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The translation of Genomic Science to Social Well-Being and Human Health

Amis des instituts de recherche en santé du Canada
FCIHR/AIRSC
Friends of Canadian Institutes of Health Research

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FORWARD

Symposium 2003 of FCIHR was organized to help explain how genomic science translates to social well-being and human health. CIHR and Genome Canada, two of Canada's premiere research agencies are involved in the creation of new knowledge in genomics and its translation into practical outcomes. Biotechnology research offers great promise to improve health, to protect the environment, to enhance our economy, and thereby improve our quality of life. A public forum helps to accelerate the acceptance of new knowledge and encourages its practical application in an ethically sound way. While genomic science is a relatively new area of research the potential spin-offs are remarkable and have spawned entirely new areas of inquiry in record time. The volume of new knowledge produced is overwhelming for any individual to absorb and new information is produced at blinding speed. (The most impressive recent example of this is the sequencing of the SARS coronavirus genome at UBC within weeks of starting its analysis.) Public discourse helps demystify the wonders of genomic research, mitigates fears and misconceptions, and thereby enhances its acceptance in the general population.

It is important to understand how individual Canadians can benefit from their investment in health research generally, and genomic sciences specifically, and how this can be translated in a way that benefits human kind. It is no accident that Canada is an international leader in genomic research. Our federal and provincial governments invested significantly in this research and we are witnessing impressive returns. This is just the beginning and we hope that many of the young students who visit the Geee! in Genome exhibit at the Canadian Museum of Nature will recognize the diverse and fascinating career opportunities that abound in health research.

Aubie Angel, M.D.
President FCIHR

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Introduction and Welcoming Remarks

Dr. Aubie Angel, President FICHR
Aubie Angel noted that this year is the 50th anniversary of the discovery of the DNA structure, highlighting the current "GEEE! in Genome" exhibit at the Canadian Museum of Nature. He explained that the symposium aims to clarify how genomic science translates into social well-being and human health and to demystify genomic research, thereby enhancing its acceptance by the general public.

Dr. Alan Bernstein, President CIHR
Alan Bernstein emphasized that this is merely the beginning stage of an exciting revolution in the knowledge about genomes. Noting that profound ethical and social issues are involved, he encouraged the next generation of scientists to take part in learning about the genes and proteins that make us human and contribute to our behaviour, health, longevity, and diseases.

Joanne DiCosimo, President and CEO, Canadian Museum of Nature
Joanne DiCosimo remarked on the importance of engaging the public—and in particular students—in the emerging field of genomics. The Museum is pleased to be partnering with Genome Canada and CIHR to produce the "GEEE! in Genome" national touring exhibition. DiCosimo stressed that information, discussion, and debate are critical and invited the audience to explore the exhibit and its Web site at **http://nature.ca/genome.**

Martin Godbout, President and CEO, Genome Canada
Martin Godbout explained that the mandate of Genome Canada is to fund genomic and proteomic research in Canada. He invited the students in the audience to make contributions in these fields and to act as ambassadors to their parents and friends to raise awareness of these important technologies.

Keynote Address: *Biotechnology-Inventing a Future*

Dr. Arnold Naimark, Chair Canadian Biotechnology Advisory Committee
Arnold Naimark noted that genomics and proteomics are the two dominant fields in biotechnology research today. They have widespread implications for increasing our understanding of genomes, genes, and proteins, and their crucial roles in governing all life processes.

Biotechnology can be defined as the body of technological knowledge about living organisms and their constituent parts. There are roughly two categories of technology: techniques involving the manipulation of cells, tissues, organs, or whole organisms; and techniques involving organic molecules found exclusively in living organisms, such as DNA. Some applications include modifying the genetic makeup of plants and animals, testing for gene presence, tissue, and DNA matching, and producing novel pharmaceutical compounds.

Naimark had ten messages for the audience. First, he advocated making a long-term commitment of people and resources across a broad front of research to increase progress toward beneficial outcomes. Second, he encouraged the Canadian

government and industries to continue their strong investment and participation in these transformative technologies of the future, noting that solutions of important biological problems involve a diverse array of scientific disciplines.

Third, there are enormous opportunities for young people to pursue careers in the biosciences. Fourth, these opportunities exist at universities and in industry, within Canada and abroad, in laboratories and in the field. As well, they exist in the policy- and regulation-making arena to ensure that the development of these technologies remains accountable and trustworthy, reflects the core ethical and social values of Canadians, generates economic and social benefits, and protects human and animal health and the environment.

Fifth, Naimark pointed out that the double helix is truly double, requiring scientific discovery and social applications to be in balance. Scientists in civil society must take social responsibility for their work, especially in the life sciences where fundamental and ethical questions are involved about the nature of humanity and the meaning of life.

Sixth, the social, legal, ethical, and economic implications of biotechnological discovery point toward the expansion and integration of dimensions of technology and scales of knowledge beyond the traditional disciplines of physics, chemistry, and biology. Directions for the future include developments in the areas of nanotechnology; genes biotechnology; and information, communication, computer, and networked technologies for the natural world.

Seventh, the stretching of the scale of knowledge and the convergence of disciples will mean a rich array of new approaches to solving complex scientific problems. Eighth, new tools such as those required for diagnostics and testing will be invented to improve the health status of Canadians and people worldwide.

Ninth, as human beings, we differ from other species in that we can see where we stand on the path of evolution and have the imagination, ingenuity, and inventive capacity to create our own desired future. Finally, Naimark encouraged the students in the audience to be part of the effort to realize the benefits of advances in the life sciences. This field will certainly offer challenges, excitement, enormous satisfaction, and great potential for further intellectual and personal growth.

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Session 1: *Genomic Science-Realizing Its Potential*

Chair: Martin Godbout, President and CEO, Genome Canada

Genome Canada and its Role in Society

Martin Godbout discussed the importance of being literate in and at the leading edge of genomics. The knowledge of human gene sequencing will provide access to the "Dictionary of Life" and fundamentally change perceptions of health.

Godbout explained that genomics will offer new tools to transform health care, moving in five to ten years toward proactive medicine that will be more predictive, preventative, and personalized. It will be possible to detect diseases long before symptoms appear, exponentially increasing the efficacy of treatment and the likelihood of survival. The orientation of healthcare will shift toward keeping well and preventing disease, similar to the approach used in dentistry. Finally, genomics will lead to biology-based and gene-profile-based medicine that will be much more effective than the current symptoms-based drugs.

Godbout cautioned that these advances would be accompanied by ethical and social consequences. However, he emphasized the vast opportunities, potential, and advantages inherent in becoming fluent in the language of genes and their related proteins. In conclusion, he recognized the federal government for its funding commitment.

Dr. Rod McInnes, Scientific Director, Institute of Genetics, CIHR

The Genome Project: *What Does it Mean for the Future of Science and Health Care?*

Rod McInnes discussed the ethical issues surrounding genomic research. Cracking the DNA code has changed the way Canadians (and many others) live, treat diseases, and imagine the future, but it has also raises questions about whether this research is good or bad for society and for humans.

McInnes first provided some definitions. The genome is the full set of genes inside the nucleus of each cell. It is the entire DNA sequence of a person, population, or species. The human genome is comprised of 23 pairs of chromosomes, each one composed of DNA molecules in the shape of a double helix. On each chromosome are different genes that give the codes for making proteins—the body's building blocks. Genetics is the study of individual genes, while genomics refers to the structure and function of the full set of genes—the genome. Stem cells are the mother of all cells, cells that have not yet become specialized in function.

The Human Genome Project is an international effort to learn about the approximately 35,000 genes in the human genome and the complex ways in which they interact and work together to express physical, intellectual, and other kinds of traits.

McInnes explained how the project benefits humankind. First, it allows us to understand human biology and the reasons behind normal and abnormal functions. For example, knowing how genes control cell size and organism size can help explain when normal cell division occurs, such as in a baby that gradually grows in size, as opposed to abnormal and uncontrolled cell division, such as in cancer.

Second, the project contributes to the understanding and treatment of single-gene disorders, of which there are thousands. If a person carries the gene with a mutation for a single-gene disorder, he or she will get the disease. Some examples include haemophilia, cystic fibrosis, muscular dystrophy, and Huntington disease. Gene therapy shows promise of success toward permanent cures. Some social and ethical questions include when to do testing, and when and how to inform the patient and family members.

Third, knowing how genes work will help researchers understand the causes and possibly develop cures for genetically complex diseases such as cancer, asthma, and high blood pressure. Most diseases are of this type, resulting from multiple conditions that include genetic predisposition and environmental and lifestyle factors such as diet, viruses, smoking, and pollution. Genetic knowledge can help identify predisposition, determine lifestyle changes that lower the risk of getting the disease, and develop cures.

McInnes then spoke about the ethical issues surrounding genomic research and medicine. For example, the study of the genetics of behaviour shows that certain genetic variants may explain some forms of violence. Questions arise as to how—and the extent to which—one could modify such a behavioural trait. Another example involves the use of embryonic stem cells, the cells that exist at the earliest stages of cell division, to develop cures for diseases such as diabetes. Questions arise about whether these cells should be used for such therapies, which may be different from the original purpose for which the cells were created. A fine balance exists between relieving human suffering and protecting the dignity of the embryo.

The cloning of humans is another controversial issue. Mounting evidence shows that cloned animals are not at all normal, and surveys indicate a universal rejection of human cloning in virtually all cultures worldwide.

McInnes concluded that it will take decades of research and debate to resolve the challenges of managing genomic medicine and controlling expectations.

Dr. Jason Scott Robert, CIHR New Investigator, Dalhousie University
Making Good on Oft-Heard Promises

Jason Scott Robert, a philosopher of science, discussed the general challenges in realizing the potential of genomic medicine and science in an ethical way in the future. He addressed three types of often-made promises: those that have been kept, those that can't be kept, and those that shouldn't be kept.

Promises that have been kept are few and far between. Two of these include compiling a complete sequence of the human genome (and the genomes of other organisms) by 2005, and making them available free to any and all researchers. These are both remarkable achievements that have required ingenuity, enormous computational and technological advances, and a sustained commitment to publicly accessible data. At present, two genomes have been published, although only one has been made publicly accessible. Thanks to CIHR many Canadian scientists have access to both genome sequences.

Robert then discussed three promises that cannot be kept: genomics will solve the problem of development, genomics will revolutionize medicine, and genomics will reveal the secret of what it means to be human. It is now generally recognized that these overblown, public relations-style promises were made with the underlying purpose of securing project funding and support, and were far from scientific. Speaking more realistically, he said, the more one learns, the more one realizes how much more there is to learn. Any DNA-based transformation in medicine will more likely be slow and gradual in coming rather than be radical and abrupt.

Robert presented several quotations that gave a more realistic context to the promise of genomics research. On the subject of whether there will be a revolution in medicine as opposed to incremental progress, Harold Varmus asserts that the full potential of a transformation will only be realized over the course of decades as more is understood about the content of genomes and the physiological consequences of variations in their sequence. On the subject of what it means to be human, Svante Pääbo says that human nature is a complex puzzle of which genes are only one part that shape human development. There are large environmental and interactive components to common diseases, behaviour, and personality traits. The genetic history of the human species cannot be considered in isolation; other histories related to architecture,

science, technology, and political ideals, etc. may be even more important.

Next, Robert discussed promises that should not be kept. First, he asked whether millennial dreams may actually be eugenic nightmares if they advocate using genomic technologies to alter genes in order to ensure that every child is born physically and mentally healthy. Second, he raised the issue of the desire of some to use genomic knowledge to enhance, control, and indeed perfect the human species and eliminate both flaws and limitations. The idea of engineering the future through genetic technology rather than social policies and cultural means must be rationally debated by well-informed and well-intentioned citizens.

Robert concluded with some future challenges. To realize the potential of genomics to improve health and well-being, researchers must integrate emerging knowledge about genomics with all other knowledge about the determinants of health, study complex sequence variations and gene-environment interactions in detail, and create and enforce rational laws and guidelines that protect humanity. Researchers must be more grounded in science, and more integrative and comprehensive in their research and advances. Finally, Robert emphasized not only the prospect of careers in science but also serious opportunities to participate through the humanities and social sciences.

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Session 2: *Translating Genomic Science for the Social Good*

Chair: Sonya Corkum, Vice-President Knowledge Translation, CIHR

Sonya Corkum spoke about translating genomic knowledge and evidence into social benefits. For example, the health risks of tobacco use are well known. What is the best way to get this information out and reduce smoking rates? Knowing the genetic predispositions for certain behaviours, how should teachers and counsellors in schools be informed, and what is the best way to manage or change those behaviours? Corkum introduced the next two speakers who explored the topic in more depth.

Dr. Fraser Mustard, President, Founders' Network
Biosciences and Social Change

Fraser Mustard discussed translating genomic and bioscientific knowledge and technologies into social good. The ability to do this is crucial to the future of society, he said, noting that society cannot ignore environmental interactions with genes. The nature versus nurture perspective is still important.

Mustard first provided an historical perspective on the growth of knowledge and technology in relation to the growth of world population. In the last 10,000 years of their 200,000-year evolutionary history, homo sapiens have moved from agricultural revolution to urbanization, from writing to mathematics, then from books to the current electronic media. Each stage has been marked by social, economic, political, institutional, and religious/spiritual change. The most dramatic growth has occurred in the last 250 years in both technology and population, and it continues exponentially.

Fogel, a 1993 Nobel Prize winner, defined four periods of great awakenings in the United States, beginning in 1730. Each period of new knowledge and technologies had major effects on societal values and institutions. The Fourth Great Awakening began in 1960. There is no doubt, he argued, that new genomic and bioscientific research will bring major challenges and change to society through its accompanying ethical questions and implications on humankind's beliefs about the origin and meaning of life.

Mustard presented several current controversies surrounding genomic science. In the control and management of reproduction, controversies include abortion, birth control, infertility treatment, cloning, gene screening for disease susceptibility, and genetic modifications to alter behaviour. In stem cell research, questions surround cloning, cadaver cells, embryo surplus, adult stem cells, and the creation of embryos. When inventing new drugs to target specific brain receptors, issues exist around their use for modifying mood and behaviour.

As knowledge and technologies evolve to create a social and medical revolution, society will increasingly be required to create regulations to prevent misapplication. However, perhaps even more important is an understanding of how conditions in the early years of life—including time in utero—affect experienced-based brain development and have consequences later in life for physical and mental health, learning and behaviour, and the need for drug therapy. These conditions relate to everyone, magnify the nature versus nurture debate, and represent huge and significant challenges for society.

Mustard presented study results indicating that young children subjected to severe abuse can be left with permanent damage to their brain structure and function. Potential consequences later in life include depression, anxiety, suicidal thoughts, violence and aggression, impulsiveness, hyperactivity, and substance abuse with drugs and alcohol. Studies show that four to ten per cent of children are subject to some form of abuse. Many of these consequences can be helped by drug therapy and have led to the design of drugs such as Prozac for depression and Ritalin for ADHD. However, the bigger issue is

that adverse environmental conditions harm development and contribute to a drug-modified and drug-dependent society.

Mustard discussed a study with rhesus monkeys showing that poor mothering in the first six months of life resulted in adults with poor behaviour and abnormal stress (cortisol) and serotonin metabolism in the brain. Nurturant mothering, however, resulted in adults with normal stress and serotonin measures, normal behaviour, and a robust immune system.

What implications do behavioural genetics have for society? Mustard recommended that genomic research strive to better understand how experience-based brain development in early life interacts with genetic coding in the brain to influence behaviour. This issue recalls the need to have a better appreciation for how new knowledge affects societal beliefs and values.

The poor literacy and capacity of Canada's adult population to understand complex subjects is a current obstacle. One study shows that 42% of Canadians from age 16 to 55 are functioning at the low-end Levels 1 and 2 in reading and writing. Mustard recommended creating a Ministry of Human Development and substantially investing in early childhood development (ECD) programs that provide optimal environments for human development, focusing on education, health, social capital, and equality. Policies that foster human capital are crucial for economic growth. Heckman, a Nobel Prize winner in 2000, has stated that the early years have a critical effect on language skills and literacy, and ability to adjust in adult life that intervening after children reach school age may be too late.

Mustard expressed hope that the CIHR will become a strong advocate for quality ECD. He concluded that improving the next generation's ability to understand the potential of genomics would ensure that this research and technology translate into social good.

Dr. Peter Singer, Director, Joint Centre for Bioethics, University of Toronto
Genomics and Global Health

Peter Singer discussed some promises that Canada—a world leader in innovative work and social policy ideas—should make in the field of genomic research. These include harnessing genomics to improve global health equity and applying genomics to convergent biotechnologies across diverse areas of research.

Singer noted that global health inequity is a key ethical challenge in the world today. The life expectancy in some African countries is expected to be 30 years by 2010, compared with 80 years in Canada, which demonstrates an unbelievable gap in mortality rates and health between the developed and developing countries in the world. Too often, he said, the human suffering behind this gap is neglected. While acknowledging that there are structural causes and financial and other issues involved, Singer asserted that genomics and its related scientific and technological advances have an important role to play in narrowing this gap to advance global public good. In its international development policies and genomics work, Canada should be concerned and is in a good position to help.

Singer pointed out that recent human development research reports by the United Nations and the WHO have indicated that genomics is very relevant in developing countries. The problem is a lack of concrete examples.

To address this issue, a recent study was conducted asking prominent global health scientists around the world to identify the major biotechnologies that could improve health in developing countries in the next five- to ten-year timeframe. The top ten biotechnologies from this study include molecular technologies to diagnose diseases; recombinant technologies to develop drugs, vaccines, and other products; and technologies to improve drug and vaccine delivery systems, improve the environment, and protect against diseases.

Singer said that Canada has an important foreign policy role to play in ensuring that these biotechnologies are used to improve global health equity. To make change in the real world, Canada should give maximum support to research that is interested in this work. He highlighted a program established by Bill Gates, called Grand Challenges in Global Health, to support research that aims to overcome the crucial gaps of global health inequities for the world's poor. Noting that this is an exciting initiative, he encouraged Genome Canada and the CIHR to apply for grants under this program. As well, he recommended a Web site called **www.grandchallenges.org** that lists links to a variety of other "grand challenges" in different areas of research and development.

Singer also spoke about the United Nations Millennium Development Goals (MDGs), an initiative to fight global problems such as poverty, hunger, and disease. A task force has been established to work on scientific and technological

innovations, and a genomics working group will focus attention on the top ten biotechnologies and their justification for public good. He mentioned the importance of understanding the role of developing countries in genome innovation, involving all sectors of society in policy making, and being aware of issues surrounding governance.

Singer noted that biotechnologies and information and communications technologies (ICTs) are very important tools for change. Issues surrounding confidentiality and consent need to be resolved, but bioethics, equity, and global health are immediately more important. Genomics specifically, and science and technology more generally, will form part of the solution.

In conclusion, Singer pointed out that Canada has an enormous opportunity to take a leadership role internationally, distinguishing ourselves from the U.S. Canadian scientific and technological assets can be used to work with scientists in developing countries to make improvements in human health and the environment. Innovation within Canada's foreign policy agenda is needed to allow these assets to work with a common vision, and the domestic agenda must be harmonized with a powerful foreign policy if Canada is to contribute to global health equity.