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THE CANADIAN BIOTECHNOLOGY STRATEGY ONLINE

SECTOR CONSULTATION DOCUMENT: RESEARCH AND DEVELOPMENT

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Research and Development Consultation Document

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1. Introduction

To maintain position as a global biot :hnology leader and to address public concerns, a review of Canada's biotechnology strategy is underway. One of the key areas under review is biotechnology research and development (R&D) at the federal level.

The consultations bring together members of Canada's biotechnology research and innovation communities to consider a number of key issues and identify the necessary elements of an effective biotechnology research and innovation system. Other consultations are being undertaken on the organizational and ethics issues, and also on sector specific areas. Please see details of the full Canadian Biotechnology Strategy Consultation Process at the following websites: http://strategis.ic.gc.ca/cbs (English t xt), and http://strategis.ic.gc.ca/scb (French text)

Given Canada's minority position in the world's production of biotechnology research and development and given the demands of the public policy mandate that can be served through biotechnology, it is time that Canada considered making some strategic choices in the biotechnology arena. We cannot do it all, but we can maintain and accelerate in some areas – with true world class excellence. If we invest public resources wisely, to establish sufficient scope and scale in these R&D areas, we will create innovation clusters or technopoles, which become self-sustaining engines of innovation and economic growth.

The issue of how to translate ideas and knowledge into innovation is one of the central concerns facing contemporary science and technology in general and biotechnology specifically. The question is not only "how" to translate knowledge into innovation, but also to identify "what" key areas of knowledge and research need to be sustained, nurtured or developed over the coming decade in order to establish seminal biotechnology platforms to meet the public mandate for the next century.

Making these choices will require a shared sense of the future breakthroughs in biotechnology, a clear view of Canada's present competitive position in each potential area, a useful set of criteria to employ in making the choices, and a concrete plan to improve the translation of research into innovation in the chosen areas. These four questions form the structural framework of these consultations.

The consultations on research and innovation being led by the National Research Council in conjunction with the Medical Research Council and participating federal departments are seeking guidance from the leaders of Canada's biotechnology research and innovation communities on the key issues and concerns outlined in this document. This important communication opportunity is an essential lead component of the *Renewal of Canada's Biotechnology Strategy*. No doubt, other issues will be identified in the course of these consultations and much compilation, reflection and integration of the various contributions will be necessary.

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2. Meeting the Public Mandate in Biotechnology

Drawing to the close of this decade, Canadians sense that order has been brought to public finances and that the country is entering a period of strong growth. New jobs are being created; inflation is low and interest rates lower than at any time in the past 30 years. More Canadian firms are selling more goods and services to the world than ever before.

The focus now is to build on the progress that has been achieved, to take considered action that will encourage new investment and launch other initiatives to build a strong society and a strong economy representing the values of Canadians and sustaining their desire for a high quality of life and environment.

Two interactive principles contribute substantially to building a strong economy and society for all Canadians. An economy based on knowledge, learning and innovation will create more and better jobs as well as higher living standards for Canadians. Secondly, by building a strong society—through preserving and enhancing Canada's health, education, environment and other valued programs—all Canadians can participate in and benefit from economic growth. These goals are recognized as being mutually reinforcing. A strong economy provides Canadians with the opportunity for more and better jobs and generates the revenues needed to maintain and enhance important programs that contribute to a strong society. A strong society provides Canadians with the sense of security and ability to achieve their goals for health, quality and the environment.

In an increasingly knowledge-based economy, research and technology are the principal engines for growth. Promoting the creation of knowledge and translating it into social and economic innovation are the keys to ensuring a more positive future for Canada.

Certain technology domains have unusual potential to sustain significant social and economic growth. Biotechnology is one of these high potential domains that makes a significant contribution to our lives, enhances our health and well being, creates jobs and economic growth, and also supports environmental sustainability. Biotechnology is a "strategic and enabling technology" for Canada and all other countries because it has already a proven capability to affect a wide range of economic activities and social endeavours.

The Government of Canada has a public mandate to ensure that Canadians' health, safety and the environment are safeguarded, that jobs, economic growth and international competitiveness are enhanced, and that biotechnology is developed responsibly for the maximum benefit of Canadians, both now and in the future. These responsibilities of government are understood and supported by Canadians. The opportunity to help realize this mandate is provided through the Canadian Biotechnology Strategy Renewal (CBS).

Biotechnology is a particularly challenging area for public policy due to its widespread impact and complex cycles of research, technology transfer and innovation. Unlike other technologies such as communications or software, in biotechnology the required initial investment costs are high, and the time necessary to complete the cycle from basic discovery to commercial product is long. Therefore there is significant need for sustained support (patient capital) through most of that cycle. In addition, biotechnology must match innovation with regulatory acumen on a global scale.

2.1 Building Critical Mass into Technopoles

In order to fulfil the public mandate and create an effective public policy framework, a number of key research and innovation decisions are now required. Many strategic opportunities exist and insufficient human and fiscal resources are available to pursue all areas of biotechnology research and innovation. At the same time, Canada's biotechnology research and innovation system has too many gaps to ignore. As a result, two key challenges exist.

The first challenge is to create a critical mass in key areas of Canada's biotechnology effort. Critical mass can be created by fostering significant clusters of focused skills and knowledge at a scale sufficient to become self-sustaining. These clusters need, and if they are of sufficient size, can attract lead researchers, management skills and capital financing for commercialization within Canada in order to address national and international markets. Critical masses clustered in geographic proximity are referred to as technopoles. To become optimally effective, a technopole must be of sufficient scale and substance so as to ameliorate the special constraints of development in the sector, and to allow innovations to be translated into timely social and economic growth.

Technopoles allow for easier technological bundling, for tacit knowledge exchange and for informal sharing of knowledge and skills. Technopoles rapidly become job magnets and job markets. From such clusters commercial activity is regularly spun off and regulatory capacity is simultaneously created. Within Canada such clusters are beginning to create the receptor capacity to successfully exploit indigenous commercializable products and processes.

The second key challenge is the need to reinforce Canada's research and innovation system to ensure that knowledge and research can be translated into innovative products and services. That system includes those firms, research organizations and institutions in the public and private sectors whose interactions create, import, modify, transfer and diffuse biotechnology within the context of an effective regulatory system.

The challenge is to create and sustain the relationships amongst these organizations to ensure the creation and uninterrupted flow of knowledge into innovation. Innovation cycles are more apparent and more self sustained in technopoles because of the close and ongoing interactions.

Strategic Issues Underpinning Consultations

Achieving sufficient scale to create one or more technopoles in biotechnology within a framework of federal fiscal responsibility implies that choices must be made. Strategic investment in these choices over a 5- to 10- year period could position Canada as the world's leading provider of a range of biotechnology products and processes with a matched set of non-regulatory and regulatory capacities to guarantee public health, safety and efficacy.

Governments have a key role in creating this dynamic and in supporting the strategic choices. Industry traditionally has a shorter return-on-investment horizon than is required for strategic investment in biotechnology. To capitalize on biotechnology requires a longer term investment to fully capture the benefits. There is also a need to develop a regulatory capacity which is effective and responsive to the dynamic needs of the industry. The research and development (R&D) consultations are one section of the CBS review to initiate these considerations because R&D is fundamental to the future of biotechnology in Canada and elsewhere.

Therefore the strategic issues underpinning the consultations are:

- **What are Canada's strategic research platforms today, and what will they be for the year 2005?**
- **What investments are needed to strengthen Canada's biotechnology innovation system?**
- **How can the federal government best use its research and development capabilities to realize the possibilities offered by biotechnology for Canada in the 21st century?**

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3. The Context

A strong R&D capacity is fundamental to innovation in terms of new biotechnology products and services. An effective research and innovation system is based on a nation's ability to undertake a number of related scientific activities; provide intellectual property protection; support effective technology transfer and commercialization; address issues associated with human resources and regulation of biotechnology products; and deal with a range of social and ethical questions.

The Canadian federal government has invested substantially in biotechnology R&D. In 1997, seventy-five percent of the $300 million contribution was oriented towards wealth generation (innovative); 15% was regulatory (in support of public and environmental health and safety), and 11% was basic (advancing science and the quality of life).

The majority of all expenditures were in health care and agri-food. The most active federal members in biotechnology R&D are Agriculture & Agri-food Canada (AAFC), Health Canada, and the National Research Council of Canada (NRC).

A part of the federal government investment in biotechnology research is in universities and hospitals through three granting councils. The largest biotechnology supporter among these is the Medical Research Council (MRC) whose 1996-97 budget of $242.4M was 70% devoted to research that is primarily or substantively biotechnology focused. The Natural Sciences and Engineering Research Council (NSERC) also provides support to university researchers, which includes $40.1M in 1996-97 for research in biotechnology. The Social Sciences and Humanities Research Council (SSHRC) does some biotechnology research in social issues.

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4. Why is Strategic Choice Essential?

A number of factors dictate that a ›gic choice is required among the possible biotechnology research platforms.

4.1 Optimizing Results from Available Research Resources

Canada does not invest nationally in R&D to the same extent that other countries do, and ranks behind the US, Europe, Japan, and now Taiwan and Singapore. Given this small support base, efforts to address all existing and emerging research directions in Canada, including biotechnology, is unrealistic and not a viable strategy for producing internationally competitive research groups or achieving the requisite scale to be self-sustaining.

4.2 Better Return on Canada's Investments in Innovation

For a whole range of reasons a significant number of Canadian biotechnology discoveries are sold rather early in the discovery cycle, thereby depriving Canada and Canadians of downstream control of their intellectual property and rewards for the R&D investment. Making strategic choices to build and sustain biotechnology companies and technopoles will allow investment to be concentrated sufficiently to better protect and develop intellectual capital.

4.3 Optimizing Results from National Capacities

Most analysts put Canada's contribution to global R&D in biotech at between 3% and 5%. If we are to be "leading edge" producers, Canada will have to focus this contribution quite specifically. Even if we are to be "rapid followers" we must be sufficiently capable to recognize best practice as it emerges and then rapidly adapt and deploy that technology. Either strategy requires critical questions to be answered, such as, "Where do we want to build the capacity to be leaders or 'rapid followers?'", and, "How can that strategy be used to gain leverage in further R&D in application/innovation, in manufacturing and stewardship, both domestically and internationally?"

4.4 Optimizing Private Sector Investment

Significant biotechnology R&D investments are made by multinational enterprises (MNEs), but these are predominantly in application-development and tend to locate near internationally competitive basic science groups, effectively leveraging national R&D investment. Focused public investments which create critical mass of sufficient scale would create technopoles that can create and drive market conditions to attract appropriate MNE investment.

4.5 Capitalizing on Canadian Experience

Canada already has successful experience with the R&D cluster dynamic and technopole effects. In communications technology, the Kanata, Ontario technopole has been well established and is now internationally self sustaining. In biotechnology, there is the example of Saskatoon and the initiation of a cluster around plant and animal biotechnology. Montreal is also developing as a centre of biotechnology activity in pharmaceuticals.

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5. Addressing the Strategic Issues

The R&D Public Consultation has been designed to present these issues to a broad spectrum of leaders and champions of Canadian science, to facilitate deliberation and to solicit consensus on the key principles that should frame future action and the next steps.

In order to initiate discussions in a systematic way, the following four deliberation points are suggested.

1. What will be the key research fields and key platform technologies in biotechnology over the next 10-15 years?

2. What is Canada's competitive position (research, knowledge and innovation) in these key biotechnology opportunity areas?

3. How can we best ensure that research is translated into commercial products for the global marketplace?

4. What criteria should be used for making choices among potential areas?

To provide scope and context for respondents, each of the consultation questions are examined and summarized in the accompanying pages. The object in posing this series of questions is to collect the informed and considered

opinions of Canada's science leaders about the most potent areas of science within biotechnology. Potency, in this case, is the potential for impact within any sector of application and particularly, potential for impact across many sectors.

QUESTION #1:

What will be the key research fields
and key platform technologies in biotechnology over the next 10-15 years?

Biotechnology has been employed by humans for millennia. But the recent research developments in molecular biology have given biotechnology new meaning, new prominence, and new potential. It is this "new molecular biotechnology" that has captured attention even though the revenue it generates is as yet only a fraction of that produced by traditional biotechnology.

Through the use of advanced tools, such as genetic engineering, biotechnology is poised to have a dramatic effect on the world economy over the next decade. Innovations emerging in the food and health care sectors offer only a hint of the enormous potential of biotechnology to provide diverse new products, including disease-resistant plants, "natural" pesticides, environmental remediation technologies, biodegradable plastics, novel therapeutic agents, bio-chips and biochemicals and enzymes that will reduce the cost and improve the efficiency of industrial processes.

Biotechnology has to date been focused primarily on the health field. The results of this research are having a profound impact on medicine and health care, providing improved approaches to the diagnosis, treatment, and prevention of disease. While health-related research remains a priority, researchers are poised to build on the common foundation in basic science to bring the power of biotechnology to bear in other fields. For example, agricultural biotechnology offers efficient and cost-effective means to produce a diverse array of novel, value-added products and tools. It has the potential to increase food production, reduce the dependency of agriculture on chemicals, and lower the cost of raw materials, all in an environmentally friendly manner. Environmental biotechnology's focus on bio-remediation promises the possibility of using living organisms or their products to degrade wastes into less toxic or non-toxic products and to concentrate and immobilize toxic elements, such as heavy metals, to minimize industrial wastes and rehabilitate areas fouled by pollutants or otherwise damaged through ecosystem mismanagement.

The demand for new and improved commercial products increasingly will be met through bio-processing, a type of advanced manufacturing that employs chemical, physical, and biological processes employed by living organisms or their sub-cellular components. Bio-processing can provide products with unique and highly desirable characteristics and offers new production opportunities for a wide range of items. Advances in molecular biology, bio-sensor technology, aquaculture, and bio-process engineering now promise fundamentally new approaches and opportunities for identifying, using, and managing biological resources, including those from the sea. Key platform infrastructure technologies are needed in support of research advances in biotechnology. These include advances in instrumentation, gene sequencing, and analytical tools.

Biotechnology research offers the possibility of a vast array of opportunities that are beyond the capabilities of any one country, government or innovation system. As a result, other countries have examined these opportunities with a view to making strategic choices and identifying key opportunities for themselves. These world leaders in biotechnology have then made sustained commitments to biotechnology, and to specific areas within biotechnology, even in times of budgetary restraint.

United States: In the early 1990's the US Federal Biotechnology Research Initiative brought twelve federal agencies to agreement about focusing their biotechnology activities on six areas of research and five infrastructure developments. The research areas are: health, general foundations, manufacturing/ bio-processing and energy. The infrastructure areas are training, instrumentation, facilities, repositories and databases.

Europe: Europe is beginning to identify, network and co-ordinate the components of key science platforms, such as structural biology, which underpin innovation and competitiveness in a broad range of life science-related sectors, including biotechnology. The European Union is also targeting training programs in biotechnology. Over the past two years ECU 18 million was focused in the areas of cell factories, genome analysis, animal genome mapping, animal models, cell communication in neurosciences, trans-disease vaccinology, bio-safety and bio-diversity.

Japan: In Japan a key emphasis in targeted public funds is to promote genomic R&D. The Council for Science & Technology (a cabinet level advisory committee) recently established a Genome Council charged with promoting national multidisciplinary genomic research overriding other research areas.
In support of this targeting and co-ordination effort, five government departments will receive substantial funding allocations for genomic research in their 1998 budgets and will co-ordinate their efforts through an inter-ministerial liaison committee.

QUESTION #2:

What is Canada's competitive position (research, knowledge and innovation) in these key biotechnology opportunity areas?

Some initial analyses have been conducted to document Canada's areas of strength in biotechnology. Statistics Canada, Canadian federal departments and the EuropaBio Organization have recently undertaken surveys using somewhat different terminology and underlying scope for biotechnology. Using the terminology provided in these three surveys, a composite lexicon was developed which provides a tool for sampling the research/technical competencies of organizations with an emphasis more in the "modern" or "advanced" than in "traditional" areas of biotechnology.

The terms in the master lexicon fall into several loose and overlapping categories:

1. DNA based
    - Genetic Engineering
    - Gene Probes
    - Bioinformatics / Genomics / Molecular Modelling
    - DNA Sequencing / Synthesis / Amplification
    - Gene Therapy
2. Biochemistry / immunochemistry based
    - Drug Design / Delivery / Pharmacogenetics
    - Diagnostic Tests / Antibodies
    - Peptide / Protein Engineering
    - Molecular / Cell Markers
    - Cell signalling / Cell Receptors
    - Biosensors / Biomaterials
    - Microbiology / Virology
3. Bioprocessing
    - Cell / Tissue Embryo Culture & Engineering
    - Bioprocessing / Biotransformation
    - Purification / Separation
    - Bioremediation
    - Natural Products Chemistry

The first two categories overlap because genetic engineering can be used to produce peptides, proteins, antigens and vaccines. Bio-processing is used to isolate and purify some of the items mentioned in the first two categories.

The key technical capabilities of Canadian biotechnology companies were determined using the 1997 version of the Canadian Biotechnology directory published by Contact Canada. These were then categorized using the terminology developed above. The biotechnology R&D expenditures of the companies as reported or interpreted from the directory were used as a measure of the relative effort in that particular technical field. Where companies had more than one key technical capability, as a first approximation all the company R&D effort was assigned to the one judged to be predominant.

The following table contains the results of the analysis. Around 15% of the Canadian bio-industry technical efforts (as measured by R&D expenditures) are focused on DNA based techniques. Another 65% are focused on biochemistry, immunology and micro-organisms. Finally, almost 20% are involved with using micro-organisms or enzymes to modify or process substances as well as with the processes for analyzing and separating out the products of such processing.

The two areas where there was the most technical capacity were drug design/ delivery/ pharmaco-genetics (32%), and antigens/ vaccines (23%). Both of these areas are focused on human and animal (including fish) health and could indicate a potential for capitalizing on opportunities resulting from the findings of the Human Genome Project. However, a key capacity for undertaking this is poorly represented in Canadian industry (gene therapy 2%).

Other areas of significant industrial capability are genetic engineering (11%) as applied to micro-organisms, plants and animals, bio-processing/ bio-transformation (5%), and bio-remediation (4%). These indicate potential for harnessing capabilities to develop "green" or more sustainable industrial processes for application in Canada's resource industries.

Based on the 1995-96 data from the Contact Canada directory, it appears that Canada has a relatively fledgling

effort in bio-informatics, genomics and gene probes or gene therapy, all key fields for future competitiveness in the health biotechnology sector.

A somewhat different set of conclusions is apparent in an analysis of reported core biotechnology competencies within federal government departments. Within the federal government the strength in biotechnology lies in

- bio-informatics, genomics and molecular modelling; genetic engineering, and
- to a lesser degree, and more focused on wealth generation, there is federal government strength in biological control and bio-pesticides, microbiology and virology, bio-remediation and mine effluent treatment.

Canadian Biotechnology Technical Capabilities

Bio-Technical Capability	Relative Industrial R&D Effort (%)		Stated Government Actvity	
		Innovative	Basic	Regulatory
DNA Sequencing / Synthesis / Amplification	2.1			
Bioinformatics / Genomics / Molecular Modelling	0	x	x	x
Genetic Engineering	11.4	x	x	x
Gene Probes	0.3	x	x	x
Gene Therapy	1.8			
Drug Design / Delivery / Pharmacogenetics	32.0	x		
Peptide / Protein Engineering	1.2			
Diagnostic Tests / Antibodies	4.4	x	x	x
Antigens / Vaccines	22.8	x	x	
Cell Signalling / Cell receptors	0.3			x
Biosensors / Biomaterials	2.5	x	x	x
Microbiology / Virology	4.6	x	x	x
Biological Control / Biopesticides	2.3	x		x
Bioremediation	3.7	x	x	x
Bioprocessing / Biotransformation	5.4			
Purification / Separation	1.2			
Cell / Tissue Embryo Culture & Engineering	2.4	x		
Natural Products Chemistry	1.6	x	x	
Ecotoxicology, environmental biology		x	x	x
Organic/analytic chemistry		x		
Environmental impact studies		x	x	

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QUESTION #3:

How can we best ensure that research is translated into commercial products for the global marketplace?

Identifying the strategic directions and opportunities for biotechnology research for the coming decades and understanding Canada's positioning are the first challenges in establishing in a research and innovation framework. The answers and choices will determine the research platforms and competencies that need to be nurtured and developed in order to sustain a viable biotechnology sector in Canada.

Investments in biotechnology research alone are not enough. A second key challenge is the need to reinforce Canada's research and innovation system to ensure that knowledge and research can be translated into commercialized products and processes. That system includes those firms, research organizations and institutions in the public and private sectors whose interactions create, import, modify, transfer and diffuse biotechnology. The challenge is to create and sustain the relationships amongst these organizations to ensure the flow of knowledge into innovation.

In addition to the important research efforts within universities and hospitals, the innovation includes key federal government departments and agencies such as Agriculture and Agrifood Canada, National Research Council, Health Canada, Natural Resources Canada, Environment Canada and the Department of Fisheries and Oceans. A 1997 Statistics Canada survey revealed that 348 firms reported total industrial biotechnology R&D expenditures of $341 M in 1995. This is up from 207 firms reporting just $116 M in 1989.

Canada's biotechnology sector includes a number of federal government programs that support research and innovation. The National Biotechnology Strategy (NBS) support to industry via the NRC - IRAP program provides SMEs with technical and financial support for R&D projects.

The Medical Research Council and NSERC, NRC's IRAP program and Industry Canada's Technology Partnerships Canada all provide assistance to universities and firms for research, network building, technology transfer and commercialization. For example, the Networks Centres of Excellence have fostered excellence and creativity in research, built multi-investigator and multi-partner research programs and created spin-offs and financial vehicles
to help transfer and commercialize technology.
In addition to the federal government, provincial governments provide support to biotechnology through support programs and research institutes.

While the data is not complete, the level of expenditures for biotechnology R&D in Canada for 1997 was over $750 M. The distribution of expenditures in various organizations is:

- $341 M in industry
- $160 M in federal laboratories and institutes
- $144 M by federal granting councils
- $115 M by private not for profit organizations

Based on a 1997 survey of core biotechnology firms, Canada has 224 such firms, of which 72% are small companies with 50 or fewer employees. Most of these firms are found in Quebec and Ontario (57 %). Clusters of biotechnology firms can be found in such locations as Vancouver and Saskatoon where a strong infrastructure of government, university and federal departments has attracted agricultural based biotechnology firms. BC has a strong bio-health-care sector in part due to the prolific university spin off activities and favorable venture capital and Vancouver Stock Exchange listing procedures.

Capital financing for biotechnology amounted to $2 B for the period 1991-96. Over 93% of this was in the human health care sector. Even so, when a new drug costs over $250 M to develop, the funds available are barely enough to complete the development of those products already in the pipeline let alone cover the future ones, whether they be for human health care or in agriculture, forestry, or environment.

The biotechnology innovation system's capability to transfer technology and commercialize it is quite variable but is beginning to show significant results. Of the new drug chemicals introduced world wide between 1971-89, none were developed in Canada. More recently, new Canadian biopharmaceuticals are being developed and as of June 1996, more than 100 biotechnology and life science products were in the pipeline for pre-clinical or clinical trials.

At the same time, there has been a growing number of university spin off firms being formed in the life sciences, including BioChem Pharma, which in terms of market capitalization is now the 4th largest biopharmaceutical company in the world.

Even with these signs of success and growth, Canada's biotechnology system lacks competitive strength. There

are gaps in the flow of research to technology development and commercialization. Canadian firms and institutions generally lack technology evaluation and transfer expertise. In comparison with other OECD countries Canada's biotechnology system lags behind, if only in comparison to the investment of other countries. The US federal spending on biotechnology is $6 B annually; Germany spends $900 M per year. Members of the European Union have a combined budget for biotechnology of over $4.4 B. Japan has made a $1 B strategic commitment over the next 10 years to neuroscience, another $1 B investment plan for marine bio-sciences.

If an effective innovation system is characterized by the strength of its relationships amongst firms, institutions and organizations, as well as its linkages to financial institutions and venture capitalists, then Canada's system can be said to have some significant innovation gaps. There are promising efforts in this regard by MRC and NSERC to link universities and firms, and venture capitalists to research endeavours. NRC's IRAP network also connects SMEs to research institutions and technical advice from across Canada. NRC's research institutes and other federal departments and agencies interact with a multitude of small companies and multi-national enterprises. It is recognized that more is needed to promote better co-operation and collaboration across industries, amongst federal, provincial and municipal governments and between Canada's multinational and SME firms.

Canada's future biotechnology innovation system will require a greater ability to use and manipulate enormous amounts of data. Canadian research institutions, universities and firms will need databases and data networks. Bio-informatics promises to underpin research and support the development of nation-wide research networks.

QUESTION #4:

What criteria should be used for making choices among potential areas?

The previous sections address the need to make strategic choices in the face of emerging research opportunities, the needs associated with having an effective system that translates knowledge into innovation in Canada, and given the Canada's research and innovation positioning in the world. These have addressed the "what" issues—*what decisions must Canadians take to realize the potential for biotechnology in this country and for the federal government to meet its policy mandates?*

Given the complex and long term nature of biotechnology research and innovation, decision-making and direction setting must be sustained over a long period of time. This leads to the important question: *What are the principles and criteria that need to be used by decision-makers in governments, institutions and organizations to make decisions among all possible research platforms in biotechnology, and among all possible innovation support techniques?*

Some of these criteria are already evident in statements by governments on their role as a catalyst for science, technology and innovation. The federal government has recognized the need to address the gaps in the current innovation system and those things that work to drive it in Canada. As Minister of Finance Paul Martin recently stated:

"Knowledge-based growth offers the prospect of equalizing opportunities across the country. Our goal must be nothing less than to change the economic culture of Canada to one of innovation. And what this means is creating synergy amongst the components of innovation in Canada."

In Canada and around the world, criteria have been developed to help make strategic research and innovation decisions. Policy options, plans and strategies are typically examined using such criteria:

1. Fit with public policy goals:
    - how plans and strategies ensure that jobs are created, sustained, economic growth occurs and international competitiveness is enhanced,
    - safeguarding Canadians' health, safety and the environment,
    - that biotechnology is developed responsibly for the maximum benefit of Canadians now and in the future.
2. Canada's knowledge base, research, and capabilities are advanced:
    - Do the plans, strategies and investments provide Canada with a scientific competitive advantage?
3. Canada can retain the benefits of research and innovation:
    - Does Canada have the receptive and innovation capacity to maximize the benefits of biotechnology research for Canadians?
4. Canada's long term research and innovation system is strengthened:
    - Do plans and strategies address gaps in Canada's research and innovation system so that there is greater access by Canadians to the benefits of biotechnology?

Other criteria will be equally important and need to be identified in the course of creating an overall strategy for biotechnology. Given biotechnology's complexity, and its diverse and changing nature, good information will be a prec ·sor to effective decision-making. The need for strategic choices focused on distant opportunities will require the ability to foresee the future. A biotechnology strategy requires a good foundation of scientific and technical information, the institutions to provide and dissemination the information, and the organizations and networks to convert information into intelligence

One tool that governments around the world are recognizing as critical to sound scientific decision-making is technology foresight or competitive intelligence. Technology foresight is a systematic review in both short and longer terms of emerging generic technologies likely to yield the greatest economic and social benefits.

First amongst the information needs is a good understanding of the dimensions of biotechnology research and innovation in Canada. At present there are no clear indicators or measurement of biotechnology and Canada's biotechnology industry, and there is an incomplete understanding of the nature of biotechnology research and technology efforts. Filling in these information gaps, partly by the direct consultation process, and indirectly with follow-up dialogue, will significantly enhance the government's mandate for formulation of the CBS renewal.

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