Science-Metrix

Final Report

March 2005

Canadian Biotechnology Initiatives Addressing Developing Country Issues

Prepared for the

National Research Council Canada

Research Program Support Office

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David Campbell
and Grégoire Côté

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Science-Metrix specializes in the measurement and evaluation of science, technology and innovation. Our data collection and assessment methods include bibliometrics, scientometrics, technometrics, surveys and interviews, environmental scans, monitoring and intelligence gathering. We perform program and policy evaluations, benchmarking and sector analyses, market studies and strategic planning. Science-Metrix has a robust knowledge of life and environmental sciences.

514.495.6505 • 4572 avenue de Lorimier • Montréal • Québec • Canada • H2H 2B5
info@science-metrix.com • www.science-metrix.com

Executive Summary

Demonstrating responsible world leadership in biotechnology is one of the ten key themes of the Canadian Biotechnology Strategy, created in 1998. This objective was reinforced in 2004 with the launch of the Government of Canada's Blueprint for Biotechnology. The Blueprint emphasizes that "Canada's leadership, both domestically and internationally, requires that the new Stewardship Framework is supported by leading-edge regulatory research, foresight, capacity-building in regulatory sciences, dialogue with Canadians, and international cooperation", and recommends various initiatives to achieve the desired international impact.

One of these initiatives recognizes that the knowledge harnessed from biotechnology advances has a powerful potential to address critical issues in developing countries, and recommends the establishment of a new national initiative for international development. This initiative would facilitate the coordination of strategic research and technology development networks encompassing research centers in Canada and the developing countries.

As part of this initiative, the National Research Council of Canada is leading a project focusing on Canadian capacities and competencies in biotechnology research and development. There are two components to the project: 1) analysis of Canadian strengths in biotechnology research and development; and 2) analysis of Canadian development assistance in biotechnology. Science-Metrix was mandated to conduct both these analyses. The first analysis has been completed and resulted in a report entitled "Scan of Canadian Strengths in Biotechnology". The second is the focus of the current study which aims to:

- identify Canadian initiatives addressing developing country issues using biotechnology;
- identify complementary competencies within and opportunities for research and development collaborations between Canadian organizations;
- make recommendations to improve the current models of collaboration to connect and increase the synergy of Canadian initiatives in biotechnology and international development.

In order to provide the best possible coverage of Canadian biotechnology initiatives on issues of importance to developing countries, Science-Metrix adopted a triangulation approach, whereby information was drawn from complementary sources of data including an environmental scan, a bibliometric analysis, and telephone interviews.

The review of Canadian biotechnology initiatives in international development has revealed a wide range of scientific, technologic and innovation activities aimed at providing solutions to some of the most critical issues faced by developing countries. Within the federal government, several departments contributed significantly to these initiatives, namely the International Development Research Center, the Canadian International Development Agency, the National Research Council Canada, the Canadian Institutes of Health Research, Health Canada, and Agriculture and Agri-Food Canada. Universities, non-governmental organizations and biotechnology companies have also led important initiatives. For example, the National Research Council Canada's Industrial Research Assistance Program provided assistance to many developing countries' biotechnology industry through its services to support innovation and commercialization. Alongside initiatives to boost the innovation system of developing countries, the National Research Council Canada is also

involved in research and development initiatives to develop, for example, vaccines for tuberculosis. These pertain to areas as diverse as health, agriculture and aquaculture, the environment, capacity building, and the innovation system.

However, it appears that these initiatives are not making full use of some of the major Canadian strengths in biotechnology that could be useful to developing countries. In particular, efforts should target forestry, aquaculture, and development assistance to help developing countries expand their own biotechnology strategies. In the years to come, Canada should also pay more attention to the potential use of biotechnology to address the growing burden of diabetes sufferers in developing countries.

Based on complementary competencies, many potential partnerships amongst Canadian organizations have been outlined; to provide a more detailed picture, further work would be required. This could involve a study in which every Canadian organization involved in biotechnology and international development would be interviewed to compile a database of their strengths and weaknesses, which could be shared on the internet. This would allow the strengths of particular organizations to compensate for weaknesses in others. Another route would be to organize consultations between researchers from Canada, developing countries, and relevant working groups to identify the needs of developing countries that could be tackled using biotechnological means. The goal of these workshops would be to identify problems not currently being addressed by Canadian initiatives, and to identify organizations, engaged in complementary work, that could tackle these issues together.

Ultimately, the aim should be to get Canadian organizations to work collectively to integrate individual initiatives into well functioning assistance programs. However, the creation of such national networks requires appropriate models of research and development collaboration. Four models of research and development collaboration have been suggested.

The first involves only the Canadian International Development Agency and the International Development Research Center to initiate and support cooperation activities. The second model is based on the successful Global Health Research Initiative. It consists of establishing networks to foster international cooperation in specific fields. The networks would be built around the Canadian International Development Agency and the International Development Research Center in order to benefit from their long experience in international development, but would also include a federal funding agency appropriate to the field targeted (e.g. the Canadian Institutes of Health Research for health; the Natural Sciences and Engineering Research Council of Canada for agriculture and aquaculture, and the environment, etc.), a federal department with authority in the targeted field (e.g. Health Canada for health; Agriculture and Agri-Food Canada for agriculture, etc.) and an established national network (e.g. Networks of Centres of Excellence). The third model involves creating a Canada-Africa Research Chairs program modeled after the Canada Research Chairs program. The fourth model would entail establishing an International Networks of Centres of Excellence based on the Canadian Networks of Centres of Excellence. The four models are complementary such that, in a perfect scenario, they would all be implemented.

Table of Contents

1 Introduction

During the 1980s and 1990s, biotechnology expanded significantly in Canada in terms of both fundamental knowledge and applications, thereby fuelling the emergence of a dynamic industry creating tangible economic benefits such as employment and export revenues. Based on the significant contribution of biotechnology to the growth of Canada's knowledge-based economy and its further potential for development, the Minister of Industry was asked in 1997 to instigate a renewal process for the National Biotechnology Strategy (CBS, 1998). This led to the launch of the Canadian Biotechnology Strategy (CBS) in 1998. As biotechnology generates important benefits in addition to those of an economic nature, such as for health, the environment, and food production, it has been perceived as a potent tool to address issues of importance to developing countries such as food and drinking water supply, and pollution and disease control (Kryl, 2001; Johnson, 2002; Daar *et al*., 2002). Accordingly, the CBS vision emphasized that Canada should position itself as a responsible world leader by undertaking international cooperative activities. Specifically, the strategy stipulates that:

> Canada should review its international development assistance policies and programs in relation to the CBS vision, particularly with regard to the developing countries to which Canada exports or is likely to export, and work with Canadian and local industry and other stakeholders to build indigenous capacity in these countries to capture the benefits of biotechnology and assess and manage the risks. This would help lesser developed countries to enhance their quality of life, ensure environmental sustainability and improve their risk management systems (CBS, 1998).

This position was reinforced in the 2004 Government of Canada Blueprint for Biotechnology which recognized the huge potential for the knowledge harnessed from biotechnology to tackle issues of importance to developing countries. To achieve Canada's desired international impact and recognition as a responsible world leader, the Blueprint recommended the launch of a national initiative for international development. This initiative aims to facilitate the coordination of strategic research and technology development networks between research centers in Canada and developing countries (CBS, 2004).

In a first step towards establishing the initiative, the Federal Biotechnology Deputy Minister Coordinating Committee (BDMCC) has approved funding for a background analysis of the key areas where biotechnology programming would be of strategic interest in creating benefits to address critical issues in developing countries and to assess the risks associated with biotechnology. More than ten governmental organizations are collaborating on this project, including the Canadian Biotechnology Secretariat (CBSec), Health Canada (HC), the National Research Council Canada (NRC), the Canadian Food Inspection Agency (CFIA), Foreign Affairs Canada (FAC), and International Trade Canada (ITC), the International Development Research Center (IDRC), Agriculture and Agri-Food Canada (AAFC), Environment Canada (EC), Industry Canada (IC), and the Department of Justice Canada. The CBSec, which coordinates the management and operations of the CBS, is conducting a study to identify developing countries' policy needs in biotechnology and ongoing Canadian

initiatives that aim to address these needs; HC is analyzing stewardship frameworks in developing countries to examine how they address economic, ethical, legal, social and regulatory aspects of biotechnology, to identify areas where there is a lack of activity, and to determine how Canadian expertise in stewardship could help address these gaps; the NRC is leading a project focusing on Canadian capacities and competencies in biotechnology R&D.

The NRC's project has two objectives. Firstly, it included a scan of Canadian strengths in biotechnology research and development (R&D) and in the innovation system supporting biotechnology activities (R&D capacities, research networks, funding mechanisms, access to capital, etc.) to identify key areas where Canada could show leadership internationally and provide help to developing countries. This component of the project has already been completed by Science-Metrix, and the results are presented in a report entitled "Scan of Canadian Strengths in Biotechnology" (Campbell *et al.*, 2005). The second part of the project, which is the subject of the current study, focuses on ongoing Canadian initiatives aimed at providing development assistance through biotechnology.

Because biotechnology is directly applicable to all fields in the life sciences such as agriculture, health, and the environment, Canadian domestic efforts to help developing countries using biotechnology cut across departmental lines, institutions, political jurisdictions, and public constituencies in Canada. There are no "horizontal" mechanisms in place to connect these efforts and leverage them through an effective national synergy. In a bid to correct this situation, NRC gave Science-Metrix the mandate to:

- identify Canadian initiatives addressing developing country issues using biotechnology;
- identify complementary competencies within Canadian organizations and opportunities for R&D collaborations;
- make recommendations to improve the current models of R&D collaboration to connect and increase the synergy of Canadian initiatives in biotechnology and international development.

This report starts by providing an inventory of Canadian organizations involved in biotechnology for foreign aid, and an inventory of developing countries that have benefited from this assistance (see Section 2). This section also provides an overview of Canadian initiatives in biotechnology and international development led by those organizations. Section 3, based on the complementarities among their activities, explores potential avenues for R&D collaborations amongst Canadian organizations to maximize the usefulness of help provided to developing countries. Finally, Section 4 identifies mechanisms used to connect and increase the synergy of Canadian initiatives, and makes recommendations to improve the current model of collaboration for international development in biotechnology.

2 Biotechnology and International Development

In order to identify significant Canadian biotechnology initiatives on issues of importance to developing countries, an environmental scan, a bibliometric analysis, and a series of telephone interviews were conducted. The environmental scan consisted of searching the internet using the search engine Google and combinations of keywords related to biotechnology, and international development. The bibliometric analysis was performed to identify publications co-authored by Canadian researchers and foreign scientists from developing countries. The publications dataset previously constructed using SCI Expanded (Thomson-ISI) to identify Canadian strengths in biotechnology was used for this purpose (Campbell *et al.*, 2005). The dataset that was based on Medline (US National Library of Medicine) was not suitable for this analysis since it contains only the first author's address. Canadian papers written in collaboration with developing countries were identified by searching in the address field for countries on the Canadian International Development Agency's (CIDA) list of countries eligible for Canadian Official Development Assistance. These papers were then scanned in order to retain those addressing developing countries' issues. Telephone interviews were conducted with key informants from a number of government departments, universities, non-governmental organizations (NGOs), and companies.

Section 2.1 describes the key Canadian organizations that conduct activities related to biotechnology and international development, and the developing countries involved. Section 2.2 describes some of the most important past, ongoing and planned Canadian initiatives addressing developing country issues based on the modern tools of biotechnology.

2.1 Canadian Organizations and Developing Countries Involved

Canada's overseas development agencies, IDRC and CIDA, are instrumental in fostering international aid through biotechnology and have supported dozens of such projects in the past 15 years. IDRC was established by the Government of Canada to tackle developing country problems through R&D activities. IDRC's status as a crown corporation allows it to support projects that the Government of Canada would like to promote, although is not in a position to do so directly for political reasons. CIDA is Canada's official agency for providing assistance to developing countries to help them develop sustainable activities, to increase welfare and equity, and to reduce poverty. Overall, at least 50 Canadian institutions, mainly universities and government departments, have carried out biotechnology projects to address issues of importance for at least 40 different developing countries. Some of these activities were conducted independently, and some in partnership with international organizations and/or foreign countries.

2.1.1 Universities

Among the universities most active in biotechnology and international development are the University of Ottawa, the University of Toronto, McGill University, the University Health

Network, the University of Guelph, the University of Waterloo, the University of Saskatchewan, the University of Alberta, the University of British Columbia, the Institut National de la Recherche Scientifique (INRS), the University of Manitoba, the Université de Montréal, Dalhousie University, the Université Laval, Simon Fraser University, and McMaster University.

2.1.2 Government

Federal departments other than CIDA and IDRC, who have provided or are currently providing assistance to developing countries through biotechnology include AAFC, the NRC, HC, EC, Natural Resources Canada (NRCan), Fisheries and Oceans Canada (DFO), and the Canada-ASEAN Centre in Biotechnology in Singapore.

Some federal and independent funding agencies support biotechnology projects aimed at helping developing countries. These include: Genome Canada (GC), the Canadian Foundation for Innovation (CFI), and the Canadian Institutes of Health Research (CIHR). Although the Natural Sciences and Engineering Research Council of Canada (NSERC) does not have a funding program specifically targeting developing countries, the agency has provided financial support to few projects addressing developing countries issues through biotechnology. At the provincial level, the Ontario R&D Challenge Fund is providing support to the Canadian Program on Genomics and Global Health (see Section 2.2.5).

With support from CIHR, NSERC, the Social Sciences and Humanities Research Council of Canada (SSHRC) and IC, the Networks of Centers of Excellence (NCE) link together outstanding scientists, managers and stakeholders from universities, industry, government and not-for-profit organizations in fields where Canada has an edge within the international community. One such is the Canadian Network for Vaccines and Immunotherapeutics (CANVAC), which involves Canadian scientists in biotechnology-based development programs aimed at developing drugs, vaccines, and diagnostics tools for the developing world.

2.1.3 NGOs

NGOs also play a key role in promoting foreign aid based on biotechnology. They include the World Fisheries Trust (WFT), the Coalition for Global Health Research Canada (CGHRC), the Inter-American Institute for Cooperation on Agriculture (IICA-Canada), the action group on Erosion, Technology and Concentration (ETC group), BIOTECanada, the Canadian Drug Manufacturers Association (CDMA) and Canada's Research-Based Pharmaceutical Companies (Rx&D).

2.1.4 Firms

BIOTECanada and Rx&D represent biotechnology companies across Canada, including Aventis, GlaxoSmithKline, Merck & Co., Abbott, Bristol-Myers Squibb, Boehringer Ingelheim, Roche, Pfizer, Novartis, Eli Lilly, Bayer, Prometic Life Sciences, and CANGENE, which have used or are developing biotechnology products to help developing countries.

The most significant biotechnology firms involved in agriculture and aquaculture include Philom Bios Inc., POS Corporation, Ag-West Biotech Inc., BioAtlantech, Ontario Agri-Food Technologies, AgrEvo Canada, Monsanto Canada, Advanta Seeds Canada, and Seastar Biotech. AGBIOS is a biotechnology company that gives assistance in the form of advice to developing countries regarding ethical, regulatory, social and legal issues. There are probably many other Canadian biotechnology companies who are involved in giving aid to developing countries, but their identification would require interviewing all of the numerous Canadian biotechnology firms, an exercise whose scale is outside the scope of the current project.

2.1.5 Hospitals

Hospitals and affiliated research institutes active in the area of biotechnology and international development include Ottawa Hospital, Sunnybrook and Women's College Health Sciences Centre, the Centre Hospitalier Universitaire de Québec (CHUQ), the Institut de Recherches Cliniques de Montréal (IRCM), and the Hospital for Sick Children.

2.1.6 International Organizations

Canada also provides development assistance based on biotechnology, in partnership with international organizations such as the Consultative Group on International Agricultural Research (CGIAR), the United Nations Food and Agriculture Organization (FAO), the World Health Organization (WHO), the Global Crop Diversity Trust, the International Service for the Acquisition of Afri-Biotech Applications (ISAAA), and the Global Alliance for Vaccines and Immunization (GAVI). Other important organizations involved in international aid and biotechnology include the International Centre for Genetic Engineering and Biotechnology (ICGEB), the International Service for National Agricultural Research's Biotechnology Service (IBS), the World Bank, the Rockefeller Foundation, the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), the United Nations Industrial Development Organization (UNIDO), the United Nations Institute for Training and Research (UNITAR), Oxfam, and the Global Environment Facility (GEF).

2.1.7 Developing Countries

Canada collaborates with a number of developing countries to help them to build a national capacity in biotechnology. These countries include: Algeria, Argentina, Benin, Brazil, Burkina Faso, Cameroon, Chile, China, Colombia, Croatia, Cuba, Czech Republic, Egypt, Hungary, India, Indonesia, Jamaica, Kenya, Mexico, Morocco, Nigeria, Pakistan, Panama, Peru, Poland, Romania, Russia, Slovakia, Slovenia, South Africa, Sri Lanka, Thailand, the Philippines, Tunisia, Ukraine, Vietnam, and Zimbabwe.

2.2 Canadian Initiatives Applying Biotechnology to Developing Countries Issues

Currently, 2 billion people have no secured access to food, and 800 million people in the developing world are undernourished. They subsist on less than 1,800 calories per day, 400 calories less than the recommended daily adult requirement, despite the fact that worldwide food production is sufficient to support a consumption rate of 2,700 calories per day per capita (DaSilva *et al*., 2002; Johnson, 2002). However, most of this production occurs in developed countries where there are favourable soil and climatic conditions, and modern agricultural tools and methods are available.

Since 2.8 billion people in developing countries, approximately 50% of the developing world population, have to live on less than US$2 a day, most cannot afford food other than what is produced by themselves, which all too often is not enough to meet their needs. In addition, 1.1 billion people have no access to safe drinking water and 2.4 billion people have no access to basic sanitation (UNFPA, 2004). These conditions seriously compromise the health of developing country populations, which in turn limits the capacity of these individuals to work and to earn money, producing a vicious cycle. Each year, 11 million children in developing countries under the age of five years die from preventable causes. In Sub-Saharan Africa, the infant and under five mortality rates are above 100 and 170 per 1000 live births respectively, compared to Canada where the respective rates are 5 and 6 per 1000 live births (WHO, 2004; Doelle, 2001).

Developing countries, in their attempts to alleviate starvation and illness, are facing the complex challenge of breaking this vicious cycle of poverty. In order to make steps towards overcoming this challenge, it is broadly accepted that science-based solutions will be of paramount importance, implying a proactive role of developed nations to build the capacity of developing countries in those key areas of science that can make a difference. The UNDP, in its 2001 annual report, recognized that biotechnology is bound to play a central role in securing food supplies for an ever-increasing population, a first and important step in improving health and reducing poverty in developing countries (UNDP, 2001).

Agricultural biotechnology, by increasing the yield and nutritional value of crops in tropical and arid zones, where most developing countries are located, should help ensure appropriate calorific and micronutrient intake. This in its turn will help to improve the health of developing countries' populations and increase the incomes of small farmers (Johnson, 2002). In addition to agricultural biotechnology, nine other biotechnology applications offer a potential to improve health in developing countries.

These are: molecular technologies adapted to the reality of developing countries, to rapidly diagnose infectious disease without reliance on various infrastructures; recombinant technologies to produce cheap vaccines against infectious diseases; technologies for more efficient and secure vaccine (alternatives to syringes) and drug delivery systems; environmental biotechnologies for sanitation (anaerobic or biogas digesters), drinking water treatment, and bioremediation of soil, water and air; genomic studies of pathogens from developing countries to identify new antimicrobials; female-controlled protection against sexually transmitted diseases, both with and without contraceptive effects; bioinformatics to identify new drug targets and investigate host-pathogen interactions; recombinant

technology for the production of affordable therapeutic products; and combinatorial chemistry for drug discovery (Daar *et al.*, 2002; DaSilva *et al.* 2002). Thus, biotechnology appears to hold great promise for solving many issues critical for developing countries such as secure food and drinking water supply, disease control, pollution control, environmental conservation, and energy production (from sanitation and crop bioprocesses (biogas)), all of which directly or indirectly impact on health.

Currently, 90% of biotechnology R&D occurs in the developed world, and 90% of health research focuses on the health problems of 10% of the world's population (the 10/90 gap) (Doelle, 2001; Daar *et al.*, 2002). Hence, greater commitment is required from the developed countries to ensure that the benefits for health, the environment, agriculture, and industry that can be harnessed from the biotechnology revolution are accessible to all citizens of the world, thereby reducing the global divide between the north and the south. Canadian initiatives being undertaken to provide development assistance using biotechnology address issues in several sectors of activity: health, agriculture and aquaculture, environment, capacity building, and the innovation system. The following describes some examples of Canadian initiatives in these areas.

2.2.1 Health

Infectious diseases are the leading cause of mortality and morbidity in newborns and children in developing countries. The most pernicious of these are pneumonia, caused by bacteria such as *Haemophilus influenzae type b*, tuberculosis, diarrhoea, malaria, measles and HIV/AIDS, which together account for 90% of the deaths from infectious diseases (WHO, 1999).

In Canada, biotechnology initiatives related to viral diseases are mainly targeted at HIV/AIDS as a result of the severity of the pandemic in the developing world. Two-thirds of the world's population infected by HIV/AIDS live in Africa, which is home to only 11% of the world's total population (WHO, 2004). Other viral diseases that are being studied include hepatitis B and C. Canadian researchers are also working on the control of infectious diseases caused by bacteria: tuberculosis, pneumonia, meningitis and cholera; and parasites: malaria, leishmaniasis, amoebiasis and fascioliasis. This work is aimed at developing vaccines, drugs, and rapid and simple diagnostic tools. Below are some examples of these initiatives:

- In the fight against AIDS in the developing world, HC is collaborating with the International AIDS Vaccine Initiative (IAVI) and the Joint United Nations Programme on HIV/AIDS (UNAIDS). It is responsible for conducting R&D to develop vaccines against HIV, in its world class National Microbiology Laboratory located in Winnipeg, and to share Canada's knowledge and expertise related to biotechnology, research practices, HIV laboratory science and surveillance. These initiatives are supported by CIDA and have involved collaborations with developing countries in Africa, Europe and Asia (HC, 1999; Keough, 2003).

- HC's National Microbiology Laboratory is part of the CANVAC, a Canadian NCE, which, in partnership with CANGENE, a Canadian firm, carries out R&D to develop vaccines for Ebola Hemorrhagic Fever and Nipah Virus Infection (Keough, 2003).
- Dr. Michel Tremblay of Université Laval holds the Canadian Research Chair in Human Immunoretrovirology. He is conducting innovative research directed towards identifying the molecular "switches" that activate HIV by studying its subtle interactions with *Leishmania*, a widespread human parasite in the developing world.
- HC, together with the WHO, UNICEF, the World Bank, various foundations, NGOs, private firms and governments, is a member of GAVI. GAVI's mission is to broaden and accelerate the distribution spectrum of vaccines, especially new ones, among the 75 poorest countries of the world. The objective, part of the United Nations' Millennium Development Goals, is to reduce by two-thirds the mortality rate of children under the age of five, between 1990 and 2015 (Keough, 2003). On February 23 2005, The Canadian government pledged a CDN$160 million grant to GAVI, the largest contribution made by any government to the organization (GAVI, 2005).
- Dr. Eleonora Altman from the NRC's Institute for Biological Sciences (NRC-IBS) has received financial support from the Global Health Research Initiative (GHRI) (a first for Canada) to develop a series of vaccines against the childhood diseases afflicting developing countries (Hackett, 2004).
- The Michael Smith Genome Sciences Centre in British Columbia responded quickly to the SARS (Sudden Acute Respiratory Syndrome) epidemic, sequencing the coronavirus within 6 months of the first case of SARS being reported in China in November 2003 (Marra *et al.*, 2003). Researchers at Vancouver's SARS Accelerated Vaccine Initiative (SAVI) developed four prospective vaccines for SARS, two of which demonstrated potential in animal models 18 months after initiation of the project, towards the end of the sequencing initiative (Finlay *et al.*, 2004).
- Currently, NRC has two proposals pending under the Bill and Melinda Gates Grand Challenge in Global Health Initiative. The first, by NRC-IBS, aims to develop, in collaboration with the tuberculosis Research Center in India, a single dose vaccine for tuberculosis. The second, by NRC's Industrial Materials Institute (NRC-IMI), seeks to develop rapid and affordable molecular diagnostic tests for infectious diseases in the developing world (Hackett, 2004).
- Dr. René Roy (formerly at the University of Ottawa), holder of the Canada Research Chair in Therapeutic Chemistry at the Université du Québec à Montréal (UQAM) and Dr. Vincente Verez Bencomo from Universidad de La Habana in Cuba, with support from the WHO, have co-developed a new vaccine against *Haemophilus influenzae type b* (Hib). This bacteria produces severe outbreaks of pneumonia and meningitis throughout the world, leading to an annual death of between 400,000 to 700,000 children aged between 4 to 18 months. Most of these deaths occur in developing countries, which cannot afford to buy the existing anti-Hib vaccines, a problem that the new, low cost production vaccine should resolve. This low cost production was made possible by eliminating the need for large scale bacterial cultures in the production process; because the vaccine is 100% synthetic it has no components originating from the bacteria, which further reduces its side-effects and associated risks. The patent is co-owned by the University of Ottawa and Universidad de La Habana, who have an equal

share of the intellectual property. The vaccine is to be produced by a Cuban company, Heber, which will distribute the product in the international marketplace. In cases of humanitarian aid, the universities will forgo their royalty payments (Gauvreau, 2003).

Recently, CIDA funded some collaborative research between Dr. Roy and groups of West African researchers (from Mali, Togo, and Guinea) to list the medicinal plants used to treat diseases such as malaria, pneumonia and AIDS.

- Dr. Kevin C. Kain from the University Health Network in Toronto, who is Director of the Centre for Travel and Tropical Medicine, holds the Canada Research Chair in Molecular Parasitology. He is recognized as an outstanding researcher in the development of diagnostics and therapeutics for malaria, and has conducted multiple R&D projects in collaboration with scientists from developing countries such as Peru, Thailand and Vietnam.
- Dr. Terry Spithill has built up great knowledge of the molecular biology and protein biochemistry of parasites in the course of his career at Monash University in Australia. In 2001, he was appointed Director of the Institute of Parasitology at McGill University and now holds a Canada Research Chair in Immunoparasitology. His research focuses on the study of host-parasite interactions directed towards the development of vaccines and/or drugs for the treatment of malaria and liver fluke. He is actively collaborating with Indonesia, Vietnam and Thailand.
- Dr. Marc Ouellette is Professor of Microbiology at the Centre de Recherche en Infectiologie of the Université Laval. He conducts works on multidrug resistance in malaria, on resistance mechanisms in the protozoan parasites, such as Leishmania, mainly affecting people in developing countries, and he is promoting exchanges with researchers from the developing world. Dr. Ouellette holds the Canada Research Chair in Antimicrobial Resistance and is also a member of CANVAC (CIHR-III, 2004).
- Dr. Terry Pearson is a faculty member of the Department of Biochemistry and Microbiology at the University of Victoria (UVic). His research focuses on African sleeping sickness. He is characterizing the surface molecules on the parasites that control its interaction with its vector, the tsetse fly. He has developed diagnostic tests for African morning sickness, and is currently conducting work at UVic and in four African countries (UVic, 2003).
- One of the main health problems in developing countries concerns access to essential medicines, such as penicillin, which have the potential to cure a wide variety of diseases afflicting these countries. According to a recent study published in *Health Affairs*, 98% of the 319 essential medicines on the WHO list lack intellectual property protection in 65 low and middle income countries, which are home to 4 billion people. This is likely due to the absence in developing countries of competitors to the "bigpharmas" of the industrialized world who therefore do not see the need to protect their assets in these countries (Attaran, 2004). Therefore, if biopharmaceutical companies were to be established in developing countries, they could provide generic medicines to their populations at a fraction of the price that the "bigpharmas" demand.

  Currently, NRC's Biotechnology Research Institute (NRC-BRI) in partnership with Prometic Life Sciences, an international biopharmaceutical company based in Montreal, the Institut Pasteur de Tunis and the Tunisian state corporation, the central pharmacy of Tunisia, is launching a biopharmaceutical company in Tunisia. The mission of the

firm will be to produce and distribute affordable medicines to treat hepatitis and cancer in Africa, the Middle East and parts of Europe. This project will make Tunisia a cornerstone of the biotechnology industry in this region, which is likely to attract foreign investors and eventually grow a biotechnology cluster. NRC-BRI and Prometic Life Sciences will develop and scale up therapeutic protein production (Hackett, 2004).

- NRC-BRI, together with the Lyceum Research Company in New Brunswick, is collaborating with traditional healers in Ghana and Cameroon to turn traditional medicines into well characterized natural health products for local use and for the international market (Hackett, 2004).
- With financial support from CIHR, Dr. Mira Johri, Dr. Thomas Pogge and Dr. James J. Orbinski from the Université de Montréal are leading a project aimed at defining Canadian and global responsibilities regarding access to essential medicines in developing countries (CIHR, 2004a).
- The CDMA and Oxfam are supporting the government of Canada proactive approach to providing developing countries with access to essential medicines (CDMA, 2003; Oxfam, 2003).
- Numerous members of Canada's Research-Based Pharmaceutical Companies (Rx&D) are engaged in international outreach programs to help developing countries combat some of their most threatening diseases.

  Abbott is providing its rapid diagnostic kit for HIV/AIDS, Determine, and its antiretroviral medicines Kaletra and Norvir at reduced prices to 68 developing countries.

  Pfizer is providing its antifungal drug Diflucan, free of charge, to treat HIV/AIDS related fungal infections in Least Developed Countries (LDCs) and Sub-Saharan Africa.

  Bristol Myers-Squibb has established a program to help women and children suffering from AIDS in Sub-Saharan Africa. The company is also providing its anti-AIDS cocktail at a 76% discount in Brazil.

  GlaxoSmithKline has developed an international program aiming at providing HIV/AIDS education, prevention, psychosocial care, and support. The program aims to abolish the stigma and discrimination that is attached to the disease, and to provide GlaxoSmithKline's Combivir medicine at a reduced price. In addition, GlaxoSmithKline has established the African Malaria Partnership to combat malaria, in seven African countries. The company makes its antimalarial drugs available at no profit prices.

  Novartis distributes unlimited quantities of its Coartem antimalarial drug at no profit to developing countries, through the WHO.

  All these pharmaceutical companies are also engaged in various R&D projects aimed at developing new vaccines and drugs for some of the most life-threatening diseases afflicting the developing world. These diseases include HIV/AIDS, malaria, tuberculosis, leprosy, river blindness, blinding trachoma, and sleeping sickness. [1]

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[1] See Rx&D's website for more details: http://www.canadapharma.org/Industry_Publications/Fact_Sheets/, February 2005.

2.2.2 Agriculture & Aquaculture

- Through the CGIAR Canada contributes to alleviating poverty, enhancing human well-being, and preserving the environment in developing countries, using the tools provided by science and technology (S&T). Canada is a key founder member of CGIAR, being one the top five investors and providing important intellectual resources, research directions, and policy advice. CIDA and the IDRC are the principal organizations supporting CGIAR. AAFC, McGill University, the University of Guelph, the University of Ottawa, the University of Western Ontario, the University of Saskatchewan, the University of Manitoba, and the Université du Québec are also partners. Worldwide, CGIAR has 15 international centers, each involved in exchanges between scientists, stakeholders, policy makers, and members of Civil Society Organizations (CSOs), both within and outside the developing world. Canada was involved in establishing two centers: the World Agroforestry Centre in Kenya and the International Center for Agricultural Research in Dry Areas (ICARDA) in Syria. Canadian researchers also play key roles at the International Center for Tropical Agriculture (CIAT) in Colombia, at the International Potato Center (CIP) in Peru, at the International Institute of Tropical Research (IITA) in Nigeria, and at the International Livestock Research Institute (ILRI).

  CGIAR's priorities are to strengthen developing countries' national agricultural research systems; develop and promote the use of sustainable agricultural practices and natural resource management procedures to improve crop yields, and preserve the environment and biodiversity; and to provide policy advice. Increasing the nutritional value and productivity of subsistence crops in the developing world is the key to improving health, by securing food supply and access to essential nutrients, and increasing incomes for small farmers, who are often women. Biotechnology, by allowing the development of resistant crops (e.g. tolerance to pests, draught, salt, etc.) with enhanced nutritional value through genetic engineering, has contributed towards achieving this goal. Below are a few examples of Canadian-CGIAR biotechnology initiatives that have had significant development impacts.

  Cassava forms part of the staple diet in many developing countries, and CIAT has established the Cassava Biotechnology Network (CBN) to find technologic solutions to improving cassava yields to help to alleviate hunger and poverty. To ensure the active participation of small farmers in the development and application of the technology, IDRC provided two years of assistance starting in 2000, to establish the CBN within regional communities in Latin America and the Caribbean (IDRC, 2000). In addition, Dr. Kutty Kartha, Director General of NRC's Plant Biotechnology Institute (NRC-PBI), has developed a technique to produce mosaic disease-free cassava plants, which is improving yield by as much as 65-95%, and a cryopreservation technique for the long-term conservation of these disease-free plants. The technologies were transferred to CIAT (Hackett, 2004).

  CIAT and IITA have conducted research on improving yields and the nutritional values of beans, which are the primary source of proteins for millions of people worldwide (CGIAR, 2003). Researchers from the University of Saskatchewan studied genetic diversity of 90 cowpea (bean) breeding lines developed by IITA in order to orient future breeding strategies (Lee *et al.*, 2001).

Canada has also been very active in animal science biotechnology for foreign aid with some Canadian universities (University of Victoria and University of Guelph) interacting with CGIAR's International Livestock Research Institute in Kenya (Nthale *et al.*, 1995; Stella *et al.*, 2002).

- AAFC collaborates on many projects with CGIAR and has signed memorandums of understanding with two of its centers: the CIP and the International Center for the Improvement of Maize and Wheat (CIMMYT). AAFC has collaborated with CIAT to develop a molecular method for the detection and quantification of *Verticillium dahliae*, a fungal pathogen of the potato (Mahuku and Platt, 2002). AAFC, with support from IDRC, collaborated with IITA to investigate the characteristics and distribution of viruses and their strains for four major African crops: cassava, cowpea, maize, and pepper. AAFC produced monoclonal antibodies essential for the development of detection and diagnostic tests for viruses. These are being used by IITA in its investigations (IDRC, 1993a). Dr. Campbell Davidson, the International Genetic Advisor at AAFC, is a board member of the International Treaty on Plant Genetic Resources for Food and Agriculture of the FAO.
- Outside its partnership with CGIAR, AAFC conducts biotechnology projects aimed at improving agricultural practices in the developing world. At the AAFC's Summerland Research Center, a collaboration project with China in 2004 trained young Chinese scientist to determine the molecular basis for 1-methylcyclopropene (1-MCP) effects on fruit quality enhancement (Dr. Johanne Boisvert, AAFC–International Affairs, Personal Communication). Examples of earlier work include collaboration with Slovenia to study potato viruses (Weilguny and Singh, 1998), and with Argentina to genetically improve wheat (Khan *et al.*, 2000). AAFC has also conducted biotechnology projects targeting animal health. Working with Argentina, Canadian researchers at AAFC developed monoclonal antibodies to diagnose bovine brucellosis (Uzal *et al.*, 1996) and *Campylobacter fetus* causing vibriosis of cattle (Brooks *et al.*, 2002). AAFC also developed methods for diagnosing swine fever virus in Brazil (Clavijo *et al.*, 2001) and *Campylobacter* in poultry in the Philippines (Magistrado *et al.*, 2001).
- AAFC has several ongoing collaborative biotechnology projects with developing countries. Scientists at AAFC's Eastern Cereal and Oilseed Research Center (ECORC) in collaboration with China's Soybean Research Institute, an affiliate of Nanjing Agricultural University, are developing a novel method of soybean transformation and are localizing the cellular compartment in soybean seed that optimizes storage of foreign proteins in order to improve soybean protein quality. ECORC, in partnership with Zhejiang University in China, is studying the phylogenomics of the genus *Trichoderma*, a group of cellulolytic fungi with potential application as biological control agents. ECORC is conducting similar studies with Columbia on *Trichoderma* species from neotropical soils, with Hungary to determine metabolic indicators of chitinase activity in *Trichoderma*, and with Russia to develop a *Trichoderma*-based biocontrol agent for conifer seedling diseases (Dr. Johanne Boisvert, AAFC - International Affairs, Personal Communication).
- Dr. Illimar Altosaar is a professor in the department of Biochemistry, Microbiology and Immunology at the University of Ottawa. He has been extensively involved in partnerships with China to develop BT rice (rice transformed with insecticidal genes

from *Bacillus thuringiensis*), which promises to eradicate yield losses caused by insect pests and to reduce the use of pesticides.

- In 1999, IDRC funded a four year project to improve biotransformation of Morocco's olive production, the country's principal fruit crop. Traditionally, olive oil was produced in units with poor crushing capacity resulting in small, poor quality oil production and a large volume of dregs. These untreated dregs were a serious threat to the environment. The IDRC project aimed at developing technologies and methods to increase yield and quality of the olive oil produced, and to transform the dregs into protein enriched feed for livestock and added-value secondary metabolites for industrial applications (IDRC, 1999).
- In 1997, CIDA's Canada–Brazil Technology Transfer Fund, together with the World Bank, supported a five year project in conservation genetics of migratory fish species in four major drainage systems in Brazil. The partnership involved the World Fisheries Trust (WFT), an environmental institute in British Columbia, Seastar Biotech, a Canadian firm in British Columbia, DFO, and the Federal Universities of Minas Gerais and Santa Catarina in Brazil. The project's goal was to promote the conservation of Brazilian wild fish genetic resources, thereby ensuring sustainable fisheries.

  To achieve its aim, the project trained 77 Brazilian biologists in genetic conservation technologies, including gamete cryopreservation, DNA fingerprinting, larviculture and radiotagging; effective protocols for the cryopreservation and fertilization of 12 Brazilian fish species were developed for restocking programs for small-scale commercial fishing; five Brazilian gene banks were created as part of the Brazilian Fish Genetic Resources Network fostering the exchange of genetic information between industry, universities and government; and educational activities were conducted to increase professional and public awareness of the importance of the preservation of wild fish biodiversity for economically sustainable fisheries (CIDA, 2001).

  This successful initiative led the WFT to launch the "Brazil Inland Fisheries: Sustainable Livelihoods and Conservation" project in 2003 with support from CIDA. However, this new project puts less emphasis on biotechnology than its predecessor. The WFT leads numerous projects related to conservation genetics of aquatic resources. [2]

2.2.3 Environment

- Collaborations on environmental biotechnology with developing countries have included bioremediation of soil, air and water, and biotreatment of wastes using bioreactors, biofilters and biosorption columns. In both these cases, the main objective was to destroy toxic coumpounds and pathogens and to provide safe drinking water, for example, to developing countries' populations. In a Global Health Initiative workshop organized by the University of Toronto Joint Center for Bioethics (UofT-JCB), how the sequencing of arsenic-metabolizing bacteria could help solve contamination of groundwater in Bangladesh was discussed. Environment Canada, in collaboration with Indonesia, analyzed the factors affecting the efficacy of bioremediation reactors for the elimination of aromatic hydrocarbon particles (Purwaningsih *et al.*, 2002). Another

[2] See WFT's website for more details: http://www.worldfish.org/projlist.htm, January 2005.

important aspect of collaborative research in environmental biotechnology is biomonitoring as a pollution surveillance tool. For example, the Université du Québec à Rimouski, in collaboration with the Universite de Sfax in Tunisia, conducted a study aiming to establish the potential of the clam *Ruditapes decussatus* as a biomarker for metal exposure along the south-eastern coast of Tunisia (Hamza-Chaffai *et al.*, 2000). These are just a few examples of collaborations between diverse institutions from Canada and developing countries in environmental biotechnology: we do not claim to provide an extensive list of past projects.

2.2.4 Capacity Building

- In 2004, CIHR, through the CIHR/Rx&D Research Program, and Sanofi Aventis launched the CANADA-HOPE Scholarship Program devoted to improving the health R&D system in developing countries. CIHR and Sanofi Aventis each provided $1.7 million to establish the program based on the successful HOPE clinical trial led by Dr. Salim Yusuf and other Canadian researchers. The short term goal of the initiative is to enable talented student from Low and Middle Income Countries (LMIC, identified by CIDA and the United Nations (UN)) to train in Canada before returning to their home countries. In the long run, the initiative is expected to further expand international collaborations between prominent Canadian researchers and promising scientists and clinicians from LMIC providing them with access to expertise, knowledge and equipment from some of the best laboratories and training environments in Canada. The initial target of the program will be sub-continental South Asia and will gradually be extended to other regions of the world (CIHR, 2004b). CIHR has a diversified suite of programs designed to foster international cooperation.[3]
- In 2004, CIDA provided $30 million as part of the $500 million Canada Fund for Africa (CFA) for the establishment of a biosciences facility in Nairobi, Kenya. The facility will be central to the African bioscience NCE established by the New Partnership for Africa's Development (NEPAD) (R$, 2004).
- The CFI invested CDN$3.8 million in a Canada-Kenya research project on HIV/AIDS. The collaboration involves teams working under the leadership of Dr. Plummer, at the University of Manitoba, the University of British Columbia, the University of Toronto, the Université de Montréal, the Université Laval, and the University of Nairobi in Kenya. Dr. Plummer holds the Canada Research Chair in Resistance and Susceptibility to Infections and is a member of the CANVAC which is part of the Canadian NCE. The CFI fund will finance the expansion of the Centre for Infectious Diseases Research at the University of Nairobi. In particular, laboratories for retrovirology (e.g. HIV/AIDS), functional immunology and emerging pathogens, together with a level 3 biosafety laboratory to study hemorrhagic fever viruses (e.g. Ebola, Marburg, Congo-Crimean, Dengue), will be constructed and furnished with state-of-the-art equipment, enhancing the research capacities of both Kenyan and Canadian scientists. Scientists will have access to imaging, flow cytometry, molecular biology, serology, genomics, and bioinformatics facilities (CFI, 2004).

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[3] See CIHR's website for more details: http://www.cihr-irsc.gc.ca/e/23403.html, February 2005.

- Thailand gives high priority to biotechnology as a means of fostering economic growth, and is investing substantially in R&D. As a developing country with a growing biotechnology sector, Thailand could greatly benefit from Canadian expertise to increase its R&D capacity, and Canadian companies could take advantage of interesting opportunities in this emerging market, especially in the agri-food and the pharmaceutical/health care sectors. International cooperation activities in biotechnology are underway.

  Guelph University, Waterloo University, the University of Saskatchewan, McMaster University and Simon Fraser University are offering assistance to Thai universities for the establishment of graduate programs in diverse areas involving biotechnology. In partnership with the Canada-ASEAN Centre in Biotechnology, Thailand benefits from researcher and staff exchanges, and consultancy and training programs. This Canadian center was established in Singapore in 1989 in collaboration with the Association of Southeast Asian Nations (ASEAN) to provide development assistance. Thailand's National Science and Technology Development Agency (NSTDA) and the NRC signed an umbrella agreement to collaborate on biotechnology R&D activities (Agri-Food Trade Service, 2002).
- CIDA, by supporting the Canada-China 3x3 University Project (1998-2003), has helped China to achieve its goal in relation to biotechnology, an objective that was identified as a national priority by the Chinese State Science and Technology Commission under the "863 Plan in High Technology Development". The biotechnology project linked the University of British Columbia, the University of Toronto, McGill University and the Université de Montréal with Peking University, Nankai University and Tsinghua University. The primary role of the Canadian biotechnology working group was to train and upgrade the skilled labor force in biotechnology. The group also assessed the capacity of established Chinese biotechnology agencies to meet their goals, contributed to the purchase of essential laboratory equipment, and engaged in technology transfer activities with Chinese institutions (CIDA, 2003).
- For most developing countries, the modern tools of biotechnology are out of reach. Therefore, from 1991 to 1994 IDRC supported the International Service for the Acquisition of Agro-Biotech Applications (ISAAA), a not-for-profit international network dedicated to bringing biotechnology applications to those in greatest need in the developing world. The network is still active today with three centers located in North America, Africa and Asia (IDRC, 1991).
- CamBioTec was an international network involving a coordination unit in Mexico and five national focal points in Argentina, Canada, Chile, Colombia, and Mexico. Organizations in Brazil and Cuba were also involved, together with international biotechnology networks such as the IICA-Canada, the Technical Co-operation Network on Plant Biotechnology in Latin America and the Caribbean (RedBio-FAO), the International Service for National Agricultural Research's Biotechnology Service (IBS), and the International Life Sciences Institute (ILSI). The network was established in 1995 by the IDRC. Central to CamBioTec's activities was the vision that biotechnology could and should contribute to agriculture in a manner that would be sustainable for the environment. Accordingly, its goal was to introduce biotechnology applications in the agri-food and environmental management sectors of Latin America, by promoting an

environment conducive to the development of the industry, and by raising public awareness about the benefits and potential risks of the technology.

To achieve its goal, the network conducted activities to foster technology transfer, partnerships and strategic alliances between Canadian biotechnology firms and companies from Latin America; carried out training activities in Latin American countries; and developed, negotiated and conducted projects addressing key issues for developing countries in Latin America. The focal point of the network in Canada, until 1999, was BIOTECanada, an association representing individual biotechnology industry and service firms, regional associations and networks in Canada. Unfortunately, the participation of BIOTECanada was terminated due to its diverging views regarding CamBioTec's mission. However, CamBioTec continued to be active in connecting Canadian and Latin American organizations interested in partnering. Areas targeted for partnership included: genetic improvement of organisms, biofertilizers, disease diagnostics, biocontrols and biopesticides, soils and water bioremediation and development of clean process technologies such as biopulping, mineral bioleaching and biobleaching.

After two phases of the CamBioTec initiative, IDRC withdrew its funding in 2002, which resulted in the termination of the project. However, since its creation in 1995, the network had fostered over 50 partnerships between Canadian and Latin American firms. Canadian companies that entered into agreements with Latin American firms include Philom Bios Inc., POS Corporation, Ag-West Biotech Inc., BioAtlantech, Ontario Agri-Food Technologies, AgrEvo Canada, Monsanto Canada, Advanta Seeds Canada. CamBioTec II, in 2001, produced an extremely detailed report on the current state of the biotechnology industry in Latin America. It describes key trends in research, industrial production and public policy in all Latin American countries. IDRC funded the publication of this report (AgBiotechNet, 2000).

- Extremely hazardous chemical pesticides are widely used in developing countries, the newer biopesticides highly specific to just a few insect pests, and with allow toxicity profile for humans, are available in the richer countries. These specific low toxicity pesticides are based on the use of a bacterium, *Bacillus thurigiensis* (BT). Developing countries could perhaps access BT pesticides produced in the north, but the price would be prohibitive. Furthermore, it is dangerous to use a single bacterial strain to fight pests on a large scale because of the risk of resistance. IDRC funded a collaborative project between researchers at the University of Western Ontario and the Universidad Nacional Autonoma de México to transfer the production technology of BT pesticides. This will allow Mexican BT strains to be used in the manufacture of pesticides, and will give Mexico access to environmentally friendly pesticides at reasonable prices. Biotechnic S.A. de C.V., a small biotech firm in Mexico also became involved in the collaboration. The project ended in 2000 (IDRC, 1998).
- From 1989 to 1995, IDRC funded the "Aquaculture Genetics Network in Asia" to link aquaculture genetics research projects in the Philippines, Indonesia, China and Thailand with each other, and with the Biology Department of Dalhousie University. Researchers at Dalhousie University provided expertise and know-how for fish breeding improvements using genetic engineering; trained human resources; undertook collaborative projects; and attended network meetings (IDRC, 1989).

- In January 2000, over 130 countries signed the Cartagena Protocol on Biosafety, a sub-agreement of the 1992 United Nations Convention on Biological Diversity (CBD). The Protocol's aims to provide nations with an efficient mechanism to protect their environment and population from the risks, or potential risks, brought by the use of Living Modified Organisms (LMOs), while maximizing their benefits and promoting their trade. The Protocol also requires strict notification, detailed documentation and risk assessment procedures for LMOs to be released into the environment. If a country judges a product unsafe due to insufficient evidence, imports of the product can be banned by applying the precautionary principle. In addition, the Protocol requires that exports of LMOs be labelled "may contain living modified organisms" (Smith, 2000).

  However, in most developing countries, scientific and technologic competencies are not sufficiently well developed to competently assess and manage risks linked to the exploitation of LMOs, which renders the application of the Protocol rather difficult. This situation could lead to either the unmanaged introduction of LMOs in their territories with potentially adverse effects on their wild life, or to a complete ban on LMOs, applying the precautionary principle (Smith 2000; De Vere Pitt and Roberts, 2004). As LMOs with improved nutritional values are designed to help improve health in developing countries and secure food access in a manner sustainable for the environment, none of these situations is desirable. Furthermore, if LMOs were to completely supplant wild varieties, developing countries' crop exports could be seriously affected by the European ban on LMO products. Such a negative impact has already been observed in Zambia, which rejected food aid from Canada in November 2002 assuming that the corn obtained through biotechnology procedures was associated with safety risks. In addition, the country feared that its trade could be negatively affected due to the European Union moratorium on genetically modified food (Council for Biotechnology Information, 2003).

  In response to the need for developing countries to increase their capacity to apply the Protocol, Canada, through the Organization of American States (OAS), contributed to the launch of the "Biosafety Regulations in Latin America and the Caribbean Under the International Biosafety Protocol" project with the aim of strengthening skills for the assessment and management of risks of biotechnology food products in the participating countries in the region, and to enhance public awareness about their benefits and risks (De Vere Pitt and Roberts, 2004).
- AGBIOS, a Canadian company, through the "Program for Biosafety Systems", an international consortium with a $US14.8 million budget, actively contributes to building developing countries' capacities to implement biosafety in Africa and Asia. Bangladesh, India, Indonesia, the Philippines, and East and West Africa will be the first to benefit from the program. The primary role of AGBIOS is to coordinate the activities of the "Program for Biosafety Systems" which include: building the scientific and technical capability of developing countries to make them autonomous in assessing environmental, health, food and feed safety of biotechnology products; setting up protocols for the safe conduct of experimental field trials; and creating a permanent regional communication infrastructure (AGBIOS, 2003).
- The context in which genetic resources are controlled and managed is more complex than ever since under the 1994 Trade Related Intellectual Property Rights (TRIPS) agreement of the World Trade Organization (WTO) genetic resources are now subject to

property rights, and under the 1992 United Nations CBD to national regulations to preserve biological diversity. The TRIPS agreement is recognized as one of the most litigious to come out of the WTO, providing the multinational corporations of the richest countries with a tool that allows them to dominate the poorest countries in the world. By allowing the patenting of LMOs the agreement provides multinationals a monopoly over their seeds, restricting the right of farmers to keep and reuse seed from their crops, which are, anyway, often sterile due to genetic modification or hybridisation.

While the TRIPS agreement protects the inventions of biotechnology firms, which are mainly in the developed world, the knowledge, resources and technology of farmers are left prey to biopiracy by multinationals. Furthermore, since LMOs have enhanced yields per acre, they favor the trend towards monoculture, which inexorably erodes biological diversity in the developing world (Graham, 2002). This is where the CBD should have a role. Unfortunately, most developing countries do not have the capacity to elaborate policies to take advantage of the TRIPS agreement, to protect their indigenous knowledge, resources and technology against biopiracy, and to harmonize the requirements of the TRIPS agreement with the CBD. The WTO required developing countries to establish national policies regarding the TRIPS agreement before the end of 2000, and the least developed countries by 2005. The developing world is thus in urgent need of help to formulate policies for the control and management of genetic resources.

To this end, the Crucible Group, an international network linking speakers from both the north and the south, and from civil society organizations, and the public and the private sectors, is addressing the issues mentioned above to help developing countries cope with the reality of globalization. The 28 representatives of the 19 countries that participated in Crucible I (1993-1998) and the 45 representatives of the 25 countries that participated in Crucible II (1998-2001) include members of communities subsisting on agriculture, commercial diplomats, researchers, specialists in intellectual property, and policy analysts. In Canada, supporting organizations are the IDRC, CIDA, and the ETC group (formerly RAFI). So far, the initiative has produced three publications providing 15 key recommendations to policy makers regarding the control and management of genetic resources. One such recommendation stipulates that the security of gene banks established by the CGIAR should be reinforced by placing them under the auspices of the Parties of the International Undertaking on Plant Genetic Resources (IUPGR) (Davy and Hibler, 2003).

- In 2001, IDRC funded a 6 year project entitled "Towards a Genetic Resource Policy Institute" with the goal of providing a framework for the work of the Crucible Group. This it was hoped would allow it to become a long term independent initiative, with multiple donors, on genetic resource policy. Within the scope of the project, the needs of diverse research and capacity building services from the south would be evaluated and linked with existing resources. The results thus gathered were incorporated in an information sharing center, and laws and policies adapted to the need of the south were recommended (IDRC, 2001).
- In 2004, IDRC, together with the International Plant Genetic Resources Institute (IPGRI), launched the Genetic Resources Policy Initiative (GRPI) website. IPGRI is a Centre of the CGIAR devoted to conservation and sustainable use of genetic diversity. CIDA provided funding to support the GRPI website. The objective of GRPI is to build

the capacity of developing countries to implement comprehensive laws and policies for genetic resources. Current partnerships involve Egypt, Ethiopia, Nepal, Peru, Vietnam and Zambia, and countries from East, West and Central Africa.[4]

- Over the course of its existence, the CGIAR as developed a great diversity of cultivars to secure food supplies for developing countries and there have been fears expressed that CGIAR centers acquire the property rights to negotiate license agreements with biotechnology firms. Consequently, NGOs recommended in 1994 that the CGIAR's gene banks be placed under the supervision of the FAO. One of these NGOs, the ETC group, a Canadian NGO, played a significant role. The ETC group actually initiated the review process of CGIAR's organizational structure, which led to CGIAR's reform in 1999. A major change was made to the composition of its administrative boards with the proportion of administrators from the south, from countries targeted by CGIAR programs, increasing from 25% to 50% (Mooney, 2002). The ETC group is actively involved in a number of other initiatives relating to biopiracy, abusive intellectual property rules in international trade, and promoting protection of indigenous knowledge in developing countries.[5]
- Recently, Canada, through CIDA, contributed $10 million to the Global Crop Diversity Trust, an international fund dedicated to building the capacity of developing countries to develop programs for the conservation of plant genetic resources in particular (Dr. Campbell Davidson, International Genetic Advisor – AAFC, Personal Communication). For example, the Trust endowment could provide financial support to help developing countries establish crop genebanks. Up to now, close to $110 million has been raised for the Global Crop Diversity Trust, the final objective being to raise $260 million.
- In 1998/1999, BIOTECanada, with support from CIDA, reinforced the capacity of Chile and Argentina to implement biosafety laws and policies for environmentally sound biotechnology applications. The project also was designed to increase public awareness regarding food and feed safety of biotechnology products, and provided Canada with a better position in the biotechnology markets of the south (CIDA, 2005).
- In 1993, IDRC funded a three year project based on the traditional performance arts, to pass on information on soil fertility, land husbandry, agroforestry technologies and the use of biotechnology in cultivation practices to illiterate communities of small farmers in Uganda, Kenya and Tanzania. The most successful learning activities were those using dance and songs to diffuse information. Overall, the Ndere dance troupe's shows and other activities attracted over 25,000 farmers and national and international policy makers. Two videos were produced with support from IDRC to support a long-term fundraising strategy (IDRC, 1993b).

2.2.5 Innovation System

- On January 10, 2005, the CIHR and the Indian Council for Medical Research (ICMR) signed a Memorandum of Understanding (MOU) to foster bilateral cooperation in biomedical/health research and to reinforce CIHR-ICMR partnership in life style

[4] See GRPI's Website for more details, http://www.grpi.org/index.php, January 2005

[5] See ETC group's website for more details: http://www.etcgroup.org/, February 2005.

diseases, public health, disease surveillance and other areas of common interest (Andrew McColgan, Partnerships – CIHR, Personal Communication).

- In 2004, the National Institutes of Health (INS) of Mexico and the CIHR signed a collaborative agreement to foster excellence of research on tuberculosis. The program should be mutually beneficial increasing the experience of researchers from both countries with respect to tuberculosis and leading to significant discoveries in tuberculosis research for the benefit of global health (Andrew McColgan, Partnerships – CIHR, Personal Communication).
- NRC's Industrial Research Assistance Program (NRC-IRAP) is a key element of Canada's innovation strategy providing advice, financial support for R&D and commercialization assistance to technology-based Small and Medium-sized Enterprises (SMEs). In contribution to its goal of increasing development capacities of companies in developing countries, NRC-IRAP helped Thailand's NSTDA to create the Industrial Technology Assistance Program (ITAP). Based on Canadian experience, ITAP will provide Thai SMEs with key services to foster innovation (Carty, 2001). NRC-IRAP is also collaborating with a Canadian consortium of financial institutions to help African SMEs increase their innovation capacity. To achieve this objective, a pilot project is underway in Senegal, whereby NRC-IRAP will transfer Canadian expertise for networking and technology transfer via the internet. Finally, IDRC supported a three year project involving NRC-IRAP, the Saskatchewan Research Council, and South-African R&D organizations including the Council for Scientific and International Research (CSIR). The project goal was to produce programs similar to the NRC-IRAP for South Africa (Hackett, 2004).
- Access to scientific information is of paramount importance to the innovation process. This is particularly true in the case of biotechnology, which relies heavily on the Internet for the sharing of genetic data through gene banks. Developing countries often lack appropriate knowledge infrastructures. Canada has a strong expertise in information and communication technology (ICT) having developed the fastest and most advanced optical Internet test bed in the world. In addition, Canada, through initiatives such as *Schoolnet*, is now the country with the greatest proportion of its population with direct access to the Internet (Carty, 2001). To allow developing countries to benefit from Canada's expertise in this area, IDRC supports various projects in ICT. For example, IDRC collaborated with Datacom Co. Ltd., a Mongolian Internet pioneer, to establish Mongolia's first Internet connections and web development services. This infrastructure contributed significantly to the creation of a dynamic environment for business, government, educators, and non-profit groups in Mongolia (Canada NewsWire, 2003).
- NRC's Canada Institute for Scientific and Technical Information (NRC-CISTI) works closely with Morocco's S&T library community and with other S&T information organizations in developing countries to build their capacity in information acquisition and dissemination. NRC-CISTI, through the International Programme for the Enhancement of Research Information (PERI), also gives developing countries access to NRC's Research Press electronic journals (Hackett, 2004).
- In 2003, NRC conducted exploratory activities in India to identify potential collaborations in biotechnology. Partnerships should follow up between Canada and India (Hackett, 2004).

- As part of the North American Free Trade Agreement (NAFTA), the North American Biotechnology Initiative (NABI) was jointly established in 2002 by Canada, Mexico and the United States. NABI's goal is to identify and resolve biotechnology issues of common interest and to identify opportunities for additional collaboration in R&D, commercialization, and regulation. In 2003, the initiative led to an agreement regarding the documentation requirements of the Cartagena Protocol on Biosafety with regard to LMOs for use as food or animal feeds, or for processing. The agreement aims to ensure the objectives of the Cartagena Protocol on Biosafety are fulfilled, while limiting its potential side effects on trade and exchange of scientific information (Ruiz, 2004).
- In 2002, IDRC established the Task Force on Biotechnology and Emerging Technologies with the goal to clarify the biotechnology debate in the developing world; to identify key research questions around the more contentious issues; to identify niche areas that should be prioritized by IDRC to strengthen the South's capacity to assess technology, institute appropriate policy, and identify needs; and to develop programs to pursue niche choices. In 2004, IDRC, through the Task Force, conducted a series of subregional consultations in Latin America and the Caribbean, Eastern and Southern Africa, the Middle East and North Africa, West Africa, and Asia. The objective of these consultations was to build inventories of biotechnology applications to meet the needs of populations in these regions and those requiring further research, the goal being to develop an aid strategy based on potential lines of action for future IDRC initiatives. These consultations involved scientists, NGOs, private firms, policy makers, the media, representatives of community groups, regional organizations, and international organizations (IDRC, 2004).
- Dr. Peter Singer and Dr. Abdallah Daar from the University of Toronto Joint Centre for Bioethics, together with Dr. David Castle from the University of Guelph, are leading the Canadian Program on Genomics and Global Health (CPGGH) to ensure that the benefits of the genomics revolution in health and agriculture are accessible to all. According to the researchers, genomics must be used to address diseases afflicting developing countries, for example, HIV/AIDS and malaria, and not just to produce new medicines for the industrialized nations, which increase rather than reduce global health inequalities. The project is funded through the IDRC, the Norwegian Agency for Development Cooperation (NORAD), the ICMR, the Food Systems Biotechnology Centre and Communications Network, the National Institute of Health (NIH), Merck & Co., GlaxoSmithKline, Sun Life Financial, the Ontario R&D Challenge Fund, the University of Toronto, the University of Guelph, the University Health Network, the Hospital for Sick Children, Sunnybrook and Women's College Health Sciences Centre, and through the Ontario Genomics Institute by GC.

  The team is leading various projects under the CPGGH program to address scientific, legal, social, ethical and political issues pertaining to genomics and biotechnology. For example, they carried out a project aimed at identifying the Top 10 biotechnologies for improving health in developing countries, the results of which were published in the prestigious journal *Nature Genetics* (Daar *et al.*, 2002). As part of a new project on regenerative medicine, the CPGGH aims to identify applications appropriate for developing countries, such as stem cell-based regeneration of organs or tissues.

The "Harnessing Genomics and Biotechnology for the UN Millenium Development Goals" project was set up to investigate how genomics and biotechnology could help to improve global health as part of the United Nations Millennium Development Goals to be achieved by 2015 (Acharya *et al.*, 2003). In 2004, the research group published the results of the "Genomics as a Global Public Good for Health" project in the *Bulletin of the WHO* (Smith *et al.*, 2004). This study consisted of determining the global benefits of the creation of knowledge about genomics, and of its worldwide applications. They found that, although genomics have the potential to generate significant global public good, this is not being achieved due to the limited use of genomics in developing countries, and a recommendation was made for collective action in global genomics governance to build up the capacity of developing countries in this field for the benefit of all nations. As a follow up, the CPGGH suggested the establishment of a Global Genomics Initiative linking industries, academia, citizens, NGOs, and governments worldwide to promote discussion on scientific, legal, social and ethical issues related to genomics, and to develop relevant policies designed to appropriate the benefits of genomics as global public goods.

Through the "Genomics and Public Health Policy Executive Course" project, members of the CPGGH convened courses for developing countries on aspects such as ethics, social and legal issues, infrastructure, media relationships, business development and regulation, to foster the creation of innovation strategies for genomics and biotechnology in the developing world. These courses are intended to promote dialogue between the leaders in academia, industry, government, NGOs, and the media in the elaboration of appropriate strategies. Courses were held in Africa, India, the Eastern Mediterranean Region, Latin America and China and led to the establishment of two opinion leaders' networks: the African Genome Policy Forum and the Indian Genome Policy Forum. Their purpose is to maintain dialogue on a regional basis and between regional networks to establish a Global Genome Policy Forum as part of the Global Genomics Initiative. The "Global Health Initiative" project established by the CPGGH will provide the cornerstone for the creation of a Commission on Genomics and Global Health. Elizabeth Dowdeswell, former director of the UN Environment Program and Undersecretery General of the United Nations, heads this Canadian initiative, which should provide the international community with an institution to collectively tackle global genomics issues.

In December 2004, the research group led by Dr. Singer published the results of a large scale study in a special issue of *Nature Genetics* devoted entirely to its work.[6] The project based on seven developing countries (Brazil, China, Cuba, Egypt, India, South Africa, and South Korea) with established biotechnology sectors, aimed to identify the key factors leading to successful biotechnology innovations in developing countries. The knowledge acquired through the project is expected to help other developing countries

[6] Online access to the special issue on *Nature*'s website: http://www.nature.com/cgi-taf/DynaPage.taf?file=/nbt/journal/v22/n12s/index.html), December 2004.

with similar innovation environments to build their capacity in a field that has huge potential to improve the well-being of their populations.

The "Biosciences Business Ethics" project, among other objectives, studied the ethical strategies of multi-national pharmaceutical and biotech companies to make recommendations for good practice regarding developing countries' health situations. Andrew Taylor, a M.Sc. candidate at the UofT-JCB, is conducting a project that aims to explore the barriers to and needs (intelligence and capital) of Canadian SMEs to commercialize health and environmental biotechnologies within emerging (e.g. China, India, Brazil, Mexico and South Africa) and developing (e.g. Bangladesh, Kenya, Bolivia and Ethiopia) country markets (Andrew Taylor, Personal Communication).[7]

- The CIHR, together with the IDRC, CIDA and HC, instigated the Global Health Research Initiative (GHRI) in 2001. This network was a first in Canada bringing together the expertise of complementary organizations towards the goal of developing research strategies to address health problems faced by the developing world and enhancing the cost-effectiveness of development assistance. IDRC has long experience of research in developing countries; CIDA has a significant experience of development assistance; HC has a wide knowledge base in health playing a role in the surveillance, prevention and control of diseases, approval of medicines, etc.; and CIHR, as the federal health research funding agency, supports excellence in research through the peer-review process. In addition, the network interacts with the CGHRC which involves health researchers, NGOs, sponsors and other stakeholders dedicated to supporting the pursuit of common goals towards global health equity in partnership with researchers from developing countries. Although not explicit in the mandate of the GHRI, this initiative will support assistance projects in the area of biotechnology (CIHR, 2001).
- Infectious diseases are the leading cause of death and morbidity in newborns and children in developing countries, and the high cost and logistical problems of vaccination limit the distribution and administration of vaccines in these countries. With the advent of biotechnology, new avenues for the development of affordable vaccines emerged and the prospect of a solution to health problems in the developing world. Consequently, IDRC supported an initiative of the Mexican Foundation for Health and the Pan American Health Organization (PAHO) to capture the potential benefits of biotechnology for the prevention of infectious diseases in Latin America and the Caribbean (IDRC, 1990; CIDA 2004). The project led to the creation of the Regional System for Vaccines for Latin America and the Caribbean (SIREVA), a network of vaccinology centers anchored in the Brazilian and Mexican biotechnology institutions. SIREVA is still in operation, and CIDA provided additional funding in 1999 to launch a regional epidemiological surveillance network for vaccine-preventable infectious diseases.

[7] See CPGGH's website for more details: http://www.utoronto.ca/jcb/home/main.htm, February 2005.

2.2.6 Links between Canadian Initiatives and Canadian Strengths in Biotechnology

Agriculture and health (infectious diseases) figure the most prominently in the biotechnology initiatives designed to help developing countries. This is not surprising since the most critical issues for populations in the developing world pertain to food supply and to infectious diseases. Although these areas are not among the main Canadian strengths in biotechnology, Canada has a significant pool of outstanding scientists in both fields.

The greatest Canadian strengths in biotechnology R&D include forestry, aquatic sciences, environmental sciences, animal sciences, diabetes research, hormone research, stem cell research and research on the musculoskeletal system (Campbell *et al.*, 2005). However, it appears that initiatives using biotechnology in international assistance do not make full use of some of these strengths, namely forestry, aquaculture, diabetes research, stem cell research and research on the musculoskeletal system.

Forest trees are of major importance to humans providing food, fuel wood to cook food and heat houses, paper, and other products. Forests are also of unique ecological value for preserving biological diversity and as carbon sinks. However, with the rapid growth of population, especially in developing countries, the ever increasing demand for wood products constitutes a significant threat to native forests worldwide. One of the most promising solutions to relieve pressure on native forests lies in enhancing the productivity of tree plantations. This can be achieved through genetic improvement of forest trees. Thus, the outstanding performance of Canada in forest biotechnology could be instrumental in implementing sustainable timber practices in developing countries, such as Brazil, that are facing a rapid depletion of their forestry resources. Canada has contributed to enhancing forest management in developing countries for more than 30 years and continues to provide development assistance for forestry projects, although, according to a research coordinator from the Canadian Forest Service (NRCan-CFS), only few of these initiatives touch upon biotechnology.

While close to 1 billion people, mainly in developing countries, rely on fish as their primary source of animal protein (Denton, 2004), more than 70% of the world's fisheries are being exploited at a non-sustainable rate resulting in the depletion of many fish stocks (FAO, 2000). Thereby, aquaculture is likely to play an increasing role in feeding human populations. However, in its current state, the aquaculture industry cannot, on its own, fill the worldwide demand for fish. In this regard, biotechnology can contribute to aquaculture by improving the growth performance and health of fish. Yet, no ongoing initiative to help developing countries using aquaculture biotechnology was identified in Canada.

According to the WHO, in the next 20 years, diabetes will become the leading cause of deaths in developing countries. By 2025, the number of people with the disease in the developing world is expected to rise to 228 million, a 76% share of the world population affected by diabetes (WHO, 2003). Thus, the strength of Canada in diabetes biotechnology is likely in the near future to become a key asset towards improving global health.

With respect to stem cell research, the CPGGH is currently evaluating the value for developing countries of regenerative medicine techniques using stem cells, and also their capacity to absorb such technologies.

Initiatives undertaken to help developing countries have made extensive use of Canadian strengths in the innovation system in biotechnology. For example, there is a close connection in Canada between government, academia and the private sector, referred to as the "triple-helix dynamics". These interactions have contributed to the growth of the Canadian biotechnology industry. Through initiatives like CamBioTec, Canadian organizations from diverse sectors (e.g. government, NGOs, universities, firms) have contributed to the establishment of an environment suitable for technology transfer between Canadian firms and companies from developing countries. This in turn has fostered the growth of the biotechnology sector in these countries.

Across Canada, NRC's first-class R&D institutes, NRC-IRAP and NRC-CISTI have played an essential role in seeding and supporting the growth of technology clusters. Numerous initiatives from each of these organizations have been launched to expand the biotechnology industry in developing countries. For instance, NRC-BRI is working to establish a pharmaceutical company in Tunisia, which it is likely, will attract foreign investors and eventually produce a biotechnology cluster in that country; NRC-IRAP helped the NSTDA to create the ITAP, an equivalent of NRC-IRAP; and NRC-CISTI through PERI has given developing countries access to NRC's Research Press electronic journals.

In Canada, organizations such as NSERC, CIHR, and CFI have provided significant financial support to maintain and grow the biotechnology scientific base. These organizations launched a series of initiative to support biotechnology R&D in developing countries. For example, CFI contributed CDN$3.8 million in 2004 to expand the Centre for Infectious Diseases Research at the University of Nairobi, Kenya.

Canada also has a relatively solid regulatory system to protect intellectual property, and some Canadian initiatives are aimed at helping developing countries build their capacity to implement policies within the framework of the TRIPS agreement. Attention is also directed to the protection of indigenous knowledge against bio-piracy.

The availability of venture capital is an important strength that serves to attract biotechnology companies in Canada: it does not benefit developing countries. Venture capitalists might be reluctant to invest in developing countries with an unfavourable economy.

Finally, the government of Canada could launch initiatives to help developing countries develop their own national strategies to foster the growth of their biotechnology sector. Such an initiative has already been conducted with Thailand (Carty, 2001)

3 Complementary Competencies and Opportunities for R&D Collaborations amongst Canadian Organizations

This section attempts to identify projects where the competencies of Canadian research groups could be matched to more efficiently deliver aid to developing countries using biotechnology and to generate a value added that could not be achieved by organizations working independently. Since imagination is the main factor limiting the number of possible matches, the present study does not intend to provide an extensive listing of such projects, but rather to provide a few scenarios that, at first sight, would appear to have a high potential impact for developing countries.

- Recently, the CIHR and the ICMR signed a MOU to foster bilateral cooperation in biomedical/health research between Canada and India. In that respect, both agencies could benefit from NRC's exploratory activities conducted in India to identify potential collaborations in biotechnology. On the other hand, NRC could benefit from the agreement between the organizations.
- In Canada, both the CIHR and the NRC are collaborating with developing countries to develop vaccines against tuberculosis. The CIHR signed a collaborative agreement with the INS in Mexico to foster excellence of research on tuberculosis and the NRC-IBS is working in partnership with the Tuberculosis Research Center in India to develop a single dose vaccine. These groups should work collectively, sharing information in pursuit of a common goal.
- Both HC's National Microbiology Laboratory, in partnership with CANGENE, and the team led by Dr. Plummer (University of Manitoba), director of the Canada-Kenya program on HIV/AIDS, are conducting R&D to develop vaccines for Ebola. A partnership between these groups might be mutually beneficial.
- Dr. Kevin C. Kain at the University Health Network, Dr. Terry Spithill at McGill University and Dr. Marc Ouellette at Université Laval are renowned scientists working on malaria. Yet, they are conducting projects independently. It could perhaps be appropriate for them and other researchers working on malaria to pool there efforts to speed up the delivery of efficient diagnostic tools, drugs, and vaccines for developing countries. These researchers might have common interests in other pathogens afflicting developing countries.
- Dr. René Roy from UQAM, in partnership with a group of West African researchers, is currently involved in a project funded by CIDA, which aims to list medicinal plants used to treat diseases such as malaria, pneumonia and HIV/AIDS. NRC-BRI and the Lyceum Research Company in New-Brunswick are conducting similar work with traditional healers in Ghana and Cameroon to turn traditional medicines into well characterized health products. These groups could work collaboratively to compile indigenous knowledge in medicine; they should seek advice from NGOs such as the ETC group, on how to protect this knowledge from biopiracy. In order to distribute these natural health products at preferential prices to the populations most in need, pharmaceutical companies in developing countries, such as the one to be established in Tunisia by NRC-BRI, Prometic Life Sciences, the Institut Pasteur de Tunis and the Tunisian State Corporation, should be contacted to negotiate agreements.

- The project to launch the pharmaceutical company in Tunisia aims to manufacture and distribute generic medicines at reduced prices for developing countries in Africa, the Middle East and parts of Europe. This initiative conducted in Canada by NRC-BRI and Prometic Life Sciences should be replicated in other regions of the developing world, so that additional players can become involved.

  For example, NRC-IRAP could provide key services to support innovation and commercialization by these newly established companies, or help developing countries create programs similar to NRC-IRAP, as has been done in Thailand. In addition, links could be developed with Canadian companies for particular purposes, such as technology transfer.

  In achieving this goal, the initiative could benefit from projects undertaken at the JCB-UofT. For example, the "Biosciences Business Ethics" project aims to make recommendations for good practice to biotechnology companies, regarding developing countries' health situations. Another project, conducted by Andrew Taylor, aims to investigate the barriers to and needs of Canadian SMEs to collaborate with developing countries. Biotechnology company associations (BIOTECanada and Rx&D) whose members might get involved in collaborations with developing countries could also participate.

  Ultimately, a network linking universities, government departments, companies and NGOs would contribute to the creation and growth of a prosperous health biotechnology industry in developing countries. CamBioTec, a similar network, existed for agriculture and the environment at one point, but once funding from IDRC was terminated at the end of 2002, the network disintegrated. This points to the importance of providing long term support; the former administration of CamBioTec could be contacted to gain from their experience. An initiative similar to CamBioTec should be reestablished for agriculture and the environment. The new network could interact with the ISAAA to facilitate technology transfer with developing countries.

- The multiple projects undertaken in agriculture and aquaculture to improve crops and livestock should be linked with the different groups (e.g. ETC group) that are leading projects on biodiversity conservation, protection of indigenous knowledge from biopiracy, and trade in LMOs to ensure that the assistance provided will not have adverse effects on developing countries' economies, environment and population health. In addition, such projects should be accompanied by educational initiatives aimed at building the capacity of communities from developing countries to assess and manage the benefits and risks of these technologies in making informed decisions. However, cultural barriers often negatively affect the transfer of knowledge between developed and developing countries. Educational initiatives would therefore benefit from IDRC's expertise regarding the use of traditional performance arts, such as dance and songs, to transfer knowledge in developing countries.
- IDRC and NRC-CISTI could complement each other in the development of appropriate knowledge infrastructures for the conduct of S&T activities in diverse scientific fields. IDRC could be responsible for establishing or upgrading internet connections and web development services, while NRC-CISTI could be responsible for the sharing of S&T information. Companies from developing countries should be involved to develop the

expertise of these countries in ICT. In addition, efforts should be made to obtain agreements with publishers to provide access to their electronic journals at no fee, or at a discounted price. NRC-CISTI through the PERI used this means to give developing countries access to NRC's Research Press electronic journals.

- IDRC's Task Force on Biotechnology and Emerging Technologies is carrying out consultations with developing countries in order to determine their R&D capabilities and needs in biotechnology. To complement this work towards defining new lines of action for Canadian initiatives in development assistance, the task force should work with the research group led by Dr. Singer (JCB-UofT), which has undertaken a large scale study to identify the key factors leading to successful biotechnology innovation in developing countries.

  Both teams could work on compiling a database that would list developing countries' strengths, weaknesses, needs (e.g. infrastructure, equipment, skilled labor force, technologies, know-how, and expertise) and capacity to absorb assistance, together with the key factors fostering innovation in developing countries. This work could be achieved with the FAO, which hosts a database on developing countries' biotechnology profiles.[8] The database could be available either from IDRC's website or FAO's website. In the former case, a link to FAO's database could be added to the IDRC website. The database would serve to orient, on a case by case basis, all Canadian initiatives aimed at providing development assistance. Canadian groups could consult the database to plan their assistance such that it would be of most strategic use in creating benefits for developing countries. IDRC could give advice about aid projects.

- Collaborations between Canadian organizations could also be useful, for instance, where the specific needs of developing countries have not yet been addressed by Canadian initiatives, and where no single organization would be able to tackle the issue. Such collaborations might involve organizations whose initial focus was not on developing country issues.

  For example, research for the development of vaccines against infectious diseases is of paramount importance to developing countries. However, the current delivery system of vaccines poses a serious health risk in developing countries where contaminated syringes are often re-used. To the best of our knowledge, no Canadian initiatives have been put in place to develop safer vaccine delivery systems for developing countries so far.

  A team led by Dr. Babiuk, a member of the CANVAC working at the Veterinary Infectious Disease Organization (VIDO) in Saskatchewan, is carrying out research to develop "needle-free" delivery systems (e.g. vaccine patches, nasal sprays) for livestock. Their goal is to eliminate meat damage caused by syringes (Baca-Estrada, 2000). Even though their work was not initially designed to supply foreign aid, it could be applied to the development of systems for the safe administration of vaccines in the developing world. Thus, it would be of benefit for the group could collaborate with Canadian

[8] FAO's database on developing countries' biotechnology profiles: http://www.fao.org/biotech/inventory_admin/dep/country_rep_search.asp?lang=en, February 2005.

scientists developing new vaccines for diseases afflicting developing countries, such as HIV/AIDS and malaria.

- Another approach might consist of using plants as oral delivery systems for vaccines. Under this scenario, a group of specialists in genetic engineering of plants could be linked to a group of virologists for the development of transgenic crops expressing pharmaceutical proteins (molecular bio-pharming). Dr. Illimar Altosaar's team (University of Ottawa), which produced BT rice in collaboration with China has some interest in this area and could usefully partner Canadian groups developing new vaccines for diseases afflicting developing countries. In addition to a safe delivery system, production of vaccines in transgenic plants would provide an efficient and inexpensive manufacturing system adapted to developing countries, which often lack an appropriate bio-manufacturing infrastructure. However, this type of technology is likely to raise ethical concerns, and the UofT-JCB could address this issue and provide recommendations.

Obviously, many more examples could be highlighted. However, this would require further work that could be achieved using two approaches, not mutually exclusive. The first consists of identifying the strengths and weaknesses of each organization carrying out biotechnology initiatives in the context of development assistance. This would entail interviewing these organizations, and would probably call for a history of their activities. Strengths and weaknesses could then be compiled in a database suitable for matching organizations in order to compensate for gaps. In addition, lessons learnt by organizations over the course of their experience should be collected and compiled in the database to enable each to learn from the others. The database could be made available on IDRC's website.

The second approach involves identifying the specific needs of developing countries that have not yet been addressed by Canadian biotechnology initiatives, to identify competent and complementary organizations that could tackle the various issues, whether or not they are currently involved in foreign aid. Such a procedure would involve consultations with researchers from Canada and developing countries, who are conducting biotechnology projects in different fields, together with working groups dedicated to delineating areas where biotechnology may contribute to alleviate developing countries' problems. In Canada, IDRC has set up such a group, the Task Force on Biotechnology and Emerging Technologies, which could serve as the organizing committee to promote and host workshops.

Ultimately, the aim should be to get Canadian organizations to work collectively to integrate individual initiatives into well functioning assistance programs. However, the creation of such national networks requires appropriate models of R&D collaboration. The next section describes prospective models and sketches out potential networks of R&D collaboration.

4 Canadian Models of R&D Collaboration in International Development

The review of Canadian biotechnology initiatives in international development has revealed a wide range of scientific, technological and innovation activities aimed at providing solutions to some of the most critical issues in the developing world. These pertain to areas as diverse as health, agriculture and aquaculture, the environment, capacity building and the innovation system, and many were found to be complementary. Unfortunately, current models of R&D collaboration in international development lack efficient mechanisms to connect these efforts and leverage them to obtain a synergy at the national level. Section 4.1 reviews existing models of R&D collaboration in international development and identifies their weaknesses. Finally, Section 4.2 provides recommendations on how to improve existing models and presents complementary models that could be integrated to fill the gaps in the former.

4.1 Strengths and Limits of Existing Models

In Canada, two federal organizations have the mandate to promote and provide foreign aid to developing countries, CIDA and IDRC. Consequently, most government cooperative development activities are initiated by CIDA or IDRC, which will often request the participation of other federal organizations, universities, companies and NGOs to draw on their knowledge and expertise. In some instances, these latter organizations may decide to launch initiatives of their own, in which case they can file proposals for financial support from CIDA and/or IDRC.

Although this model fostered numerous partnerships in biotechnology to help developing countries, there is room for improvement, especially in terms of connecting the efforts of Canadian organizations. Its main weaknesses include:

- its limited capacity to link researchers working on complementary projects;
- the size of the budget and the limited reach of CIDA's and IDRC's funding programs to Canadian stakeholders;
- the lack of a mandate for federal organizations (departments, agencies, or crown corporations) other than CIDA and IDRC to provide foreign aid to developing countries;
- the lack of a program specifically designed to promote and fund development cooperative activities in biotechnology, an area given high priority by the government of Canada (CBS, 1998).

Despite these limitations, Canada's overseas development agencies, the cornerstone of this model, have vast experience in development assistance such that improvements to the model should build on this rather than being oriented to 'reinventing the wheel'. CIDA and IDRC have the resources in place to support cooperation activities, they are well positioned to identify the priorities of developing countries, and they have a significant knowledge of the key factors leading to successful aid programs. For example, according to Paul Dufour from

IDRC, there are 6 principles guiding Canadian international cooperation: 1) aid programs should be delivered upon request by developing countries; 2) help must be given to provide the necessary skills and expertise; 3) developing countries must have the capacity necessary to absorb the assistance provided; 4) the impact of assistance must be well evaluated to ensure that it does not harm the countries involved; 5) cooperation should be seen as beneficial to both partners rather than as being aid strictly for the benefit of developing countries; and 6) the assistance must be maintained over the long term (usually at least a few years) to obtain a lasting and positive impact.

Recently, the model was extended to compensate the gap pertaining to its limited capacity to link Canadian researchers, industries and NGOs undertaking complementary initiatives, and the lack of a mandate for federal organizations other than CIDA and IDRC to provide foreign aid to developing countries. The new model, the Global Health Research Initiative (GHRI), was launched in 2001. It consists of a network benefiting from the expertise of the CIHR in funding high quality research through peer-review and from HC's significant knowledge base in health, while being anchored in Canada's overseas development agencies, CIDA and IDRC.

The network's mission is to develop research strategies to address health problems faced by the developing world and to meet the UN Millennium development goals. To maximize its capacity to connect and increase the synergy of Canadian initiatives aimed at achieving global health, the network interacts with the CGHRC, a grouping of health researchers, NGOs, firms and other stakeholders. It also promotes scientific exchange through its workshops and conferences. Internationally, the GHRI increases the outreach of Canadian initiatives by interacting with international organizations such as the GAVI whose mission is to deliver aid to the populations most in need. The enhanced networking capability of this model results in greater connectivity between Canadian initiatives, and greater publicity of funding opportunities for R&D in the context of foreign aid.

Despite this improvement, the model is limited to the health sector with no special emphasis on biotechnology, and does not address the problem of budget availability, a key factor in increasing the involvement of Canadian organizations in development assistance. In addition, the model could implement mechanisms to further promote collaboration between Canadian research groups.

4.2 Recommendations to Improve and Expand Existing Models

In a first step towards improving Canadian models of R&D collaboration in international development, Dr. Peter Singer, director of the UofT-JCB, recently advised Prime Minister Paul Martin to devote 5% of Canada's R&D spending to addressing developing world issues. The prime minister approved the recommendation and is expected to deliver on his commitment in the 2005 Budget. At the Building Science & Technology Capacity with African Partners Conference, January 31, 2005, Dr. Singer urged the UK government to follow suit and, as the presidency of the G8, to incite other industrialized countries to adopt this measure (Dickson, 2005; R$, 2005).

Given that biotechnology has been recognized as having tremendous potential to solve some of the urgent issues of the developing world in areas as diverse as health, agriculture and aquaculture, and the environment, a part of this R&D spending should be allocated to a program aimed at promoting and funding development assistance activities in biotechnology. However, to effectively engage the public, private and not-for-profit sectors in biotechnology R&D collaborations to help developing countries, this funding program will have to be implemented through appropriate models of R&D collaboration.

According to Dr. Singer, four models could be applied to improve R&D collaborations in development assistance (R$, 2005). The first consists of enhancing the already existing model based on CIDA and IDRC. This would involve increasing the funding capacity of both organizations to leverage Canada's S&T efforts in international cooperation. These would ideally involve launching a common funding program to support biotechnology initiatives. As mentioned above, the programs of CIDA and IDRC are not widely publicized. Therefore, to increase the reach of the new program for biotechnology and international development within the scientific community and the private sector, news linking to the program's website should be posted on the homepage of key funding agencies (e.g. CIHR, NSERC, SSHRC, GC and CFI) and biotechnology associations (e.g. BIOTECanada and Rx&D).

The second model would be an extension of the first through programs such as the GHRI to increase interaction amongst Canadian research groups and to foster high quality research. To further boost the GHRI's capacity for networking, additional links should be created with established national networks, in particular the Canadian NCE. Among these, the CANVAC, which is already involved in international cooperation activities for HIV/AIDS relief, would be a good target. In addition, in order to increase the connections between individual initiatives, the GHRI could favour the funding of projects where collaboration is likely to generate added value on top of individual research achievements, by creating a special fund for proposals in partnership. For example, research projects involving plant geneticists and virologists for the production of vaccines in transgenic plants (molecular bio-pharming) could lead to the development of an efficient and inexpensive production system adapted to developing countries and to the production of pharmaceutical proteins free of viral contamination, results that might not be achieved by any of these groups working independently. Internationally, the GHRI interacts with GAVI on the distribution of vaccines. It could also cooperate with SIREVA in Latin America and the Carribean. Currently, the GHRI can support biotechnology-based health projects, although this is not a special focus in its mandate. Perhaps a component specific to biotechnology should be incorporated.

This model should undoubtedly be expanded to other sectors of importance to developing countries such as agriculture and aquaculture, the environment, capacity building and the innovation system. The key components that should be included in implementing the model are: 1) a federal funding agency appropriate to the field targeted (e.g. CIHR for health; NSERC for agriculture and aquaculture, and the environment); 2) the federal departments that have authority in the targeted field (e.g. HC for health; AAFC and DFO for agriculture and aquaculture; EC for the environment); 3) Canada's overseas development

agencies (e.g. CIDA and IDRC); 4) established national networks to enable the program to reach Canadian scientists and promote collective work towards development assistance (e.g. CGHRC and CANVAC for health; Aquanet for aquaculture); and 5) international organizations to increase the outreach of Canadian initiatives (e.g. GAVI and SIREVA for health; CGIAR and FAO for agriculture; UNEP for the environment).

The third model was suggested by Dr. David Strangway, former CFI president and CEO, and consists of the creation of a Canada-Africa Research Chairs program modeled after the Canada Research Chairs program. The program would focus exclusively on R&D to support outstanding African researchers working in collaboration with Canada. The Chairs would target a wide spectrum of issues of importance to developing countries. Some Chairs would likely support biotechnology projects given its potential to solve issues of the developing world.

The fourth model, Canada Biosciences International, would consist of establishing an International NCE based on the Canadian NCE. The International NCE would link African Institutes funded by Canada with Canadian institutions in biosciences. The networks would put emphasis on collaboration with the private sector to foster industrial development. In particular, the program would provide technology development support based on the NRC's successful Industrial Research Assistance Program (NRC-IRAP).

The four models are complementary such that, in a perfect scenario, they would all be implemented. However, priority should be given to the first and second models which are likely to have a greater impact on the most critical issues of developing countries, namely health, and food and water supply. Needless to say, the second model should be extended to agriculture and aquaculture, the environment, capacity building and the innovation system.

5 Conclusion

The Government of Canada Blueprint for Biotechnology emphasizes that Canada should position itself as a responsible world leader by undertaking cooperation activities internationally. Towards that goal, the BDMCC has approved funding for a background analysis of the key areas where biotechnology programming would be of the greatest strategic use in creating benefits to address critical issues in developing countries and to assess the risks associated with biotechnology.

As part of this analysis, NRC is leading a project focusing on Canadian capacities and competencies in biotechnology R&D. There are two components to the project: 1) analysis of Canadian strengths in biotechnology R&D to identify the key areas where Canada could show leadership internationally and provide help to developing countries; and 2) identification of Canadian initiatives aiming to provide development assistance through biotechnology. Science-Metrix was mandated to carry out both project components. The first has been completed and resulted in a report entitled "Scan of Canadian Strengths in Biotechnology". The second was the focus of this study which aimed to:

- identify Canadian initiatives addressing developing country issues using biotechnology;
- identify complementary competencies within and opportunities for R&D collaboration between Canadian organizations;
- make recommendations to improve the current models of R&D collaboration to connect and increase the synergy of Canadian initiatives in biotechnology and international development.

The review of Canadian biotechnology initiatives in international development has revealed a wide range of scientific, technological and innovation activities aimed at providing solutions to some of the most critical issues faced by developing countries, such as food and drinking water supply, infectious diseases, and environmental pollution. Within the federal government, several departments contributed significantly to these initiatives, namely IDRC, CIDA, CIHR, HC, AAFC, and NRC. For example, NRC-IRAP provided assistance to many developing countries' biotechnology industry through its services to support innovation and commercialization. Alongside initiatives to boost the innovation system of developing countries, NRC is also involved in R&D initiatives to develop, for example, vaccines for tuberculosis. Universities, NGOs and biotechnology companies have also led important initiatives. These pertain to areas as diverse as health, agriculture and aquaculture, the environment, capacity building, and the innovation system.

However, it appears that these initiatives are not making full use of some of the major Canadian strengths in biotechnology that could be useful to developing countries. In particular, additional efforts should target forestry, aquaculture, and development assistance to help developing countries expand their own biotechnology strategies. In the not to distant future, Canada should also pay more attention to the potential use of biotechnology to address the growing numbers of people affected by diabetes in developing countries. In addition, a new study should be launched to map the needs of developing countries that could be tackled through biotechnology means. This would allow the

identification of existing gaps between needs, and assistance provided, to point towards new avenues of collaboration with developing countries.

Based on complementary competencies, many potential partnerships amongst Canadian organizations have been outlined; to provide a more detailed picture, further work would be required. This could involve a study in which every Canadian organization involved in biotechnology and international development would be interviewed to compile a database of their strengths and weaknesses, which could be shared on the internet. This would allow the strengths of particular organizations to compensate for weaknesses in others. Another route would be to organize consultations between researchers from Canada, developing countries, and relevant working groups to identify the needs of developing countries that could be tackled using biotechnological means. The goal of these workshops would be to identify problems not currently being addressed by Canadian initiatives, and to identify organizations, engaged in complementary work, that could tackle these issues together.

Ultimately, the aim should be to get Canadian organizations to work collectively to integrate individual initiatives into well functioning assistance programs. However, the creation of such national networks requires appropriate models of R&D collaboration. Four models of R&D collaboration have been suggested.

The first involves only CIDA and IDRC to initiate and support cooperation activities. The second model is based on the successful GHRI. It consists of establishing networks to foster international cooperation in specific fields. The networks would be built around CIDA and IDRC in order to benefit from their long experience in international development, but would also include a federal funding agency appropriate to the field targeted (e.g. CIHR for health; NSERC for agriculture and aquaculture, and the environment, etc.), a federal department with authority in the targeted field (e.g. HC for health; AAFC and DFO for agriculture and aquaculture; EC for the environment) and an established national network (e.g. Canadian NCE). The third model involves creating a Canada-Africa Research Chairs program modeled after the Canada Research Chairs program. The fourth model would entail establishing an International NCE based on the Canadian NCE. The four models are complementary such that, in a perfect scenario, they would all be implemented.

In combination with diverse type of assistance, biotechnology initiatives hold great promise for reducing poverty and improving the health and well-being of developing world populations. Thus, Canada should maintain and increase the efficiency of its development assistance in biotechnology through the implementation of enhanced models of R&D collaboration and should capitalize on its strengths. This would help Canada, as a responsible world leader in biotechnology, to achieve its objective of reducing global inequalities, in line with the UN Millennium development goals.

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Acronyms

AAFC	Agriculture and Agri-Food Canada
AIDS	Acquired Immune Deficiency Syndrome
ASEAN	Association of Southeast Asian Nations
BDMCC	Biotechnology Deputy Minister Coordinating Committee
BT	*Bacillus thurigiensis*
CANVAC	Canadian Network for Vaccines and Immunotherapeutics
CBD	UN Convention on Biological Diversity
CBN	Cassava Biotechnology Network
CBS	Canadian Biotechnology Strategy
CBSec	Canadian Biotechnology Secretariat
CDMA	Canadian Drug Manufacturers Association
CFA	Canada Fund for Africa
CFI	Canadian Foundation for Innovation
CFIA	Canadian Food Inspection Agency
CFS	Canadian Forest Service
CGHRC	Coalition for Global Health Research Canada
CGIAR	Consultative Group on International Agricultural Research
CHUQ	Centre Hospitalier Universitaire de Québec
CIAT	International Center for Tropical Agriculture
CIDA	Canadian International Development Agency
CIHR	Canadian Institutes of Health Research
CIII2	Canadian International Immunization Initiative
CIMMYT	International Center for the Improvement of Maize and wheat
CIP	International Potato Center
CPGGH	Canadian Program on Genomics and Global Health

CSIR	Council for Scientific and International Research
CSO	Civil Society Organization
DFO	Fisheries and Oceans Canada
EC	Environment Canada
ECORC	AAFC's Eastern Cereal and Oilseed Research Center
ETC group	Action group on Erosion, Technology and Concentration
FAC	Foreign Affairs Canada
FAO	UN Food and Agricultural Organization
GAVI	Global Alliance for Vaccines and Immunization
GC	Genome Canada
GEF	Global Environment Facility
GHRI	Global Health Research Initiative
GRPI	Genetic Research Policy Initiative
HC	Health Canada
HIV	Human Immunodeficiency Virus
IAVI	International AIDS Vaccine Initiative
IBS	International Service for National Agricultural Research's Biotechnology Service
IC	Industry Canada
ICARDA	International Center for Agricultural Research in Dry Areas
ICGEB	International Center for Genetic Engineering and Biotechnology
ICMR	Indian Council for Medical Research
ICT	Information and Communication Technology
IDRC	International Development Research Center
IICA	Inter-American Institute for Cooperation on Agriculture
IITA	International Institute of Tropical Research
ILRI	International Livestock Research Institute

ILSI	International Life Sciences Institute
INRS	Institut National de la Recherche Scientifique
INS	National Institutes of Health of Mexico
IPGRI	International Plant Genetic Resources Institute
IRCM	Institut de Recherches Cliniques de Montréal
ISAAA	International Service for the Acquisition of Agri-biotech Applications
ITAP	Industrial Technology Assistance Program
ITC	International Trade Canada
IUPGR	International Undertaking on Plant Genetic Resources
LDCs	Least Developed Countries
LMIC	Low and Middle Income Countries
LMO	Living Modified Organism
MOU	Memorandum of Understanding
NABI	North American Biotechnology Initiative
NAFTA	North American Free Trade Agreement
NCE	Networks of Centres of Excellence
NCR-CISTI	NRC's Canada Institute for Scientific and Technical Information
NEPAD	New Partnership for Africa's Development
NGO	Non Governmental Organization
NIH	National Institute of Health
NORAD	Norwegian Agency for Development Cooperation
NRC	National Research Council Canada
NRCan	Natural Resources Canada
NRC-BRI	NRC's Biotechnology Research Institute
NRC-IBS	NRC's Institute for Biological Sciences
NRC-IMI	NRC's Industrial Materials Institute

NRC-IRAP	NRC's Industrial Research Assistance Program
NRC-PBI	NRC's Plant Biotechnology Institute
NSERC	Natural Sciences and Engineering Research Council of Canada
NSTDA	Thailand's National Science and Technology Development Agency
OAS	Organization of American States
PAHO	Pan American Health Organization
PERI	International Programme for the Enhancement of Research Information
R&D	Research and Development
Rx&D	Canada's Research Based Pharmaceutical Companies
S&T	Science and Technology
SARS	Sudden Acute Respiratory Syndrome
SAVI	SARS Accelerated Vaccine Initiative
SIREVA	System for Vaccines for Latin America and the Caribbean
SMEs	Small and Medium-Sized Enterprises
SSHRC	Social Sciences and Humanities Research Council of Canada
TRIPS	Trade Related Intellectual Property Rights
UN	United Nations
UNAIDS	Joint UN Programme on HIV/AIDS
UNDP	UN Development Programme
UNEP	UN Environment Programme
UNICEF	UN Educational, Scientific and Cultural Organization
UNIDO	UN Industrial Development Organization
UNITAR	UN Institute for Training and Research
UofT-JCB	University of Toronto Joint Center for Bioethics
UQAM	Université du Québec à Montréal
UVic	University of Victoria

VIDO	Veterinary Infectious Disease Organization
WFT	World Fisheries Trust
WHO	World Health Organization
WTO	World Trade Organization