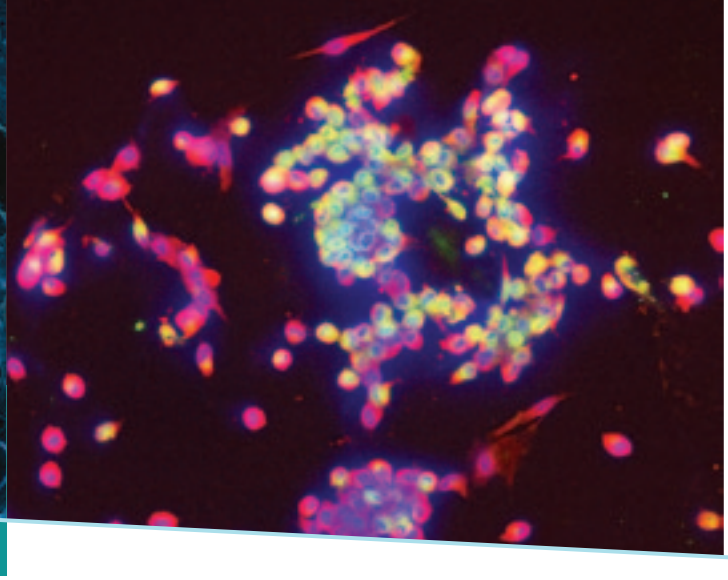
There was almost unanimous agreement that the microbiome field needs more funding. There was a lively discussion around potential options, ranging from a targeted request to government for $200-300 million, to suggestions of crowd funding. Researchers are encouraged to actively support the health charities in their efforts to raise research dollars as members of Research Canada. In addition, the Health Charities of Canada, which is comprised of 29 member organizations who collectively contribute $200 million to health research, look to researchers to join them in advocacy efforts. Certainly the climate is right, at the moment, as the microbiome is so often in the news that MPs and other government officials could not help but be aware of its potential importance to human health. One strategy could be to highlight the fact that a better understanding of the microbiome might lead to prevention strategies in otherwise healthy people, thus saving millions of dollars in health care costs. It was suggested that researchers might benefit from seeking expert advice on the best ways to communicate their science to a predominantly lay audience.

There was much discussion around traditional funding sources, such as CIHR, and the importance of the initial CMI in getting the field started in Canada. During discussions on which funding tools are best – team grants vs. catalyst grants for example, there was considerable support for catalyst grants, with some researchers feeling that a microbiome catalyst grant was one of the most important supports in their career development in terms of helping them prepare for bigger opportunities. CIHR is currently reviewing its suite of funding tools to see how they have performed and what the relative outcomes have been. This will inform future design of program delivery.

The topic of peer review was raised and the need for more microbiome expertise on peer view panels. It was noted that researchers with expertise in the microbiome can increase their presence on peer review panels by volunteering for the new Canadian College of Reviewers under the new CIHR peer review system.







## Genome Canada Presentation

### Pierre Meulien, President

Pierre Meulien, President of Genome Canada gave an impromptu presentation on Genome Canada's interest in the microbiome. Although Genome Canada was not in a position to partner on the CMI, they have a strong interest in the topic and have a history of strong partnership with CIHR in other areas such as personalized medicine and computational biology. In fact, two of the projects funded under the Genome Canada/CIHR Large-Scale Applied Research Project Competition in Genomics and Personalized Health were related to the microbiome and both teams were represented at the workshop.

As the Genome Canada mandate is broader than health their interest in the microbiome extends to its importance in the environment, agriculture, fisheries, and forestry. Genome Canada has a strong focus on technology development and support, including data storage, management, and analysis. With a planned investment of $45 million over the next few years, this area represents a major part of their Strategic Plan going forward.

Another important focus for Genome Canada is evaluation. The organization is in the process of finishing a 5-year evaluation, the results of which will be made public following its release to the Board at the end of March 2014. As Genome Canada reports through Industry Canada their reporting requirements differ slightly from those of CIHR, with the measured outputs focusing more on return on investment set against specific objectives and goals. It is clear that the CMI has been very successful in creating a fertile environment for growth and expansion on the microbiome field but that, in itself, creates a dilemma as it is difficult to quantify changes in an environment, or even the short- and long-term outcomes of a workshop such as this one. Nevertheless, evaluation is a key deliverable for any funding body.

Translating research outcomes is another challenge, as Canada's receptor capacity is different from many other countries. The key is to develop creative models of academic/industry collaborations that nurture a productive interface between academia and end-users. Sometimes the solution is to align around a specific issue or project; for example, the leaking tailings ponds in Alberta, where the energy sector came to academia for help in finding a solution through the use of metagenomics. Similarly, when socio-economic outcomes are important,

this expertise needs to be integrated into projects from the beginning. This is an area in which Genome Canada has had great success.

Going forward, Genome Canada will continue to follow progress in the microbiome field and explore partner opportunities, should new funds become available for investment in the health sector.

## Breakout Session 2

Breakout Session 2 was shortened to accommodate the CMI Team presentations. The breakout groups were re-organized with many participants moving to different tables to facilitate additional networking. The focus was on next steps and the identification of a series of topics for more in depth, small group discussion on Day 3.

## Next Steps

Several groups proposed the idea of a Microbiome Consortium/ Network of some kind that would encompass the following properties:

- Provide quality assurance and standardization
- Host a Canadian microbiome website and a communication network
- Be a central clearing house for information, with contacts for advice in a given area
- Develop a repository of tools
- Include a training program
- Have a focus on therapeutics and microbiome manipulations
- Be multidisciplinary and inclusive, e.g. bring in food scientists, environmentalists, etc
- Have international links, e.g to HMP2

Establishing such a structure, however, in the absence of an obvious funding source, other than perhaps the next Networks of Centres of Excellence (NCE) competition, will require creative thinking. Discussions turned again to the idea of capitalizing on the current interest in the media and among the general public to raise awareness and advocate for targeted funding from the government.

There was broad agreement that despite the challenges created by the complexity of the microbiome, the time has come to move towards correlating genes to function and moving from association to causation. There is a pressing need to link sequencing data to risk factors and outcomes and move beyond specific organisms to specific mechanisms - by targeting the interface of the microbe with the mucosa, for example.

One way of approaching this challenge is to focus on underlying mechanisms of action by integrating proteomics and metabolomics into microbiome studies; for example, why do only certain bacterial strains cause disease? There is a need to move beyond "what they are " to "what do they do?" but in order to do this we will have to build capacity in the metabolomics field and establish training programs for the research community. In some circumstances, however, it may be possible to intervene without actually understanding the mechanisms involved, e.g. fecal transplants for treatment of recalcitrant *C.difficile* in the elderly. Early translational successes in this area would serve to build momentum.

A suggestion was made that it is timely to establish stewardship over the microbiome, particularly with respect to high-level societal decisions and interventions, such as antibiotic use in humans and in food animals, and methods of newborn delivery and infant nutrition. We also need to take a closer look at the effects on the microbiome of common drugs which may exert long-term effects on the gut microbiota.

The effects of nutrition, for example the impact of various dietary constituents, on microbiota composition and function was identified as a priority research area in need of further study. In the future, it should be possible to design various components of foods for specific individuals based on their microbiome composition, i.e. personalized nutrition.

## Discussion Topics

The following discussion topics were identified and participants were invited to sign up for the topic of their choice for the following day.

- Successful Interventions
- Public Interaction/Education
- Personalized Nutrition
- Mechanisms
- Metabolomics
- Fecal Transplants
- Microbiome Stewardships
- From Association to Causation

## CMI Team Presentations

Each of the seven teams funded under the CMI gave a synopsis of the objectives of their original research proposal; research outcomes to date; and next steps. The presenters, in alphabetic order, and the titles of their talks were:

**Robert Beiko**

Modeling microbiomes

**Ken Croitoru**

The Influence of host genetics and the environment on the microbiome

**Brett Finlay**

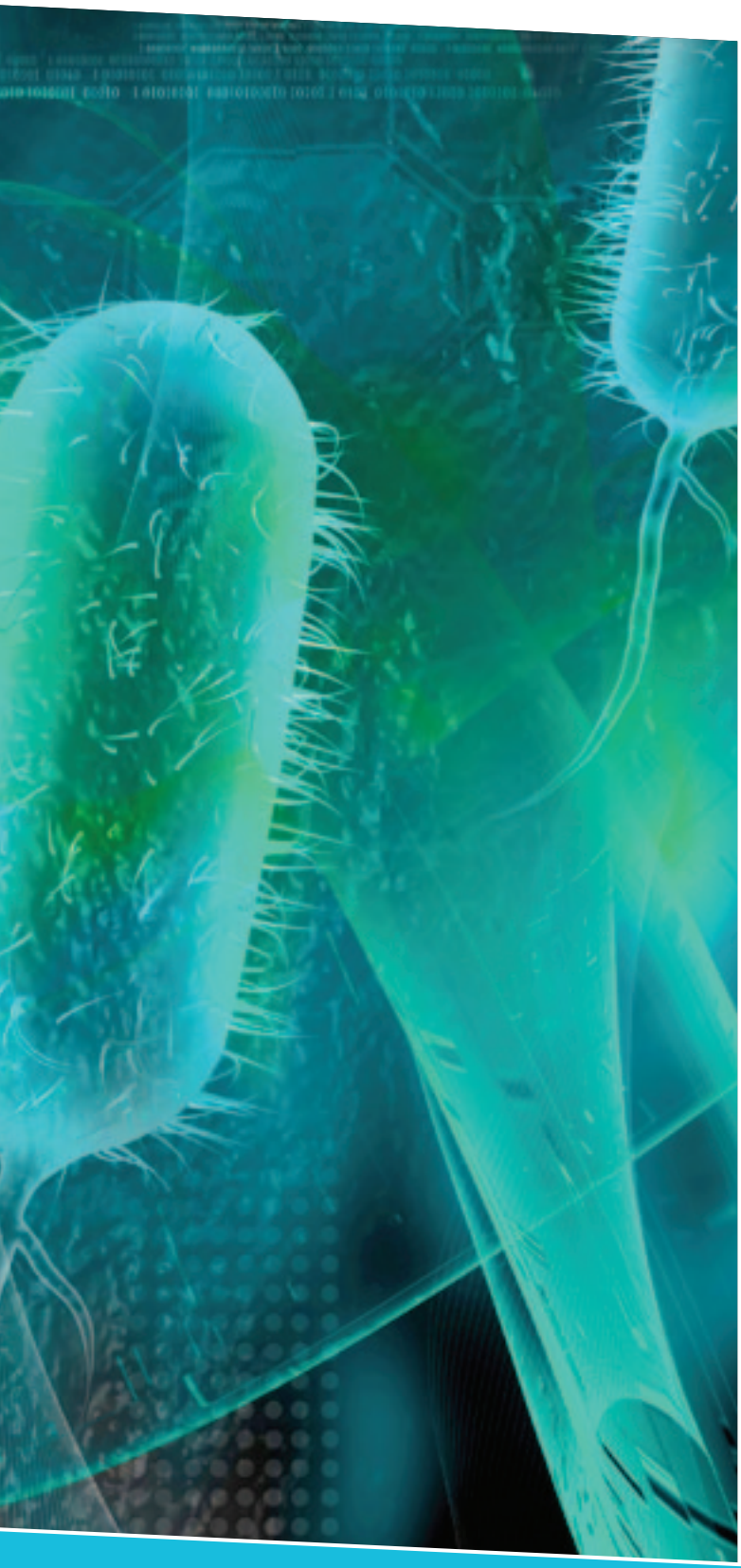
Intestinal microbiota and immune effects in asthma

**David Guttman**
The microbiome of the cystic fibrosis lung

**Mike Surette**
The airway microbiome in health and disease

**Anita Kozyrskyj**
Symbiota: synergy in microbiota research

**Deborah Money**
Vaginal microbiome group initiative



# DAY 3 FEBRUARY 14th

Following round table discussions each group gave a brief report back that was then followed by an open plenary session to identify action items and leaders for each topic area.

## Funding: Building on momentum

Although CIHR and partners have succeeded in generating momentum and building capacity through the CMI, there is legitimate concern about sustainability. The microbiome is touching many fields and has the potential to have a huge impact on human health.

Given the enthusiasm generated at the workshop for creating a Microbiome consortium or network, it was felt that the time is right to advocate for new funds ($250-300M) to maintain Canada's leadership in the field. Efforts to raise additional funds should be done in concert with the health charities and on behalf of CIHR.

As the impact of the microbiome extends well beyond the health sector, it was suggested that a more inclusive approach, that includes the three tri-council research-funding agencies, would be appropriate. It was recommended that a small group of experienced and committed individuals would work together during the next six months towards "building a case" for the microbiome in time for Budget 2015.

**Leads: Michel Bergeron and John Bienenstock**

It was also suggested that, based on the considerable industry interest in the field, it would be timely to increase efforts in exploring public/private partnership opportunities to drive the basic knowledge forward into the pre-competitive space. One way

to facilitate this could be through partnerships with CQDM and CDRD.

**Lead: Marc Ouellette**

## Networking

While an effort to raise new funds is a laudable goal, it was felt that there are also more immediate, relatively inexpensive, mechanisms to build on the enthusiasm generated by the workshop. For example, the group could develop a microbiome website, supported by a small network within the auspices of CIHR, but potentially also broader than human research - incorporating tri-council input and including environmental ecology. The website could host job postings; training opportunities; and cross--lab exchanges, for example, as well as webcasts and research updates to maintain science momentum. Potentially the website could also host a section geared towards public outreach and education. It is anticipated that over time, research will lead to a better understanding of the short- and long-term effects of current practices, lifestyles and the environment, such as antibiotic use, diet, probiotics, prebiotics, and pesticides on microbial diversity. At the same time, it is recognized that researchers and funders need to learn to manage this knowledge to avoid over-selling the health benefits of microbiome manipulations, especially if the topic is to be incorporated into the curriculum in education programs in schools, colleges, universities and schools training health professionals.

**Lead: Fiona Brinkman**

Another way to increase networking and facilitate collaborations and information sharing would be through a series of small, focused workshops on topics of broad interest to the group. The interested CIHR Institutes could provide some support for these events, as well as facilitating linkages with groups like Genome Canada and industry. It was recommended that NGOs that have identified the microbiome as a priority, such as CCFC, should be engaged in this activity and could communicate with other NGOs and associations such as the Canadian Society for Microbiology (CSM), to raise the profile. These workshops would serve as an ideal vehicle to bring researchers, funders and patients together, increasing public understanding of the microbiome and the importance of research.

**Leads: Aida Fernandes, Mike Surette and Phil Sherman**

For all Canadian efforts related to networking and collaboration, the group was reminded that international partnerships would leverage expertise and resources for maximum benefit for all. As Canada is a member of the IHMC, it was highly recommended that international collaborations be encouraged through this forum.

**Leads: Bhagi Singh and Marc Ouellette**

## Infrastructures: Animal Facilities, Biobanks and Cohorts

Workshop discussions highlighted the need to return to the basic principles of cause and effect and look at the epidemiology, of patients with dysbiosis to identify triggers and risk factors that impact on the microbiome. It was suggested that it might initially be necessary to focus on single systems, initially, as was done in the 1940's and 50's when one organism, *E. coli*, was selected for gene studies. To facilitate these kinds of studies, access to a germ-free facility is key, as it allows researchers to study mechanisms by transplanting the human microbiome into germ

free-mice and taking advantage of knock-out and "humanized" mice. The McMaster gnotobiotic facility is an important pan-Canadian resource that is open for collaborations across Canada. As the University of Alberta is planning to set up a similar facility, it will be important to link the two to better serve the research community.

**Leads: Stephen Collins and Ben Willing**

More centralized biobanks are needed to house repositories of bacteria, especially collections of strains from single individuals, as well as to store samples, such as urine and saliva. These biobanks would support a wide range of studies across the microbiome field, including metabolomics. There is increasing interest on the measurement of metabolites and how to use the metabolome to interrogate the microbiome and get functional information. There was considerable interest in making this an international effort with potential links to HMP2.

**Leads: David Wishart and Ben Willing**

## Cohorts

There was strong support for the coordination and harmonization of existing cohort studies that could potentially be aligned with international efforts. Canada needs a registry of cohorts and also a registry of clinical trials that could be leveraged to access samples for studies on the effects of drugs on the microbiome. It was recommended that the food industry should be involved in these efforts.

**Leads: Anita Kozyrskyj and Ken Croitoru**

## Clinical Applications

There is considerable evidence that fecal transplants are effective in treating recurring *C. difficile* infections despite the fact that the mechanisms of action are not fully understood. However, legal and regulatory hurdles have prevented this treatment becoming standard of care for hospitalized patients. Microbiome transplants may also prove to be an effective treatment for a number of other conditions such as IBD. There was a call for standardized protocols, and microbiome profiles from patients as they go through various disease stages, for example in IBD – from remission to flare-up of symptoms. Also, closer links are needed with regulatory bodies, such as Health Canada, to overcome existing barriers to clinical trials. One solution proposed was to think of microbiome transplants as organ transplants or prosthetics rather than therapy, as this might help with IP and regulatory issues.

**Lead: Tbd**

## Workshop Conclusion

It was agreed that a working group of volunteers would be established that included all the "volunteers" for the various areas identified above but that would also be open to additional members drawn from the broader community. Volunteers for the working group were:

**Glen Armstrong**
**Rob Beiko**
**Michel Bergeron**
**John Bienenstock**
**Fiona Brinkman**
**Stephen Collins**
**Brett Finlay**
**David Guttman**
**Anita Kozyrskyj**
**Bill Mohn**
**Deborah Money**
**Gregor Reid**
**Mike Surette**
**David Wishart**

Initially, Brett Finlay will coordinate the activities of the working group and sub-groups to "get the ball rolling" but others will be recruited to help with this task going forward. The sponsoring CIHR Institutes and Genome BC remain committed to supporting microbiome research in Canada and will explore opportunities to sustain the momentum generated through the CMI to ensure that Canadian researchers remain at the forefront of this rapidly evolving field.

William Yan et Dennis Cvitkovitch

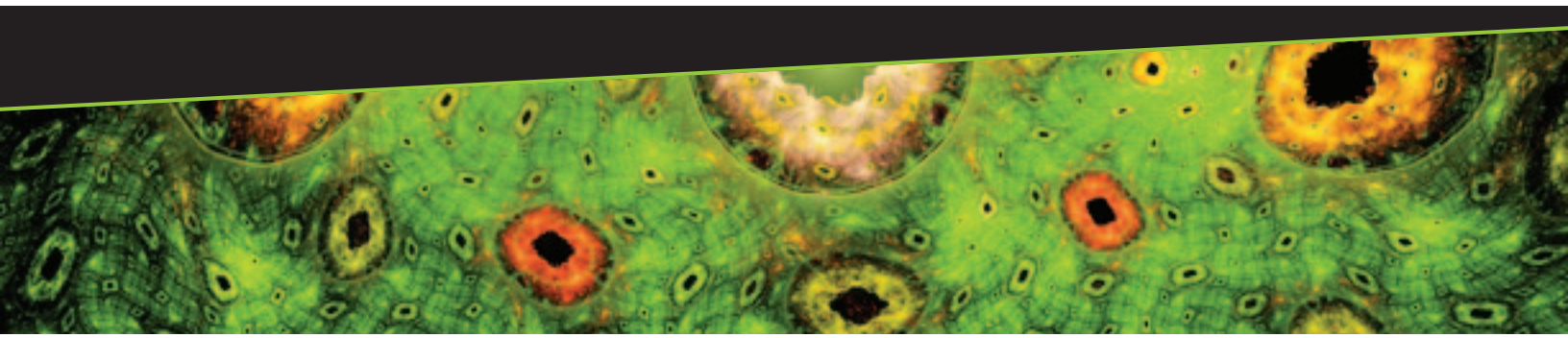
Christian Jobin

Gregor Reid

Hani El-Gabalawy

Michel Bergeron

The workshop was adjourned at 11.30 a.m., with everyone thanked for their active participation and contributions to the discussions over the course of the three days.



# APPENDIX 1 PARTICIPANTS LIST

| NAME AND ORGANIZATION | BACKGROUND |
|---|---|
|  **Johane Allard**<br>*Professor*<br>University of Toronto and Director of the Nutritional Support Program<br>University Health Network<br>Toronto, Ontario<br>johane.allard@uhn.on.ca | *Research Interests:*<br>● Nutrition and gastrointestinal disorders, including non-alcoholic fatty liver disease and inflammatory bowel disease<br>● Obesity, malnutrition and nutrition support<br>● Dr. Allard is a co-chair of the Canadian Malnutrition Task Force<br>Dr. Allard's team is managing the Canadian Home Total Parenteral Nutrition (HTPN) Registry. |
|  **Emma Allen-Vercoe**<br>*Associate Professor*<br>Molecular Biology and Genetics<br>University of Guelph<br>Guelph, Ontario<br>eav@uoguelph.ca | *Research Interests:*<br>● NutriDeveloping new techniques to culture and study novel bacterial species from the gut<br>● NutriDeveloping cutting-edge methods to image and characterize microbial interactions within the gut<br>● NutriDetermining which species of the gut micro-flora can behave pathogenically towards the host with a focus on: Inflammatory Bowel Disease (IBD), regressive (late-onset) autism, recurrent (refractive) *C. difficile* infection (CDI) and colorectal cancer |
|  **Glen Armstrong**<br>*Professor and Head*<br>Department of Microbiology, Immunology & Infectious Diseases<br>University of Calgary<br>Calgary, Alberta<br>glen.armstrong@ucalgary.ca | *Research Interests:*<br>● Microbial pathogenesis<br>● *E. coli* infection<br>● *C. difficile* |
|  **Robert Beiko**<br>*Professor*<br>Faculty of Computer Science<br>Dalhousie University<br>Halifax, Nova Scotia<br>beiko@cs.dal.ca | *Research Interests:*<br>● Member of one of the 7 CIHR funded Canadian Microbiome Initiative team<br>● Comparative, functional, and evolutionary genomics / bioinformatics focused mainly on bacterial evolution<br>● Analysis of real data and modeling, Metagenomics<br>● Construction of sophisticated and efficient algorithms that address the problems inherent in biological sequence data |

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|  | **Cindy Bell**<br>*Executive Vice-President*<br>Corporate Development<br>Genome Canada<br>Ottawa, ON<br>cbell@genomecanada.ca | Genome Canada is a catalyst for developing and applying genomic sciences. Genome Canada works in partnership to invest in and manage large-scale research and translate discoveries into commercial opportunities, new technologies, applications and solutions, building bridges between government, academia and industry to forge a genomics-based public-private innovation focused on key life science sectors. |
|  | **Premysl Bercik**<br>*Assistant Professor*<br>Department of Medicine<br>McMaster University<br>Hamilton, Ontario<br>bercikp@mcmaster.ca | *Research Interests:*<br>● The role of low-grade inflammation in the pathophysiology of gut dysfunction<br>● The effect of gut inflammation on CNS function and gut-brain axis<br>● The role of microbiota in functional GI diseases<br>● Development of new techniques to study gastrointestinal motility, including videofluoroscopy image analysis and magnet-tracking |
|  | **Michel Bergeron**<br>*Professor and Chairman*<br>Division of Microbiology and of the Infectious Diseases Research Centre<br>Université Laval<br>Québec City, Québec<br>michel.g.bergeron@crchul.ulaval.ca | *Research Interests:*<br>● The development of DNA-based diagnostic tests for the detection of microbes and their associated antibiotic resistance genes |
|  | **John Bienenstock**<br>*Professor*<br>Departments of Medicine & Pathology and Molecular Medicine<br>McMaster University<br>Hamilton, Ontario<br>Bienens@mcmaster.ca | *Research Interests:*<br>● *Comparative immunology, immunopathology and immunophysiology of mucosal tissue*<br>● *Mucosal immunology and its alteration in a variety of disease models*<br>● *The role of neuroimmune interactions in allergy and inflammation and the reciprocal communication which occurs between these two systems*<br>● *Mechanisms of action of probiotic organisms on the nervous system, behavior and in various models of inflammation* |

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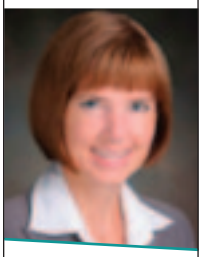
|  | **Graeme Boniface**<br>*Chief Operating Officer*<br>Vancouver Prostate Centre<br>Vancouver, BC, Canada<br>gboniface@prostatecentre.com<br>www.pctriadd.com<br>www.prostatecentre.com | The Vancouver Prostate Centre (VPC) is a UBC and VGH Centre of Excellence and Centre of Excellence for Commercialization and Research (CECR). The Centre's research focuses on the discovery of molecular mechanisms of cancer progression, therapeutic resistance, and the development of new treatments, services, and products to improve cancer patient care. The VPC comprises a multi-disciplinary team of 21 senior bench and clinical scientists and more than 130 staff in three state-of-the-art facilities. The VPC integrates the expertise of scientists and clinicians in urology, cellular and molecular biology, pharmacology, socio-behavioural sciences, functional genomics, and medical oncology. |
|  | **Judith Bray**<br>*Consultant*<br>CIHR Institute of Infection and Immunity<br>judybrayconsulting@gmail.com | The CIHR Institute of Infection and Immunity (III) supports research and helps to build research capacity in the areas of infectious disease and the body's immune system. Through the Institute's programs, researchers address a wide range of health concerns related to infection and immunity including disease mechanisms, disease prevention and treatment, and health promotion through public policy. |
|  | **Fiona Brinkman**<br>*Professor*<br>Department of Molecular Biology and Biochemistry<br>Simon Fraser University<br>Burnaby, British Columbia<br>brinkman@sfu.ca | *Research Interests:*<br>● Leading bioinformatics and identifying biomarkers and PCR texts, for multiple Genome Canada and NSERC microbiome studies, including for water quality testing and some biofilm studies.<br>● Assessing accuracy of bioinformatics methods for metagenomics analysis. |
|  | **James Brown**<br>*Director*<br>Computational Biology for Infectious Disease<br>GlaxoSmithKline<br>Collegeville, USA<br>James.R.Brown@gsk.com | Dr. James Brown leads the Microbiome Matrix Team which coordinates microbiome research in Research and Development at GlaxoSmithKline, one of the worlds leading research-based pharmaceutical and health-care companies. |
|  | **Harry Brumer**<br>Michael Smith Laboratories<br>University of British Columbia<br>Vancouver<br>brumer@msl.ubc.ca | *Research Interests:*<br>● *Fundamental and applied carbohydrate enzymology.*<br>● *Breakdown of dietary fibre (non-starch polysaccharides) by the human gut microbiota* |

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|  | **Ken Chan**<br>*Vice-President*<br>*Advocacy,* Research & Healthcare<br>Cystic Fibrosis Canada<br>Toronto, Ontario<br>kchan@cysticfibrosis.ca | Cystic Fibrosis Canada's mission is to help people with cystic fibrosis (CF). The Foundation funds research towards the goal of a cure or control for CF, and supports high quality CF care, promotes public awareness of CF and raises and allocates funds for these purposes. |
|  | **David Charest**<br>*Director*<br>Sector Development<br>Genome BC<br>Vancouver, BC<br>dcharest@genomebc.ca | Genome British Columbia is a catalyst for the life sciences cluster on Canada's West Coast, and manages a cumulative portfolio of over $625M in research projects and science and technology platforms. Working with governments, academia and industry across sectors such as forestry, fisheries, agriculture, environment, bioenergy, mining and human health, the goal of the organization is to generate social and economic benefits for British Columbia and Canada. |
|  | **Stephen Collins**<br>*Associate Dean, Research,*<br>Faculty of Health Sciences and Professor,<br>Department of Medicine, Gastroenterology<br>McMaster University<br>Hamilton, Ontario<br>scollins@mcmaster.ca | *Research Interests:*<br>● The pathophysiology of intestinal diseases (post-infective irritable bowel syndrome)<br>● Participation of muscle and nerves in the inflammatory process via activation of lymphocytes through antigen presentation, adhesion molecule expression and cytokine production<br>● Mechanisms underlying the ability of intestinal microbiota to influence gut physiology and to influence the gut-brain axis |
|  | **Jacques Corbeil**<br>Canada Research Chair in Medical Genomics<br>*Professor*<br>Department of Molecular Medicine<br>Faculty of Medicine<br>Université Laval<br>Québec City, Québec<br>jacques.corbeil@crchul.ulaval.ca | *Research Interests:*<br>● Understanding host-pathogen interactions<br>● Metagenomics software RAY and RAY meta.<br>● System biology approaches and kernel-based algorithms to assist with the massive amount of data coming out of the new sequencing and protein interactome technologies |
|  | **Kenneth Croitoru**<br>*Professor of Medicine*<br>University of Toronto and Division of Gastroenterology<br>Mount Sinai Hospital<br>Toronto, Ontario<br>Kcroitoru@mtsinai.on.ca | *Research Interests:*<br>● PI of one of the 7 CIHR funded Canadian Microbiome Initiative team<br>● Basic science of Inflammatory Bowel Disease (IBD) - focus on T cell biology and regulatory T cells in animal models of colitis<br>● Clinical Research in IBD - Project Leader for CCFC sponsored Multi-Centered Canadian Prospective Cohort study of Individuals at risk for Crohn's disease to identify the Genetic, Environmental and Microbial Factors triggering or causing Crohn's disease (GEM Project). |

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|  | **Dennis Cvitkovitch**<br>*Associate Professor*<br>Oral Microbiology<br>Faculty of Dentistry<br>University of Toronto<br>Toronto, Ontario<br>d.cvitkovitch@dentistry.utoronto.ca | *Research Interests:*<br>● The role of the acid tolerance response of Streptococcus mutans, the principal agent of dental caries<br>● The mechanisms of cell-cell signalling and its role in biofilm formation and genetic exchange by gram positive pathogens; potential vaccine targets for Streptococcus pyogenes infections<br>● The effects of dental restorative materials on bacterial growth and metabolism |
|  | **Alan Davidson**<br>*Professor*<br>Department of Biochemistry<br>University of Toronto<br>Toronto, Ontario<br>alan.davidson@utoronto.ca | *Research Interests:*<br>● Mechanisms regulating tailed phage assembly pathways, which includes protein structure determination, bioinformatics, mutagenesis, and in vivo functional assays<br>● Survival and behaviour of bacterial populations<br>● *Pseudomonas aeruginosa* |
|  | **Julian Davies**<br>*Professor Emeritus*<br>UBC, Vancouver<br>jed@interchange.ubc.ca | *Research Interests:*<br>● Microbiome<br>● Antibiotic resistance<br>● Suppression of resistance mechanisms<br>● Natural sources of antibiotics<br>● Role of antibiotics in nature |
|  | **Emmanuel Denou**<br>*Research Assistant*<br>Farcombe Family Digestive Health Research Institute<br>McMaster University<br>Hamilton, Ontario<br>denou@univmail.cis.mcmaster.ca | *Research Interests:*<br>● Microbiome and the gut/brain interaction<br>● Depression/anxiety |
|  | **Serge Desnoyers**<br>*Assistant Director*<br>CIHR Institute of Infection and Immunity<br>Centre de recherche du CHU de Québec<br>CHUL Québec, QC<br>serge.desnoyers@crchul.ulaval.ca | The CIHR Institute of Infection and Immunity (III) supports research and helps to build research capacity in the areas of infectious disease and the body's immune system. Through the Institute's programs, researchers address a wide range of health concerns related to infection and immunity including disease mechanisms, disease prevention and treatment, and health promotion through public policy. |

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|  | **Edie Dullaghan**<br>*Head, Target Validation*<br>Centre for Drug Research and Development (CDRD)<br>Vancouver, British Columbia<br>edullaghan@cdrd.ca | The Centre for Drug Research and Development (CDRD) is Canada's fully-integrated national drug development and commercialization centre, providing expertise and infrastructure to enable researchers from leading health research institutions to advance promising early-stage drug candidates. Canada's Networks of Centres of Excellence Program has recognized CDRD as a Centre of Excellence for Commercialization and Research (CECR). |
|  | **Nancy Edwards**<br>*Scientific Director*<br>CIHR Institute of Population and Public Health<br>University of Ottawa<br>Ottawa<br>Nancy.Edwards@uottawa.ca | *Research Interests:*<br>● Public and population health.<br>● Health services, policy and clinical research<br>● The design and evaluation of complex multi-level and multi-strategy community health programs.<br>● Global health spanning four continents including development-oriented and research-focused projects |
|  | **Hani El-Gabalawy**<br>*Scientific Director*<br>CIHR Institute of Musculo-skeletal Health and Arthritis<br>University of Manitoba<br>Winnipeg<br>Hani.Elgabalawy@med.umanitoba.ca | *Research Interests:*<br>● The mechanisms initiating and sustaining joint inflammation in rheumatoid arthritis; early inflammatory arthritis and the pathological features seen in the inflamed joints,<br>● Therapeutic strategies on the early stages of joint inflammation, before permanent progressive damage occurs.<br>● Synovial biology, the pathogenesis of early arthritis,<br>● Established a unique First Nations cohort to study gene-environment interactions in the pre-clinical phase of arthritis. |
|  | **Dusko Ehrlich**<br>*Research Director*<br>Microbial Genetics Unit<br>INRA Research Centre of Jouy-en-Josas<br>France<br>dusko.ehrlich@jouy.inra.fr | *Research Interests:*<br>Dr. Ehrlich is the head of the EU MetaHIT Project financed by the European Commission. Its objective is to establish associations between the genes of the human intestinal microbiota and our health and disease. |
|  | **Peter Ernst**<br>*Professor*<br>Department of Pathology<br>University of California, San Diego<br>pernst@ucsd.edu | *Research Interests:*<br>● Understanding the role of Th cells in the pathogenesis of gastroduodenal disease in humans infected with H. pylori<br>● Using mouse models of chronic colitis to study lymphoepithelial cell interactions |

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|  | **Karimah Es Sabar**<br>*President and CEO*<br>Centre for Drug Research and Development (CDRD)<br>Vancouver, British Columbia<br>kessabar@cdrd.ca | The Centre for Drug Research and Development (CDRD) is Canada's fully-integrated national drug development and commercialization centre, providing expertise and infrastructure to enable researchers from leading health research institutions to advance promising early-stage drug candidates. Canada's Networks of Centres of Excellence Program has recognized CDRD as a Centre of Excellence for Commercialization and Research (CECR). |
|  | **Jeff Farber**<br>*Director*<br>Bureau of Microbial Hazards<br>Health Canada<br>Ottawa, Ontario<br>jeff.farber@hc-sc.gc.ca | The Bureau of Microbial Hazards is responsible for policy, standard setting, risk assessment, research and evaluation activities with respect to microbial hazards and extraneous material in the food supply. The primary objective of the work is to minimize health risks which may result from consumption of foods contaminated with microbial, parasitic and extraneous material hazards |
|  | **Aida Fernandes**<br>*Chief Science and Education Officer*<br>Crohn's and Colitis Canada<br>Toronto, Ontario<br>afernandes@CCFC.ca | Crohn's and Colitis Canada is committed, first and foremost, to raising funds for research into inflammatory bowel disease (IBD). Crohn's and Colitis Canada believes it is important to raise awareness about Crohn's disease and ulcerative colitis by educating people with IBD, their families, health professionals and the general public about these diseases. |
|  | **Brett Finlay**<br>*Professor*<br>Michael Smith Laboratories<br>University of British Columbia<br>Vancouver, British Columbia<br>bfinlay@interchange.ubc.ca | *Research Interests:*<br>● PI of one of the 7 CIHR funded Canadian Microbiome Initiative team<br>● Host-pathogen interactions, at the molecular Level<br>● Cellular microbiology<br>● Pathogenic bacteria, with Salmonella and pathogenic E. coli interactions with host cells being the primary focus |
|  | **Abigail Forson**<br>*Assistant Director*<br>CIHR Institute of Gender and Health<br>Canadian Institutes of Health Research<br>Ottawa, Ontario<br>Abigail.forson@cihr-irsc.gc.ca | The CIHR Institute of Gender and Health (IGH)'s mission is to foster research excellence regarding the influence of gender and sex on the health of women and men throughout life, and to apply these research findings to identify and address pressing health challenges. |

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|  | **Elisabeth Fowler**<br>*Assistant Director*<br>CIHR Institute of Human Development, Child and YouthHealth<br>Canadian Institutes of Health Research<br>Ottawa, Ontario<br>elisabeth.fowler@cihr-irsc.gc.ca | The CIHR Institute of Human Development, Child and Youth Health (IHDCYH) supports research that ensures the best start in life for all Canadians and the achievement of their potential for optimal growth and development. IHDCYH promotes and support research that improves the health and development of mothers, infants, children, youth, and families in Canada and throughout the world. |
|  | **Humphrey Gardner**<br>*VP Translational Medicine*<br>AstraZeneca<br>Boston, USA<br>Humphrey.Gardner@astrazeneca.com | Among the core focus areas of Astrazeneca in the development of new medicines are metabolic, respiratory and inflammatory diseases. The microbiome has emerged as a relevant target for understanding, and even therapy, in these areas among others. As Head of Translational Medicine for Infection at AZ, Humphrey developed the bacterial genome sequencing programme and serves to coordinate efforts in the microbiome. |
|  | **Deanna Gibson**<br>*Assistant Professor*<br>Biology<br>University of British Columbia<br>Vancouver, British Columbia<br>deanna.gibson@ubc.ca | *Research Interests:*<br>● Dietary modulation of the intestinal microbiome<br>● Immune responses and susceptibility to inflammatory bowel diseases. |
|  | **Sally Greenwood**<br>*Vice President*<br>Communications and Education<br>Genome BC<br>Vancouver, British Columbia<br>sgreenwood@genomebc.ca | Genome British Columbia is a catalyst for the life sciences cluster on Canada's West Coast, and manages a cumulative portfolio of over $625M in research projects and science and technology platforms. Working with governments, academia and industry across sectors such as forestry, fisheries, agriculture, environment, bioenergy, mining and human health, the goal of the organization is to generate social and economic benefits for British Columbia and Canada. |
|  | **Robert Gruninger**<br>Genome Alberta and Agriculture and Agri-Food Canada,<br>Lethbridge Research Centre,<br>Lethbridge, Alberta<br>robert.gruninger@agr.gc.ca | *Research Interests:*<br>● Enzyme discovery using a functional genomic approach<br>● Protein structure-function relationship<br>● Rumen/anaerobic microbiology |
|  | **David Guttman**<br>*Director*<br>Centre for the Analysis of Genome Evolution and Function<br>*Professor*<br>Cell and Systems Biology<br>University of Toronto<br>Toronto, Ontario<br>david.guttman@utoronto.ca | *Research Interests:*<br>● PI of one of the 7 CIHR funded Canadian Microbiome Initiative team<br>● Evolution of host specificity and virulence<br>● Comparative genomics<br>● Metagenomics<br>● Evolution and ecology of the *Pseudomonas* |

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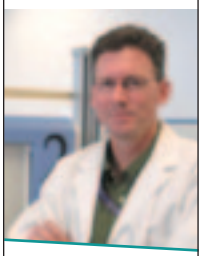
|  | **Stephen Hallam**<br>*Assistant Professor*<br>University of British Columbia<br>Vancouver, British Columbia<br>shallam@mail.ubc.ca | *Research Interests:*<br>● Environmental genomics exploring the micro-cosmos, describing microbial community structure and function across a wide range of natural and human engineered ecosystems<br>● Interdisciplinary tools sourced from ecology, molecular biology, genetics and computer science used to study distributed networks of metabolite exchange and feedback regulation |
|  | **Jennifer Hamilton**<br>*Biotechnology Industry Advisor*<br>Johnson and Johnson Family of Companies, Canada<br>West Vancouver, British Columbia<br>jjh@axionet.com | Johnson & Johnson Inc. is a leader in the consumer health care market, marketing leading brands in the baby, skin, hair, oral, wound and many other health, beauty and personal care categories. |
|  | **Bettina Hamelin**<br>*Director*<br>R&D<br>Pfizer, Canada<br>Vancouver, British Columbia<br>bettina.hamelin@pfizer.com | Pfizer is a multinational pharmaceutical corporation dedicated to developing innovative medications to prevent and treat diseases. |
|  | **James Hogg**<br>*Professor Emeritus of Pathology*<br>University of British Columbia<br>Vancouver, British Columbia<br>Jim.Hogg@hli.ubc.ca | *Research Interests:*<br>● Inflammatory processes in the lung<br>● Structure and function of the lungs in COPD. |
|  | **Robert Holt**<br>*Head of Sequencing*<br>Michael Smith Genome Sciences Centre, BC Cancer Research Agency<br>Vancouver, British Columbia<br>rholt@bcgsc.ca | *Research Interests:*<br>● Metagenomic sequencing of tumours to find microbial signatures associated with various types of cancer<br>● Developing laboratory methods for constructing large DNA molecules, engineering whole microbial genomes and exploring microbial genome interaction<br>● Technology development in DNA sequencing |
|  | **David Huntsman**<br>*Professor*<br>Departments of Pathology and Laboratory Medicine and Obstetrics and Gynaecology<br>University of British Columbia<br>Vancouver, British Columbia<br>dgh@mail.ubc.ca | *Research Interests:*<br>● Studies genetic predisposition to ovarian cancer<br>● Development of predictive and prognostic tissue based cancer biomarkers of hereditary gastric cancer and a wide variety of other tumor types<br>● Working with Professor Pieter Cullis on the creation of broad based personalized medicine initiative for British Columbia |

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|  | **David Hwang**<br>*Associate Professor*<br>Pathology<br>University of Toronto and<br>Affiliate Scientist, Division<br>of Experimental Therapeutics -<br>Respiratory & Critical Care<br>Ontario Cancer Institute<br>Toronto, Ontario<br>David.Hwang@uhn.ca | *Research Interests:*<br>● Bacterial community-wide gene expression and its role in antibiotic response and resistance in the cystic fibrosis lung<br>● Metagenomic characterization of the pulmonary microbiota in the cystic fibrosis lung<br>● Lung transplantation and repair |
|  | **Mohan Iyer**<br>*SVP*<br>Corporate Development<br>Second Genome, Inc.<br>349 Allerton Avenue<br>South San Francisco, CA 94080<br>mohan@secondgenome.com | Second Genome brings microbiome science to the discovery and development of therapeutic products. The company has established a pipeline of microbiome modulators that impact infection, immunity and metabolic diseases. Second Genome's development pipeline is fueled by novel technologies for identifying, screening and scientifically validating product candidates and microbial biomarkers. Second Genome's technologies have been rigorously validated through partnerships with leading pharmaceutical and nutrition companies, as well as academic and governmental research institutions. |
|  | **Christian Jobin**<br>*Professor of Medicine*<br>University of Florida<br>Gainesville, Florida, USA<br>Christian.Jobin@medicine.ufl.edu<br>christian_jobin@med.unc.edu | *Research Interests:*<br>● Bacteria–host interaction in the intestines and the ensuing innate and immunological responses during health and disease, particularly in the context of carcinogenesis |
|  | **Joy Johnson**<br>*Scientific Director*<br>CIHR Institute of Gender<br>and Health<br>University of British Columbia<br>Vancouver<br>joy.johnson@ubc.ca | *Research Interests:*<br>● Health promotion and health behaviour change.<br>● The social, structural and individual factors that influence the health behaviour of individuals.<br>● Sex and gender issues in substance use and mental health. |
|  | **Gabe Kalmar**<br>*Vice President*<br>Sector Development<br>Genome BC<br>Vancouver, BC<br>gkalmar@genomebc.ca | Genome British Columbia is a catalyst for the life sciences cluster on Canada's West Coast, and manages a cumulative portfolio of over $625M in research projects and science and technology platforms. Working with governments, academia and industry across sectors such as forestry, fisheries, agriculture, environment, bioenergy, mining and human health, the goal of the organization is to generate social and economic benefits for British Columbia and Canada. |

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|  | **Danielle Kemmer**<br>*Program Manager*<br>Genome Québec<br>Montreal, Quebec H3B 1S6<br>dkemmer@genomequebec.com | *Research Interests:*<br>● Genomics and its application to health<br>● Research partnerships and collaborations<br>● Research administration and impact analysis |
|  | **Malcolm King**<br>*Scientific Director*<br>CIHR Institute of Aboriginal Peoples' Health<br>Simon Fraser University<br>Burnaby, British Columbia<br>malcolm_king@sfu.ca | *Research Interests:*<br>● Pulmonary research,<br>● New approaches to treat mucus clearance dysfunction in chronic lung disease,<br>● Issues in airborne disease transmission,<br>● Respiratory health inequities facing Aboriginal people. |
|  | **Tobias Kollman**<br>*Associate Professor*<br>Division of Infectious and Immunological Diseases,<br>Department of Pediatrics<br>University of British Columbia<br>Vancouver, British Columbia<br>tkollmann@cw.bc.ca | *Research Interests:*<br>● Immunology and immunological diseases<br>● Developmental immunology/ neonatal immunology<br>● Infectious disease<br>● Vaccines |
|  | **Anita Kozyrskyj**<br>*Associate Professor*<br>Department of Pediatrics<br>University of Alberta<br>Edmonton, Alberta<br>kozyrsky@ualberta.ca | *Research Interests:*<br>● PI of SyMBIOTA (Synergy in Microbiota) research program, one of the 7 CIHR-funded Canadian Microbiome Initiative teams<br>● Early life determinants of childhood asthma such as birth mode, diet and Antibiotic use<br>● Pre- and postnatal influences on intestinal microbiota and their connection to the development of atopic disease<br>● Population-based birth cohort studies and link them to existing healthcare databases |
|  | **Tony Lam**<br>Senior Scientist<br>Division of Advanced Diagnostics – metabolism<br>Toronto General Research Institute<br>MaRS Centre, Toronto<br>tlam@uhnresearch.ca | *Research Interests:*<br>● Obesity<br>● Diabetes<br>● Glucose and energy homeostasis<br>● Intestinal signaling defects |

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|  | **Paul Lasko**<br>*Scientific Director*<br>CIHR Institute of Genetics<br>McGill University<br>Montreal, Quebec<br>Paul.lasko@mcgill.ca | *Research Interests:*<br>● Oogenesis and pole plasm assembly using the model organism Drosophila melanogaster, a.k.a. the fruit fly. Oogenesis is the process by which an egg is formed and matures |
|  | **Megan Levings**<br>*Canada Research Chair in Transplantation*<br>*Scientist*<br>Child & Family Research Institute<br>*Associate Professor*<br>Dept. of Surgery<br>University of British Columbia<br>Vancouver, British Columbia<br>megan.levings@ubc.ca | *Research Interests:*<br>● Understanding the role of T regulatory (Treg) cells in transplantation tolerance, cancer and inflammatory bowel disease.<br>● Generation of Treg cells in vitro for use as a cellular therapy to replace standard immunosuppression in the context of organ transplantation or to restore tolerance in the context of autoimmunity |
|  | **Marcia MacDonald**<br>*Manager, Scientific Affairs*<br>Genome BC<br>Vancouver, British Columbia<br>mmacdonald@genomebc.ca | Genome British Columbia is a catalyst for the life sciences cluster on Canada's West Coast, and manages a cumulative portfolio of over $625M in research projects and science and technology platforms. Working with governments, academia and industry across sectors such as forestry, fisheries, agriculture, environment, bioenergy, mining and human health, the goal of the organization is to generate social and economic benefits for British Columbia and Canada. |
|  | **David Mack**<br>*Senior Scientist*<br>CHEO Research Institute<br>*Director*<br>CHEO Inflammatory Bowel Disease Centre<br>*Chief*<br>Division of Gastroenterology, Hepatology & Nutrition, CHEO<br>*Professor*<br>Department of Pediatrics, Faculty of Medicine, University of Ottawa<br>DMack@cheo.on.ca | *Research Interests:*<br>● Pediatric IBD<br>● Gut inflammation<br>● Predicting outcomes<br>● Developing new therapeutics<br>● Understanding natural h story of pediatric IBD |
|  | **Joaquin Madrenas**<br>*Canada Research Chair in Human Immunology*<br>*Professor and Chairman*<br>Department of Microbiology and Immunology<br>*Director*, McGill's Microbiome and Disease Tolerance Centre<br>*Executive Director*, CIHR Human Immunology Network<br>Montreal, Québec<br>joaquin.madrenas@mcgill.ca | *Research Interests:*<br>Director of the Microbiome and Disease Tolerance Centre (MDTC) at McGill; Canada Research Chair in Human Immunology<br>● Human Immunology: Regulation of adaptive immunity by innate immune mechanisms.<br>● Functional Microbiomics: Mechanisms promoting commensalism by pathobionts. |

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|  | **Karen Madsen**<br>*Professor*<br>Division of Gastroenterology<br>University of Alberta<br>Edmonton, Alberta<br>karen.madsen@ualberta.ca | *Research Interests:*<br>Co-director of the "Center of Excellence for Gastrointestinal Inflammation and Immunity Research (CEGIIR)" and the Alberta IBD Consortium<br>● The role of intestinal permeability and gut microbes in human health<br>● The mechanisms of breakdown and repair of mucosal barrier integrity<br>● How probiotic bacteria interact with and modulate host epithelial and immune cell activity |
|  | **Amee Manges**<br>*Associate Professor*<br>School of Population<br>and Public Health<br>University of British Columbia<br>Vancouver, British Columbia<br>amee.manges@ubc.ca | *Research Interests:*<br>● Microbial metagenomics<br>● Intestinal microflora<br>● C. difficile infections |
|  | **Eric Marcotte**<br>*Associate Director*<br>Institute of Genetics & Institute of Neurosciences, Mental Health and Addiction<br>Canadian Institutes of Health Research (CIHR)<br>eric.marcotte@mcgill.ca | *Research Interests:*<br>● Molecular mechanisms underlying neurodegenerative and neurodevelopmental disorders, especially Parkinson's disease and schizophrenia.<br>● Regenerative medicine<br>● Epigenetics<br>● Commercialization of modern biotechnology |
|  | **Sylvie Masse**<br>CIHR Institute of Infection and Immunity<br>Centre de recherche<br>du CHU de Québec<br>CHUL – local TR-62<br>2705, boul. Laurier<br>Québec, QC G1V 4G2<br>sylvie.masse@crchuq.ulaval.ca | The CIHR Institute of Infection and Immunity (III) supports research and helps to build research capacity in the areas of infectious disease and the body's immune system. Through the Institute's programs, researchers address a wide range of health concerns related to infection and immunity including disease mechanisms, disease prevention and treatment, and health promotion through public policy. |
|  | **Debora C. Matthews**<br>*Professor and Assistant Dean (Research)*<br>Faculty of Dentistry<br>Dalhousie University<br>Halifax, Nova Scotia<br>Debora.Matthews@Dal.Ca | *Research Interests:*<br>Dr. Matthews is Director of the Network for Canadian Oral Health Research. The major objectives of this network are twofold:<br>● Foster & support research infrastructure in the oral health research community to facilitate the development of collaborative interdisciplinary research teams; and,<br>● Promote knowledge transfer and translation among researchers, health care practitioners, policy makers, business/industry and the general public. |

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|  | **Dennis McCormac**<br>*Director*<br>Genomics Services and Technology Advisor<br>Ontario Genomics Institute and The Centre for Applied Genomics<br>MaRS Centre,<br>Toronto, Ontario<br>dmccormac@OntarioGenomics.ca | As a part of the business development group at the Ontario Genomics Institute, it is our mandate is to help industry tap into the potential of life science solutions to improve business processes and promote the innovative use of life science research. We focus on relationships by identifying needs in a variety of industries, using our life science and business development expertise to connect companies to world-class researchers in the field and identify funding sources. |
|  | **Janet McElhaney**<br>*Professor of Medicine*<br>Medical Sciences Division, Northern Ontario School of Medicine<br>Member of Institute Advisory Board, CIHR Institute of Aging<br>jmcelhaney@hsnsudbury.ca | *Research Interests:*<br>● *Research on the elderly*<br>● *Impact of immunosenescence on the immune responses to vaccination*<br>● *Immunologic biomarkers of protection mediated by vaccination*<br>● *Role of vaccination in preventing disability in older adults* |
|  | **Pierre Meulien**<br>*President*<br>Genome Canada<br>Ottawa, Ontario<br>pmeulien@genomecanada.ca | Genome Canada is a catalyst for developing and applying genomic sciences. Genome Canada works in partnership to invest in and manage large-scale research and translate discoveries into commercial opportunities, new technologies, applications and solutions, building bridges between government, academia and industry to forge a genomics-based public-private innovation focused on key life science sectors. |
|  | **Yassene Mohammed**<br>*Chief Bioinformatician*<br>University of Victoria Genome British Columbia Proteomics Centre<br>Saanich, British Columbia<br>Yassene@proteincentre.com | *Research Interests:*<br>● Mass Spectrometry-based Targeted and Non-targeted Proteomics<br>● Bioinformatics for Proteomics and Meta-Proteomics<br>● Automated Big Data Analysis using Scientific Workflow |
|  | **William Mohn**<br>*Professor*<br>Department of Microbiology and Immunology<br>University of British Columbia<br>Vancouver, British Columbia<br>wmohn@mail.ubc.ca | *Research Interests:*<br>● Microbial degradation activities, addressing the biochemical mechanisms involved as well as the physiology, phylogeny and ecology of the organisms involved |
|  | **Deborah Money**<br>*Professor*<br>Division of Specialized Gynecology<br>University of British Columbia<br>*Vice-President, Research*<br>BC Women's Hospital and Health Centre<br>Vancouver, British Columbia<br>dmoney@cw.bc.ca | Research Interests:<br>● PI of VOGUE, one of the 7 CIHR funded Canadian Microbiome Initiative team<br>● Infectious diseases in obstetrics and gynecology, focused on viral pathogens in women and in pregnancy, specifically HIV, HPV, Hepatitis C and genital herpes |

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|  | **Josh Neufeld**<br>*Associate Professor*<br>Department of Biology<br>University of Waterloo<br>Waterloo, Ontario<br>jneufeld@uwaterloo.ca | *Research Interests:*<br>● Understanding the causes of microbial diversity and the relationship between taxonomic and functional diversity as it relates to ecosystem health.<br>● Next-generation sequencing, bioinformatics, and stable-isotope probing for exploring the diversity and metabolic function of terrestrial, aquatic, and host-associated microbial communities. |
|  | **Kieran O'Doherty**<br>*Assistant Professor*<br>Applied Social Psychology<br>University of Guelph<br>Guelph, Ontario<br>kieran.odoherty@uoguelph.ca | *Research Interests:*<br>● Social and ethical implications of genetics/genomics<br>● Regulatory guidelines |
|  | **Marc Ouellette**<br>*Scientific Director*<br>CIHR Institute of Infection and Immunity<br>Université Laval<br>Québec City, Québec<br>Marc.Ouellette@crchul.ulaval.ca | *Research Interests:*<br>● Antimicrobial resistance, specifically mechanisms of resistance in the parasite, Leishmania and the bacteria Streptococcus pneumoniae<br>● Development of new tools to diagnose resistance, novel drug targets and novel pathways<br>● Phage therapy<br>● Whole genome analysis |
|  | **Jackie Papkoff**<br>*Vice President Immunology*<br>Scientific Innovation<br>J&J California Innovation Center<br>jpapkoff@its.jnj.com | *Research Interests:*<br>● Identify and foster innovation across the pharmaceutical, medical devices, diagnostics and consumer product ecosystem<br>● Invest in transformational opportunities from inception through clinical proof of concept |
|  | **John Parkinson**<br>*Associate Professor*<br>Biochemistry and Molecular and Medical Genetics<br>University of Toronto<br>*Senior Scientist*<br>Molecular Structure and Function<br>Hospital for Sick Children<br>Toronto, Ontario<br>jparkin@sickkids.ca | *Research Interests:*<br>● Meta-transcriptomics study of microbiomes<br>● Evolution of biological complexity<br>● Parasites and bacterial pathogens,<br>● Computational systems biology |
|  | **Anthony Phillips**<br>*Scientific Director*<br>CIHR Institute of Neurosciences, Mental Health and Addiction<br>Strangway Building<br>University of British Columbia<br>Vancouver, British Columbia<br>aphillips@psych.ubc.ca | *Research Interests:*<br>The Institute of Neurosciences, Mental Health and Addiction (INMHA) supports research on the functioning and disorders of the brain, the spinal cord, the sensory and motor systems, and the mind. |

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|  | **Dana Philpott**<br>*Associate Professor*<br>Department of Immunology<br>University of Toronto<br>Toronto, Ontario<br>dana.philpott@utoronto.ca | *Research Interests:*<br>● Role of NOD receptors in bacterial infection and auto-immune diseases<br>● Mucosal immunity, inflammation |
|  | **Christopher Power**<br>*Professor*<br>Division of Neurobiology<br>University of Alberta<br>Edmonton, Alberta<br>chris.power@ualberta.ca | *Research Interests:*<br>● Microbiome in the brain and its relationship to disease<br>● Neurovirology<br>● Neuroimmunology<br>● Neurodegeneration<br>● Retrovirology |
|  | **Lita Proctor**<br>*Program Director*<br>Human Microbiome Project<br>National Institutes of Health<br>Bethesda, Maryland, USA<br>lita.proctor@nih.gov | The Human Microbiome Project (HMP) is a 5-year, trans-NIH Common Fund Initiative to create a community resource for microbiome-related research. |
|  | **Jennifer Raven**<br>*Associate*<br>Strategic Initiatives<br>CIHR Institute of Infection and Immunity<br>Centre de recherche du CHU de Québec, CHUL<br>Québec City, Québec<br>jennifer.raven@crchul.ulaval.ca | The CIHR Institute of Infection and Immunity (III) supports research and helps to build research capacity in the areas of infectious disease and the body's immune system. Through the Institute's programs, researchers address a wide range of health concerns related to infection and immunity including disease mechanisms, disease prevention and treatment, and health promotion through public policy. |
|  | **Gregor Reid**<br>*Professor*<br>Microbiology and Immunology<br>Western University<br>London, Ontario<br>gregor@uwo.ca | *Research Interests:*<br>● Understanding how indigenous and exogenously applied (probiotics) bacteria, especially lactobacilli confer health benefits primarily in the female gut, breast and urogenital tract |
|  | **Raylene Reimer**<br>*Professor*<br>Faculty of Kinesiology and Department of Biochemistry and Molecular Biology<br>University of Calgary<br>Calgary, Alberta<br>reimer@ucalgary.ca | *Research Interests:*<br>● Understanding how maternal diet during pregnancy 'programs' the risk of obesity and impaired glucose tolerance in offspring<br>● Understanding the link between the human host and intestinal microbial communities<br>● Clinical trials with prebiotics |

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|  | **Rachael Ritchie**<br>Genome BC<br>Vancouver, British Columbia<br>rritchie@genomebc.ca | Genome British Columbia is a catalyst for the life sciences cluster on Canada's West Coast, and manages a cumulative portfolio of over $625M in research projects and science and technology platforms. Working with governments, academia and industry across sectors such as forestry, fisheries, agriculture, environment, bioenergy, mining and human health, the goal of the organization is to generate social and economic benefits for British Columbia and Canada. |
|  | **Stephen Robbins**<br>*Scientific Director*<br>CIHR Institute of Cancer Research<br>University of Calgary<br>Calgary, Alberta<br>srobbins@ucalgray.ca | *Research Interests:*<br>● Deciphering how extracellular signals are recognized by cells to control cellular proliferation and differentiation.<br>● Defining new therapies for malaria,<br>● Novel classes of anti-inflammatory agents and new therapeutic targets for brain tumours.<br>● The use of the Microarray Technology to define molecular blueprints of various childhood cancers. |
|  | **Keeley Rose**<br>*Project Manager*<br>CIHR Institute of Nutrition, Metabolism and Diabetes<br>Hospital for Sick Children<br>Toronto, Ontario<br>keeley.rose@sickkids.ca | The CIHR Institute of Nutrition, Metabolism and Diabetes's (INMD) mandate supports research to enhance health in relation to diet, digestion, excretion, and metabolism; and to address causes, prevention, screening, diagnosis, treatment, support systems, and palliation for a wide range of conditions and problems associated with hormone, digestive system, kidney, and liver function |
|  | **Denis Roy**<br>Canada Research Chair in Lactic Cultures Biotechnology for Dairy and Probiotic Industries<br>*Professor*<br>Department of Food Science and Nutrition<br>Université Laval<br>Québec City, Québec<br>Denis.Roy@fsaa.ulaval.ca | *Research Interests:*<br>● Study of microbial cultures for food production to understand how they function and to investigate their properties and purported health benefits<br>● Applying molecular methodologies to micro-organisms in order to define their diversity and measure their gene expression |
|  | **Anthony Schryvers**<br>*Professor*<br>Department of Microbiology, Immunology and Infectious Diseases<br>University of Calgary<br>Calgary, Alberta<br>schryver@ucalgary.ca | *Research Interests:*<br>● Pathogenesis of bacterial infections<br>● Determine the detailed mechanisms involved in the iron uptake pathway and to develop effective vaccines and therapeutic agents against pathway components<br>● Microbiota |

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|  | **Fraser Scott**<br>*Professor*<br>Department of Medicine and Department of Biochemistry, Microbiology and Immunology<br>University of Ottawa<br>*Senior Scientist*<br>Chronic Disease Ottawa Hospital Research Institute<br>Ottawa, Ontario<br>fscott@ohri.ca | *Research Interests:*<br>● Determine how dietary antigens influence the development of type I diabetes<br>● Define abnormal gut immune responses to wheat peptide antigens in diabetes-prone animals and humans |
|  | **Dilani Senadheera**<br>*Assistant Professor*<br>Faculty of Dentistry<br>University of Toronto<br>Toronto, Ontario<br>dilani.senadheera@gmail.com | *Research Interests:*<br>● Characterizing oral microbial community structures associated with human health or disease<br>● Investigate the virulence mechanisms of the cariogenic pathogen,Streptococcus mutans at the molecular and genetic levels |
|  | **Nilufer Seth**<br>*Principal Scientist*<br>Immunoregulation Group,<br>Immunoscience Research Unit,<br>Pfizer, Inc.<br>Cambridge, MA 02140<br>Nilufer.seth@pfizer.com | Pfizer's Host-Microbiome Group is dedicated to discovering medicines that will reshape the treatment of inflammatory and autoimmune diseases by harnessing strategies and pathways used by the human intestinal microbiota to maintain immune homeostasis. The group's interests focus on identification of mechanism and pathways that induce, maintain and / or promote the function of regulatory and tolerogenic immune cell types. Our current projects focus on known immunomodulatory molecules, agonist and bacteria that have been observed to modulate key regulatory pathways. |
|  | **Philip Sherman**<br>*Scientific Director*<br>CIHR Institute of Nutrition, Metabolism and Diabetes<br>Hospital for Sick Children<br>Toronto, Ontario<br>Philip.sherman@sickkids.ca | *Research Interests:*<br>● Epithelial cell signal transduction responses to pathogenic, commensal, and probiotic bacteria<br>● Microbiome<br>● IBD<br>● Pediatric gastroenterology |
|  | **Bhagi Singh**<br>*Professor*<br>Department of Microbiology and Immunology<br>Western University<br>London, Ontario<br>bhagi.singh@schulich.uwo.ca | *Research Interests:*<br>● Defining a role of the lung microbiome in chronic obstructive pulmonary disease<br>● The role of regulatory T cells in the pathogenesis of type I diabetes |

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|  | **Alain Stintzi**<br>*Associate Professor*<br>Ottawa Institute of Systems Biology<br>University of Ottawa<br>Ottawa, Ontario<br>astintzi@uottawa.ca | *Research Interests:*<br>● Microbial genomic, gene expression and regulation, microarray and functional genomic<br>● Foodborne pathogens, host-pathogen interactions, colonization and virulence factors, animal models of human infection, and gut-microbe interactions<br>● *Campylobacter jejuni,* iron acquisition and metabolism, and stress responses |
|  | **Michael Surette**<br>*Professor*<br>Department of Medicine<br>McMaster University<br>Hamilton, Ontario<br>mgsurette@gmail.com | *Research Interests:*<br>● PI of one of the 7 CIHR funded Canadian Microbiome Initiative team<br>● Investigating the role of normal flora-pathogen interactions in health and disease in the area of respiratory infections with a focus in cystic fibrosis<br>● Identification of overlooked pathogens in airway disease and synergistic interactions between a virulent organisms and pathogens |
|  | **Patrick Tang**<br>*Medical Microbiologist*<br>BC Centre for Disease Control<br>*Clinical Associate Professor*<br>University of British Columbia,<br>Vancouver, British Columbia<br>patrick.tang@bccdc.ca | *Research Interests:*<br>● Infectious agents in cancer and chronic diseases<br>● Genomic epidemiology of Mycobacterium tuberculosis<br>● Viral genomics and metagenomics<br>● Diagnostics |
|  | **Elena Verdu**<br>*Associate Professor*<br>Division of Gastroenterology<br>McMaster University<br>Hamilton, Ontario<br>verdue@mcmaster.ca | *Research Interests:*<br>● Pathogenesis of chronic inflammatory disorders such as celiac disease<br>● Investigating host-bacterial interactions in particular in the context of probiotics and functional gastrointestinal diseases |
|  | **Jens Walter**<br>*Associate Professor*<br>Food Science and Technology Department<br>University of Nebraska-Lincoln<br>Lincoln, Nebraska, USA<br>jwalter2@unl.edu | *Research Interests:*<br>● Microbial ecology of the gastrointestinal tract<br>● Characterizing the interplay between diet, the gut microbiota, and the metabolism and immune system of the host with the long-term goal to develop dietary strategies that modulate composition and functionality of the gut microbiota to prevent chronic diseases |
|  | **George Weinstock**<br>*Professor*<br>Genetics and Molecular Biology<br>Washington University<br>St. Louis, Missourri, USA<br>gweinsto@genome.wustl.edu | Associate Director of The Genome Institute - Sequencing the human microbiome as part of the NIH-funded Human Microbiome Project (HMP)<br>*Research Interests:*<br>● Applies high-throughput DNA sequencing, genome-wide analysis, bioinformatics, and other genetic methods to the study of human, model organisms and microbial genomes |

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|  | **Benjamin Willing**<br>*Assistant Professor*<br>Department of Agriculture, life and Environmental Sciences<br>University of Alberta<br>Edmonton, Alberta<br>willing@ualberta.ca | *Research Interests:*<br>● Understand how different members of the resident flora contribute to the metabolism of the diet<br>● Understanding the mechanisms through which microbes regulate host physiology<br>● Metabolomics<br>● Transcriptomics<br>● Gut bacteria |
|  | **Alan Winter**<br>*President and Chief Executive Officer*<br>Genome BC<br>Vancouver, British Columbia<br>awinter@genomebc.ca | Genome British Columbia is a catalyst for the life sciences cluster on Canada's West Coast, and manages a cumulative portfolio of over $625M in research projects and science and technology platforms. Working with governments, academia and industry across sectors such as forestry, fisheries, agriculture, environment, bioenergy, mining and human health, the goal of the organization is to generate social and economic benefits for British Columbia and Canada. |
|  | **David Wishart**<br>*Professor*<br>Department of Biological Sciences<br>University of Alberta<br>Edmonton, Alberta<br>david.wishart@ualberta.ca | *Research Interests:*<br>● Nanobiology<br>● Genomics,<br>● Proteomics,<br>● Metabolomics,<br>● Bioinformatics<br>● Systems biology |
|  | **William Yan**<br>*Director*<br>Bureau of Nutritional Sciences<br>Food Directorate<br>Health Canada<br>William.Yan@hc-sc.gc.ca | The Health Canada Bureau of Nutritional Sciences comprises two Divisions: The Nutrition Evaluation Division and the Nutrition Research Division, who work in concert in four main program areas: Nutrition Labeling and Claims; Nutrition Quality and Safety; Special Purpose Foods for Vulnerable Groups; and Food Surveillance and Monitoring. |
|  | **Colby Zaph**<br>*Assistant Professor*<br>Pathology and Laboratory Medicine<br>University of British Columbia<br>Vancouver, British Columbia<br>colby@brc.ubc.ca | *Research Interests:*<br>● Defining the molecular and cellular mechanisms that regulate immunity and inflammation at mucosal sites<br>● The nematode parasite Trichuris muris and the bacterial pathogen Citrobacter rodentium<br>● Epigenetic effects of microbiome on IBD |

# APPENDIX 2
# AGENDA

## Workshop Organizers

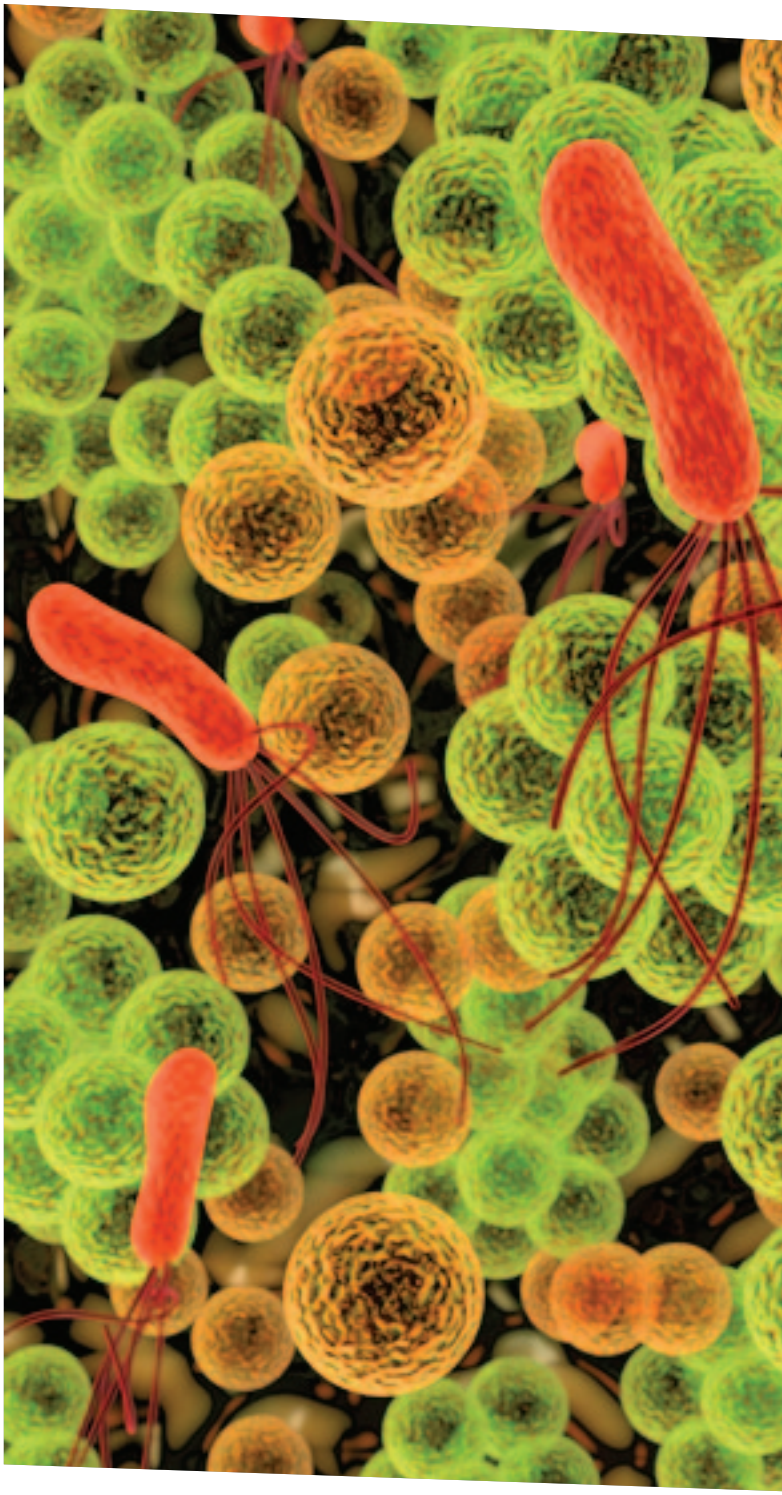
- CIHR Institute of Infection and Immunity (III)
- CIHR Institute of Nutrition, Metabolism and Diabetes (INMD)
- Genome British Columbia

## Workshop Supporters

- CIHR Institute of Aging
- CIHR Institute of Aboriginal Peoples' Health
- CIHR Institute of Cancer Research
- CIHR Institute of Circulatory and Respiratory Health
- CIHR Institute of Gender and Health
- CIHR Institute of Genetics
- CIHR Institute of Human Development, Child and Youth Health
- CIHR Institute of Musculoskeletal Health and Arthritis
- CIHR Institute of Neurosciences, Mental Health and Addiction
- CIHR Institute of Population and Public Health

## Workshop Objectives:

- To promote networking among the Canadian microbiome research community
- To foster national and international collaborations
- To assess progress in the microbiome field and consider potential "next steps"
- To engage industry and other "end-user" representatives to explore the application of research discoveries in the microbiome field



Workshop Location: Salon 1 & 2

# DAY 1 FEBRUARY 12TH

1st Floor of Conference Centre

| Time | Agenda Item | Presenter/Moderator |
|---|---|---|
| **11.30** | **Buffet Lunch** | Salon 3 |
| **12.30** | • Welcome<br>• Opening remarks and Workshop objectives<br>• Canadian Microbiome Initiative | **Judy Bray**<br>**Phil Sherman**<br>**Marc Ouellette** |
| **13.00** | **Sequencing the Human Microbiome: achievements, challenges and next steps** | **George Weinstock**<br>**Genome Institute, US**<br>*Moderator: David Charest* |
| **13.45** | **EU MetaHIT project – achievements, challenges and next steps** | **Dusko Ehrlich, MetaHIT Project**<br>*Moderator: Marc Ouellette* |
| **14.30** | **The Human Microbiome Project: achievements, challenges, and next steps** | **Lita Proctor, NIH**<br>*Moderator: Phil Sherman* |
| **15.15** | **Health Break** | Stanley Park Foyer |
| **15.45** | **From Research to Applications: Industry interests and public/private partnerships** | **GSK, Pfizer, AZ, Johnson and Johnson, Second Genome, CDRD**<br>*Moderators: Stephen Robbins and Paul Lasko* |
| **17.30** | **Networking Reception:** | Marine Room |
| **19.00** | **Meeting adjourned - Dinner on own** | |

# DAY 2 FEBRUARY 13TH

| Time | Agenda Item | Presenter/Moderator |
|---|---|---|
| 8.00 | **Breakfast** | Salon 3 |
| 8.50 | **Introduction to Day 2** | **Judy Bray** |
| 9.00 | **Introduction to Breakout Sessions** | **Brett Finlay and Judy Bray** |
| 9.10 | **Breakout Session 1:**<br>**What do we have and what do we need?** | |
| 10.30 | **Health Break** | Stanley Park Foyer |
| 11.00 | **Report Back and Plenary Discussion** | ***Moderator: Joy Johnson*** |
| 12.30 | **Networking Lunch** | Salon 3 |
| 13.30 | **Introduction to Breakout Session 2** | **Brett Finlay and Judy Bray** |
| 13.35 | **Breakout Session 2 – what is the path forward and how do we translate research outcomes?** | |
| 15.00 | **Health Break** | Stanley Park Foyer |
| 15.30 | **Report back** | ***Moderator: Hani El-Gabalawy*** |
| 16.50 | **Identification of topics for Breakout Session 3** | **All** |
| 17.00 | **Meeting adjourned – Sign up for breakout session 3** | |
| 17.00 | **Closed Session** - progress reports from the seven teams funded under the Canadian Microbiome Initiative | **Funder's panel**<br>**Prospect Room** |
| 19.00 | **Networking Dinner** | **All –** Marine Room |

# DAY 3 FEBRUARY 14TH

| Time | Agenda Item | Presenter/Moderator |
|---|---|---|
| 8.00 | **Breakfast** | Salon 3 |
| 8.45 | **Re-cap of Days 1 and 2** | **Marc Ouellette** |
| 9.00 | **Logistics for Day 3** | **Judy Bray** |
| 9.10 | **Individual Breakout Sessions – Next Steps** | **All** |
| 10.30 | **Health Break** | Stanley Park Foyer |
| 10.45 | **Report back from Breakout Groups** | ***Moderator: Malcolm King*** |
| 11.30 | **Next Steps**<br>**Closing Comments** | **Phil Sherman**<br>**Marc Ouellette** |
| 11.45 | **Meeting adjourned – Boxed lunches will be provided** | |

# NOTES