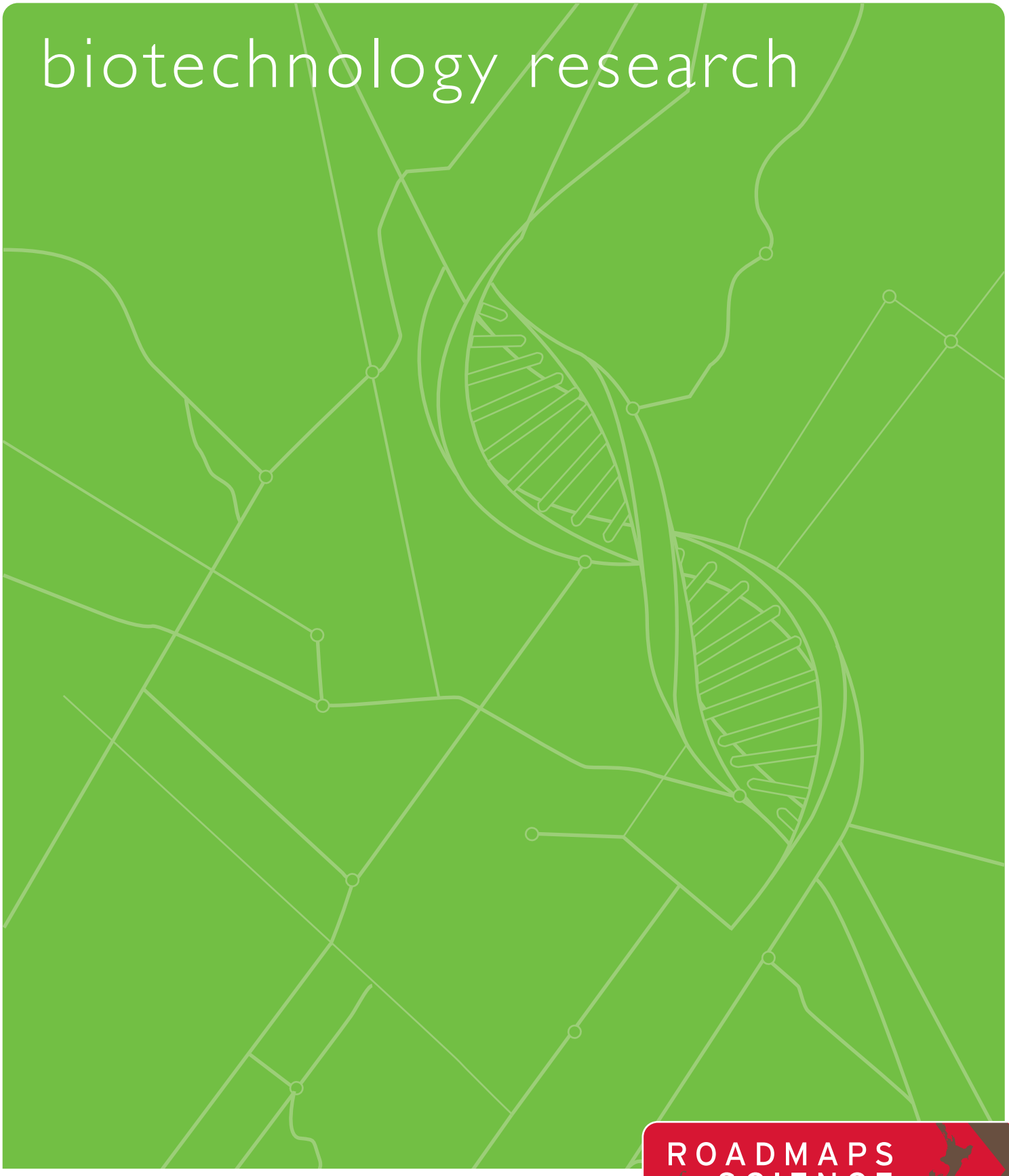
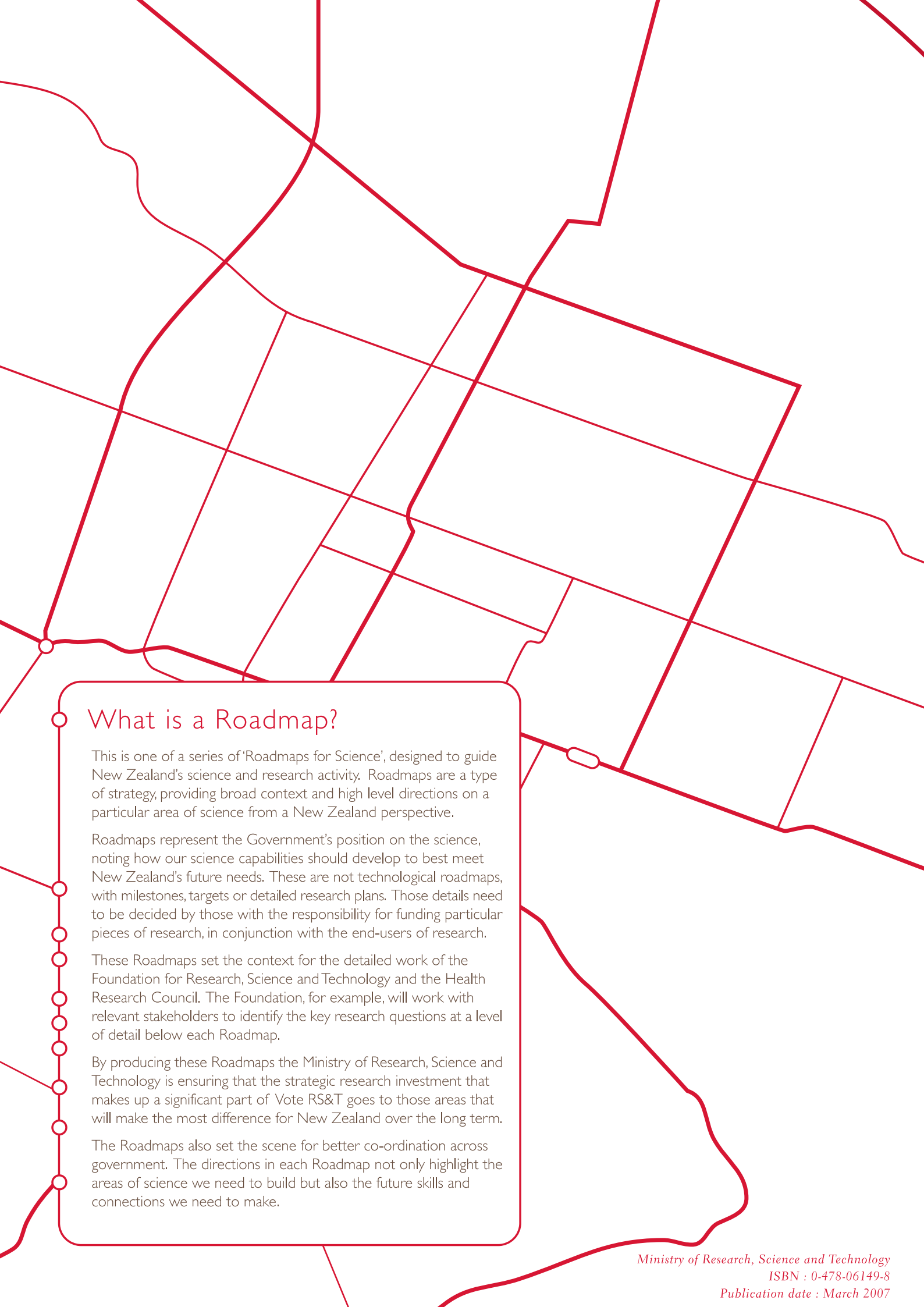
MINISTRY OF RESEARCH SCIENCE + TECHNOLOGY

MoRST
TE MANATŪ PŪTAIAO

biotechnology research



ROADMAPS for SCIENCE



What is a Roadmap?

This is one of a series of 'Roadmaps for Science', designed to guide New Zealand's science and research activity. Roadmaps are a type of strategy, providing broad context and high level directions on a particular area of science from a New Zealand perspective.

Roadmaps represent the Government's position on the science, noting how our science capabilities should develop to best meet New Zealand's future needs. These are not technological roadmaps, with milestones, targets or detailed research plans. Those details need to be decided by those with the responsibility for funding particular pieces of research, in conjunction with the end-users of research.

These Roadmaps set the context for the detailed work of the Foundation for Research, Science and Technology and the Health Research Council. The Foundation, for example, will work with relevant stakeholders to identify the key research questions at a level of detail below each Roadmap.

By producing these Roadmaps the Ministry of Research, Science and Technology is ensuring that the strategic research investment that makes up a significant part of Vote RS&T goes to those areas that will make the most difference for New Zealand over the long term.

The Roadmaps also set the scene for better co-ordination across government. The directions in each Roadmap not only highlight the areas of science we need to build but also the future skills and connections we need to make.

Ministry of Research, Science and Technology
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ROADMAPS *for* SCIENCE

A GUIDE FOR NEW ZEALAND SCIENCE ACTIVITY

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Preface

The Government recognises the critical role science and innovation have in driving New Zealand's transformation to a high-value, knowledge-based economy and society. Our focus has been on ensuring research, science and technology deliver on their potential as drivers of economic, social and environmental improvement.

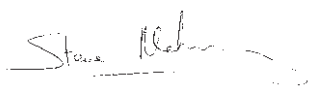
The Roadmaps for Science series represents an important step in providing more explicit guidance on science directions. They cover areas of scientific and technological research and development that present significant opportunities for New Zealand and where we feel more direction will help us make the most of those opportunities. This will ensure New Zealand is well positioned to identify future research programmes and direct our efforts towards meeting our long-term needs.

Biotechnology is an area which is playing a central role in driving long term economic growth and prosperity for New Zealand. Biotechnology research is the engine which fuels biotechnology sector growth and which will help to sustain and transform New Zealand's biologically-based industries. Biotechnology research will also provide the knowledge and tools which will assist in protecting our pristine natural environment.

The Biotechnology Research Roadmap acknowledges the long-term nature of investing in and capitalising from biotechnology research. It sets a series of enduring directions designed to ensure certainty and stability for the government's biotechnology research investments over time.

In part, these directions confirm existing research priorities which are working well, like the setting of joint targets and co-investment mechanisms for applied research investments with industry. It also identifies a range of areas where additional or re-focused efforts will need to be made for New Zealand to capitalise from emerging areas of opportunity or challenge, like emerging sustainable development challenges.

Over the coming months and years we will be introducing Roadmaps in other areas of science where we see a need for them. The Roadmaps for Science will serve us well in ensuring research, science and technology provide a strong platform for an innovative and prosperous New Zealand.



Hon Steve Maharey, Minister of Research, Science and Technology

Summary

Biotechnology research has critical roles in New Zealand. It is a mainstay of growth for New Zealand's predominantly biological economic base, providing new knowledge to keep and develop our competitive advantages. It will transform our primary sector into one producing increasingly value-added and environmentally sustainable products and processes. Biotechnology research is also fuelling the new biotechnology-based industries and enterprises of the future, including New Zealand's drug development, medical device and ag-biotech enterprises which are linked to global research partners and markets. It underpins biodiversity and biosecurity management in New Zealand and also drives innovations within the global healthcare sector to benefit the health of New Zealanders.

The importance of biotechnology research to New Zealand is reflected in the proportion of government research funding spent on it. At 25% of total government R&D investment (or around $195 million per annum), this is proportionally the highest share of government-funded biotechnology research in the OECD. Our research profile mirrors our industrial base and its dependence on the environment. We have particular strengths in plant and animal biotechnology and environmental biotechnology research leveraged from our stringent biosecurity management system and history of innovation in farming practice. New Zealand also has world-class expertise in some key biomedical research niches.

Government initiatives over the past five years have put into place the 'development with care' approach of the New Zealand Biotechnology Strategy. Changes have included the establishment of a new industry body, NZBio; support for research commercialisation; streamlined regulations; more public information about biotechnology; and the development of a whole of government approach to policy. These measures have, however, focused on the wider business, policy and public settings for biotechnology and not the strategic directions for biotechnology research. This Roadmap, developed by the Ministry of Research, Science and Technology (MoRST), addresses the gap.

This Roadmap identifies four main objectives for New Zealand's involvement in biotechnology research:

- Biotechnology research should contribute to economic transformation, through higher productivity, higher value products and diversification of the economy.
- Biotechnology research should assist in protecting the natural environment and developing environmentally sustainable industries.
- New Zealanders should benefit from biotechnology developments which will improve their health and wellbeing.
- Biotechnology research should be developed and managed responsibly.

The Roadmap also outlines eleven key directions (summarised on the next page) and associated actions for biotechnology research. These include directions which:

- affirm some existing directions and trends considered to be on track, such as the high level balance of research investment supporting New Zealand's bio-based industries and emerging opportunities from biomedical research;
- signal a number of areas where changes should be made, such as strengthening research and industry linkages and tailoring co-investment models for fragmented industry sectors; and
- indicate areas where New Zealand will need new capabilities, for example, to address future environmental sustainability challenges or to capitalise on areas of future opportunity, such as in the marine and food and beverage sectors.

MoRST will keep the directions and actions under review and track indicators of progress. MoRST will also advise the Government on the need to refresh directions by 2011.

Directions :

1 Introduction

1.1 Why a Biotechnology Research Roadmap?

In deciding to develop this Roadmap the Minister of RS&T recognised a number of distinctive aspects about the role that biotechnology research plays in New Zealand:

- Biotechnology research has a key role to play in driving economic transformation in New Zealand, both through incremental productivity gains in the primary sector and diversifying the economy through the emergence of new firms and economic niches.
- Biotechnology research also has an important environmental role to play, for example, through the development of tools and techniques to protect New Zealand's environment from biosecurity incursions, as well as assisting our industries in developing cleaner, more sustainable industrial processes.
- New Zealand cannot invest in the full range of R&D associated with biotechnology or compete effectively with global efforts in some areas. New Zealand needs to be selective in the areas it chooses, and this Roadmap has a role in helping guide those investment choices.
- Biotechnology applications can raise cultural and ethical issues and ongoing research is required to gauge how New Zealanders view them and how we can best respond to these issues.

In preparing this Roadmap we have:

- worked closely with an Advisory Group[1] that has advised on the context, issues and directions;
- developed an analysis of New Zealand's current biotechnology R&D, *The New Zealand Biotechnology Research Landscape*;
- held a series of regional workshops (May 2006) with, and received formal submissions from, research, industry and government agency representatives (October 2006);
- commissioned a report to quantify the Government's investments in biotechnology research;[2]
- built on the work that has been completed following on from the publication of the *New Zealand Biotechnology Strategy and The Biotechnology Taskforce Report*; and
- drawn information from a range of research and policy reports (listed in Annex One: References).

[1] Representatives on the Advisory Group were from the Foundation for Research, Science and Technology (FRST), the Health Research Council (HRC), the Royal Society of New Zealand, the Ministry of Agriculture and Forestry, New Zealand Trade and Enterprise (NZTE), the Biotechnology Taskforce and NZBio.

[2] Gilbertson (2005): *Analysis of New Zealand Government Investment in Biotechnology R&D 2004/05 Funding Year* (partially updated by MoRST, March 2006)

1.2 Scope of this Roadmap

Since 2002, the New Zealand Government has invested considerable effort in developing an integrated, strategic approach for this country's biotechnology sector. The Government's overarching strategic framework for "development with care" balances the drive for economic transformation with the need for effective regulation and engagement with the wider community.

In 2003, the *New Zealand Biotechnology Strategy* and the report of the Biotechnology Sector Taskforce were published detailing a series of actions and recommendations to move the sector forward. Many of these actions have now been implemented. Key efforts have concentrated on:

- Research Commercialisation: addressing the roadblocks in the research commercialisation process, notably access to pre-seed and early stage funding – through the development of the Pre-Seed Accelerator Fund and Seed Capital Investment Fund as well as contributing to a dedicated biotechnology Venture Investment Fund;
- Regulation: streamlining regulatory processes – by improving the Hazardous Substances and New Organisms (HSNO) Act[3] and improving access to information about the regulatory system;[4] and
- Community Engagement: improving New Zealanders' access to information about biotechnology - via the travelling Biotechnology Roadshow and the Biotechnology Learning Hub.

Actions to date to strengthen the position of biotechnology research have included increasing Government funding of biotechnology research through Vote RS&T by about $15-20 million per annum since 2002, and strengthening support for the funding of research into the ethical, social and economic aspects of biotechnology.

One action which has not, so far, been addressed directly is a call for more strategic approaches to biotechnology research investment, recommended in both the *Biotechnology Taskforce Report* and the *Biotechnology Strategy*. This Roadmap is the Government's response to these recommendations.

This Roadmap, therefore, concentrates on biotechnology research per se and not the broader environment surrounding it. This has been addressed by other actions coming from the Biotechnology Strategy and Taskforce reports.

Other issues, specifically human resources in science and technology (HRST), are not addressed by actions in this Roadmap because they are currently being addressed through other MoRST policy initiatives.

1.3 Audience

The primary audiences for this roadmap are:

- Agencies with responsibility for investing in publicly funded research through Vote RS&T, notably the Foundation for Research Science and Technology (FRST) and the Health Research Council (HRC);
- Research communities involved in biotechnology research;
- The New Zealand biotechnology sector and other industry sectors that will benefit from, or otherwise be affected by, the uptake of biotechnology research; and
- Government agencies with an interest in the applications and implications of biotechnologies.

[3] The New Organisms and Other Matters Bill

[4] The Biotechnology Regulatory Wayfinder: http://www.morst.govt.nz/wayfinder/

2 International context

Section summary

- The global biotechnology sector is maturing and total revenue is on a steady upward growth path.
- The United States is the dominant player in the global sector, but the Asia-Pacific region is growing rapidly.
- Governments are investing vast amounts of R&D funding into biotechnology research and infrastructure development.
- The primary focus of global efforts is the health biotechnology sector.
- Industrial biotechnology is being touted as the "next big thing" and investment is currently being driven by concerns around energy security and mitigating climate change impact.
- Research funding trends show a shift towards funding interdisciplinary research teams and research at the convergence of disciplines to drive discovery and innovation.
- Societal reactions and concerns remain an important barometer of the acceptability of emerging biotechnologies.

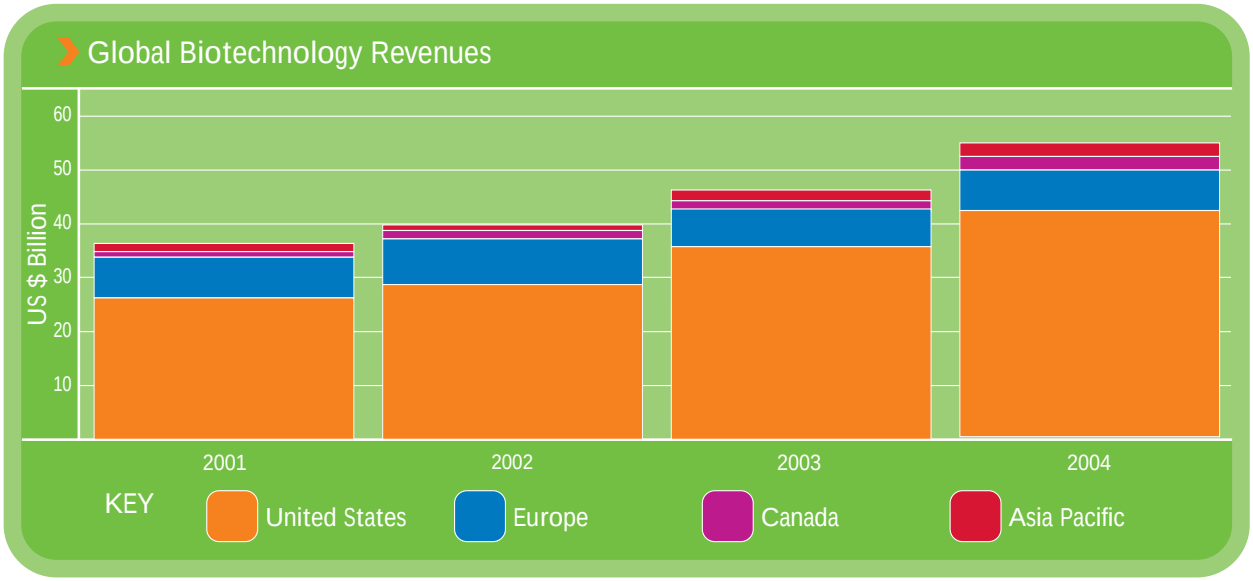
2.1 The global biotechnology sector

Biotechnology became a distinct sector in the United States (US) in the mid 1970s and has since developed into a truly global industry. The US still has by far the largest share of global revenues from biotechnology.

This is followed, at some distance by Europe, whose share of global revenues is diminishing, due in part to the rapid growth of the biotech sector in the Asia Pacific region (*Figure 1*).

Figure 1

Global biotechnology revenues 2001-2004
Adapted from Ernst and Young – *Global Biotechnology Report* – 2003, 2004 & 2005



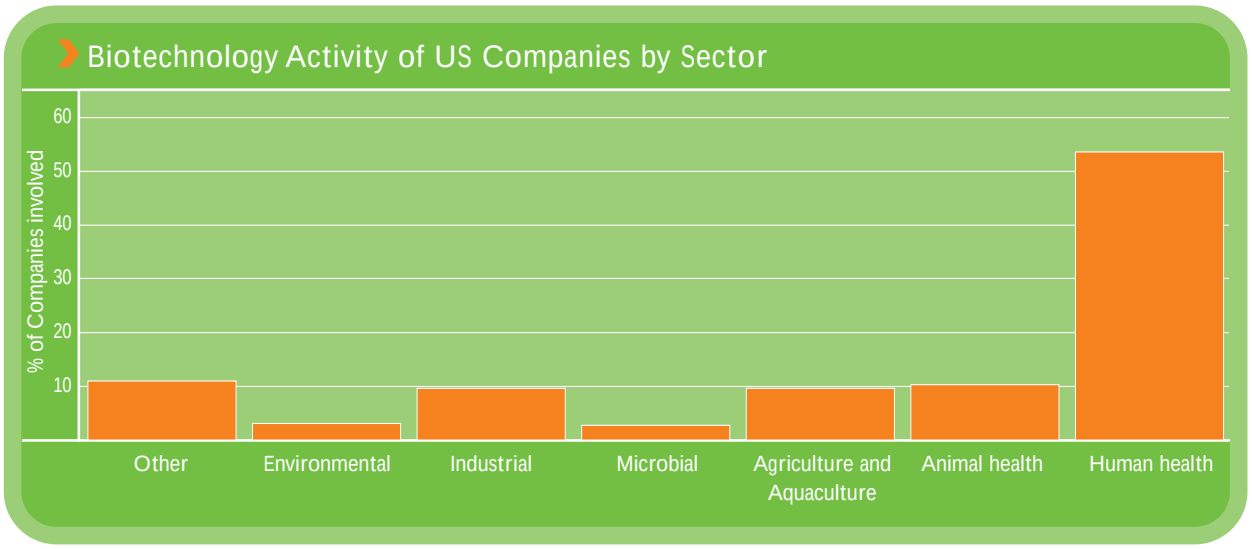
The biotechnology industry has grown up on a pattern of "boom and bust" investment cycles. These are characterised by periods when stock prices soar and initial public offering opportunities arise, followed by relatively long stretches when investors keep their distance from the sector.[5] Despite this volatility, *Figure 1* shows that the global biotechnology industry is currently on a steady incremental growth path.

This growth is projected to continue. This can be seen by the number of countries developing more established biotechnology sectors and increasing scale within the industry. For example:

- Canada and Germany are beginning to show signs of a more mature biotechnology industry, which can be characterised by growing revenues from biotechnology products and processes and a workforce that is no longer purely focused on R&D, but also on production, marketing and sales.[6]
- The emergence of mature "big biotech" companies, notably in the biopharmaceutical sector, that are beginning to successfully compete with the large multi-national pharmaceutical companies for deals.[7]

The US biotechnology sector and therefore the global biotechnology industry is dominated by the human health sector. A survey of the US industry in 2003 by the Department of Commerce[8] found that 54% of responding biotechnology companies were involved in this broad sector *(Figure 2)*.

Figure 2



[5] Ernst and Young (2005), *Coming of Age – The Global Biotechnology Industry*

[6] OECD (2004), "The Economic Impacts of Biotechnology – An Introduction" – Working paper of National Experts on Science and Technology Indicators, DSTI/EAS/STP/NETI (2004), p.6

[7] Thiel, Karl. A, (2005), "A Firm Handshake: biotech's growing negotiating power", *Nature Biotechnology*, v23, n10, p.1221-1226

[8] US Department of Commerce, Technology Administration, Bureau of Industry and Security (2003), *A Survey of the Use of Biotechnology in US Industry*

2.2 Research trends

The sustained growth of the global biotechnology sector has been stimulated in great part by massive government investments in R&D and research infrastructure. Research powerhouses like the US invest billions of dollars in biotechnology research through a myriad of Federal agencies. Increasingly, there are also considerable efforts in the US at State level to attract biotechnology researchers and investment. A notable recent example is the California-based, $US3 billion (over 10 years) State supported Institute for Regenerative Medicine.

In recent times the Asia-Pacific region has made significant investments in biotechnology research, as governments see the prospect of tapping into the growing global biotechnology market.[9] These sustained government investments have helped to stimulate the return of qualified expatriates, recruitment of offshore scientists and an inflow of private capital, both domestic and offshore, into the biotechnology sector. Key examples include:

- South Korea, which has invested heavily in biotechnology research with recent government expenditure more than doubling from $NZ965 million in 2002 to $NZ1.9 billion in 2005;[10]
- Singapore recently announcing that its biotechnology budget for the next five years would increase to $NZ11.6 billion to support capital investments in infrastructure initiatives such as the Biopolis biomedical science centre;[11] and
- China invested an extra 12 billion yuan (US$1.5 billion) into biotechnology R&D between 2001 and 2005.[12]

Biotechnology research also has a close relationship with developments in other areas, such as Information and Communication Technology (ICT), and increasingly with emerging developments in nanotechnology. ICT in particular has an increasingly symbiotic relationship with biotechnology. Advances in computing power and analytical software are vital to help make sense of the exponential amounts of data that the biological sciences are generating.

Internationally, research funding agencies are trying to drive the development of inter-disciplinary research teams and platforms to capitalise on opportunities presented by the huge quantities of data. The emergence of these types of research programmes recognises the fact that "siloed" disciplines can no longer be relied upon to answer complex questions. An example of the kinds of approaches being undertaken is in Biocomplexity in the Environment,[13] one of the US National Science Foundation's (NSF) priority research areas. The NSF's funding in this area actively incentivises inter-disciplinary research in the biological, environmental and physical sciences to investigate the interactivity of biota and the environment. Emerging evidence is also suggesting that biotechnology companies who hire researchers from a variety of fields innovate (in terms of rates of new patents and initial public stock offerings) more than those that employ only molecular biologists.[14]

[9] Louet, Sabine (2004), "E&Y Report backs Asia-Pacific biotech", *Nature Biotechnology* vol 22, n7, p.789-790

[10] STAT-USA Market Research Report: Korea

[11] Singapore Agency for Science Technology and Research (A*Star): http://www.a-star.edu.sg/astar/index.do

[12] Wu Chong (5 September, 2005), "Biotech research investment advocated", *The China Daily*

[13] NSF Biocomplexity in the Environment Program: http://www.nsf.gov/geo/ere/ereweb/fund-biocomplex.cfm

[14] Vastag, Brian (2006), "Multidisciplinary staff proves winning combination", *Nature Biotechnology*, v24 n10, p.1187

2.3 Future outlook[15]

Recent and continuing advances in the life sciences have led to an oft-cited assertion that the 21st Century will be the "biotechnology century".[16]

A wide range of biotechnology R&D activities are maturing at a rapid pace. Over the next twenty years these are projected to significantly affect the healthcare and primary production sectors and contribute to more sustainable manufacturing processes and industrial products.

Outcomes predicted include:

- healthcare technologies drawing on genetics, genomics, and proteomics that promise better, more personalised health outcomes;
- regenerative cell therapies fuelled by advances in stem cell research;
- more sustainable and value-added food and fibre production systems;
- cleaner, more efficient biofuels;
- enzymatic processing in manufacturing that cuts energy and water consumption and the generation of toxic wastes; and
- the production of novel biomaterials for medical and industrial purposes.[17]

Emerging biotechnology developments are being influenced by a range of drivers. These include:

- demographic trends such as longer life expectancies (especially in developed countries), decreased fertility and delayed reproduction, and increased consumer demand for the medical "treatment" of non-pathological "disorders"; and
- sustainability drivers spurred by the need to respond to issues like climate change and fossil fuel dependency.

2.4 Market trends

Each of the key biotechnology sectors – health, agricultural and industrial biotechnology – are currently all at differing stages of maturity. As a result, areas such as the commercialisation of biopharmaceuticals have a clear pathway to market, whereas routes to market are less well characterised for industrial and environmental biotechnology because of their earlier stage of development.

2.4.1 Health biotechnology

The most mature global biotechnology market is currently the healthcare sector. In fact, growth in this market has underpinned the sustained growth of the whole global biotechnology industry to date.

Ninety percent of current global value from biotechnology is derived from biopharmaceuticals alone and the vast majority of biotechnology firms are working across this broad field. Fifteen percent of all drugs are currently based on biotechnology and this is projected to grow to 40 percent by 2010.

To add weight to this projection, more than 30 percent of drugs currently in development are biological.[18]

Beyond the projected biological drug "pipeline", rapid advances in both stem cell research and the neurosciences are driving developments in regenerative medicine. There is still, however, much basic research to be performed to understand the underlying biology of areas such as stem cell science, not to mention many ethical issues which are accompanying developments.

[15] For a more in-depth summary of future biotechnology issues and trends see: MoRST (2005), *Futurewatch: Biotechnologies to 2025*: http://www.morst.govt.nz/current-work/futurewatch/biotechnologies-to-2025/

[16] Rifkin, J (1998), *The Biotech Century*

[17] OECD (2005), *The Bioeconomy in 2030*

[18] OECD (2004), *The Economic Impacts of Biotechnology – An Introduction* – Working paper of National Experts on Science and Technology Indicators, DSTI/EAS/STP/NETI(2004), p.6

2.4.2 Agriculture biotechnology

The global agricultural biotechnology sector is currently dominated by GM crop applications. Today, just six countries[19] account for 99% of the world's commercially grown GM crops. Their rate of adoption has increased 30 fold from the time the technology was first introduced in 1996; from 1.7 million hectares to 90 million hectares in 2005.[20]

Agricultural biotechnology is, however, much more than GM crops. Primary production sectors are forecast to be transformed through both the sustained productivity enhancement of GM and non-GM crops and animals, and the diversification of primary sector commodities to produce more value-added outputs, like bioactives and nutraceuticals.

2.4.3 Industrial biotechnology

Industrial and environmental biotechnologies are often referred to as the "third wave" of developments in biotechnology. Industrial biotechnology today chiefly consists of bioprocessing technologies (using micro-organisms and enzymes) for specialty products such as detergents, novel foods and some pharmaceuticals.

Future projections envisage a growth in the production of renewable commodity products (for example, biopolymers, fuels and energy from woody biomass), supported by a growth in the scale of production capacity and the emergence of "biorefineries" producing multiple product streams (analogous to today's petrochemical refineries).

There has been a significant upswing in investments and interest in industrial biotechnology over the past 12-18 months. This has primarily been directed at biofuels technologies driven by energy security concerns, the rising cost of oil and the need to reduce petroleum dependency as well as concerns around greenhouse gas emissions from petroleum fuels. Large markets are only just starting to become established for industrial biotechnology products such as biofuels and the economics of commodity bio-products has not been proven at a large-scale. By its very nature industrial biotechnology is more broad and diffuse and the success of the sector is more dependent on technologies filtering through to different manufacturing sectors.[21] However, the productivity gains and cost reductions that industrial biotechnology processes are adding to areas like pharmaceutical manufacturing are becoming increasingly significant.

2.5 Security and defence

In the wake of events like the September 11, 2001 attacks, many nations have reviewed and updated their strategies to counter bio-terrorism. These updated "biodefence" strategies and suggested surveillance requirements are strongly underpinned by the development of several biotechnology based counter-measures.

Biotechnologies underpinning biodefence systems fall under the following response categories: early warning through biological detection systems; and advanced vaccines, diagnostics and therapeutics. Emerging diagnostic devices (biosensors) are currently showing particular promise and will have spill-over benefits for other areas like food safety and environmental monitoring.

[19] United States, Canada, Argentina, China, Brazil and South Africa

[20] James, Clive (2005), "Global Status of Commercialized Biotech/GM Crops: 2005"

[21] Sheridan, Cormac (2006), "Diversa restructures, raising questions over bioprospecting", *Nature Biotechnology,* v24, n.3, p.229

2.6 Biotechnology and society

No technology develops in isolation and biotechnology is notable for its rich connections with society. These connections are two way: biotechnology both shapes, and is shaped by, a wide range of factors. The linear development path, "technology push" characterised by the "technology pipeline" does not always hold true for biotechnology applications.

Events like the strong consumer push-back on genetically modified food in key global markets such as Europe and Japan is a result of this complex environment. The most recent Eurobarometer survey of European's attitudes to genetically modified (GM) foods reinforced this trend, concluding that overall Europeans think that GM food should not be encouraged.[22] These findings are not as black and white as they may appear at first glance however. Other research findings have revealed that a significant percentage of consumers in European countries appeared willing to choose GM food, provided there is a price advantage coupled with a consumer benefit.[23]

These can roughly be described as "push" and "push-back" factors. For example, on one hand demographic trends like aging populations will stimulate or "push" the development of biotechnology applications to combat the growing prevalence of diseases of the aged like Alzheimer's. Whereas, on the other hand factors like ethical and religious objections to research using embryonic stem cells in countries such as the United States in particular will have potential impacts on the pace of technology development.

[22] Gaskill, G et al (2006), *Eurobarometer 64.3 – Europeans and Biotechnology in 2005: Patterns and Trends*, p. 4

[23] Knight, John et al. (2006) *Willingness of Overseas Consumers to Purchase Genetically Modified Food Products – Final Report to AGMARDT*, p.2

3 New Zealand context

Section summary

- New Zealand has a predominantly biological economic base, with 65% of total goods exports coming from the primary and food and beverage sectors.
- New Zealand's primary industries are facing challenges including the sustainable use of natural resources and changing international market conditions.
- The New Zealand biotechnology industry sector has largely evolved from this primary production base and a heritage of 150 years of genetically enhancing crops and animals.
- New Zealand's biotechnology industry mix is very distinctive when contrasted with the composition of the global industry which is overwhelmingly weighted towards the health biotechnology sector.
- The biotechnology sector has grown and consolidated over the past five years, but is still immature with the predominant use of biotechnology techniques being used in the R&D phase.
- A number of New Zealand-based health biotechnology companies are maturing to the point where there are drug targets in various stages of FDA-approved clinical trials.
- Biotechnology research and industry development is a truly global endeavour and one of the critical challenges for New Zealand is to remain well connected internationally.
- As an island nation with a high level of endemic biodiversity, New Zealand is vulnerable to introduced pests.
- New Zealanders hold a unique set of values which influence their views about emerging biotechnologies.
- New Zealand has a continuing burden of disease within its population, in part unique to New Zealand, in part common to other developed nations.

3.1 New Zealand's economic base

Primary industries form the backbone of the New Zealand economy, and this is likely to remain the case over the coming decades. Exports from the primary sector (agriculture, horticulture, forestry, fishing, food and beverage, and manufactured products based on primary sector products) make up about 65% of total goods exported.[24] Primary industries contribute more than 10% of our GDP,[25] but in fact their influence on overall economic growth is much greater since other industries (such as manufacturing) are often reliant upon them.

New Zealand's comparative advantages in land-based primary production have been derived from adaptability and the need to respond quickly to changing conditions, including volatile markets and the removal of domestic subsidies and protection. Management requirements also differ from other countries due to the climate, young soils and relatively disease-free status. For this reason, overseas technologies cannot simply be imported but need to be adapted to New Zealand conditions.[26]

[24] Statistics New Zealand (June 2005), *New Zealand External Trade Statistics*

[25] Statistic New Zealand (March 2005), *National Accounts Year ended March 2005*

[26] Cameron, Linda (May 2006), *Treasury Discussion Paper – Primary Sector Innovation*

The perception that this is a "sunset industry" has also been challenged in recent times by an up-swing in commodity prices, the increasing use of science and technology to produce food and fibre more efficiently, and a growing exploration of ways in which we can extract increasingly value-added products from our commodities. Given the size of our primary production sector, even small productivity gains translate into significant economic returns. For example, 3% per annum annual income growth in a $5 billion sector will add about $800 million over five years.[27]

This means that one of the major impacts on the economy of biotechnology is likely to come from its effect on our primary industries. This has been termed the "enabling" effect of biotechnology; that is the adoption of new technologies by an existing sector.

In order to gain some more quantitative information on the enabling effects of biotechnology, MoRST recently commissioned the Agribusiness and Economics Research Unit (AERU) at Lincoln University to develop a method for measuring the impact of biotechnology within the primary sector in New Zealand.[28]

The AERU research estimated gains to New Zealand's primary sector of $266 million per annum from four commercialised biotechnologies.[29] The wider financial impacts were also considered. The results also showed that the annual economic contribution of these four biotechnologies to the economy as a whole was, conservatively, around $300-400 million per annum. These gains have required long term investment in research of around 10-15 years.

New Zealand's primary industries face increasing challenges, not least the sustainable use of our natural resources, the risks posed by biosecurity incursions, climate change and changing international market conditions. For example, China and South America are becoming increasingly competitive in terms of producing agricultural and horticultural commodities, and countries like Brazil and Argentina are becoming increasingly competitive in meat and dairy.[30] However, as farming systems in these countries become more sophisticated they also present growing markets for ag-biotechnology products developed in New Zealand.

New Zealand's ability to truly "add-value" to the products produced by its primary industries will be a key determining factor in our future economic competitiveness. Biotechnology research will have a pivotal role to play in New Zealand achieving this. Over the longer term New Zealand also needs to "futureproof" its economy by diversifying its economic base. This will only be achieved by creating sustainable economic advantages in new areas of activity or by transforming existing industries.

Internationally, most of the value in biotechnology has come from the health area. In New Zealand a number of biomedical and drug discovery research projects are maturing towards commercialisation and have the potential to add substantial value to the country's economy in the future. Biotechnology research will have a considerable part to play in increasing New Zealand's ability to get benefits from the global health market.

3.2 The New Zealand biotechnology industry: growing in scale

A 1983 Department of Scientific and Industrial Research discussion paper on the then nascent field of biotechnology assessed what would be significant to New Zealand industry in the future. It noted that New Zealand had 'comparative advantages in its capacity to base industries on renewable biological resources' and further that 'such industries have formed the major portion of our industrial development'.[31]

Since 1983, New Zealand has become involved in the global biotechnology sector, both in the areas of opportunity identified from traditional strengths and also the biomedical sector that has done so much to fuel the

[27] MoRST (2006), *Becoming more globally competitive*

[28] Lincoln University Agribusiness and Economics Research Unit (2006), *Estimating the Economic Contribution of Biotechnology to New Zealand's Primary Sector*

[29] The four commercialised biotechnologies selected were clonal propagation; biocontrol agents; enzyme manipulations and marker-assisted selection.

[30] MAF (2006), *Statement of Intent*

[31] DSIR (1983), *Biotechnology in New Zealand, DSIR Discussion Paper No. 8.*

growth of the sector worldwide. The biotechnology sector in New Zealand has moved from a purely speculative research base to having 50 companies whose core business is biotechnology, 130 who use biotechnology, and over 350 companies that consider themselves a part of the wider biotechnology community.

Despite recent expansion, the biotechnology sector in New Zealand is still at a very early stage, with most (62%) of the biotechnology techniques used by New Zealand organisations at R&D stage. Of the 50 core biotechnology companies, 50% were created in the last three years.

On a global scale New Zealand accounts for less than 0.001% of world biotechnology revenue.[32]

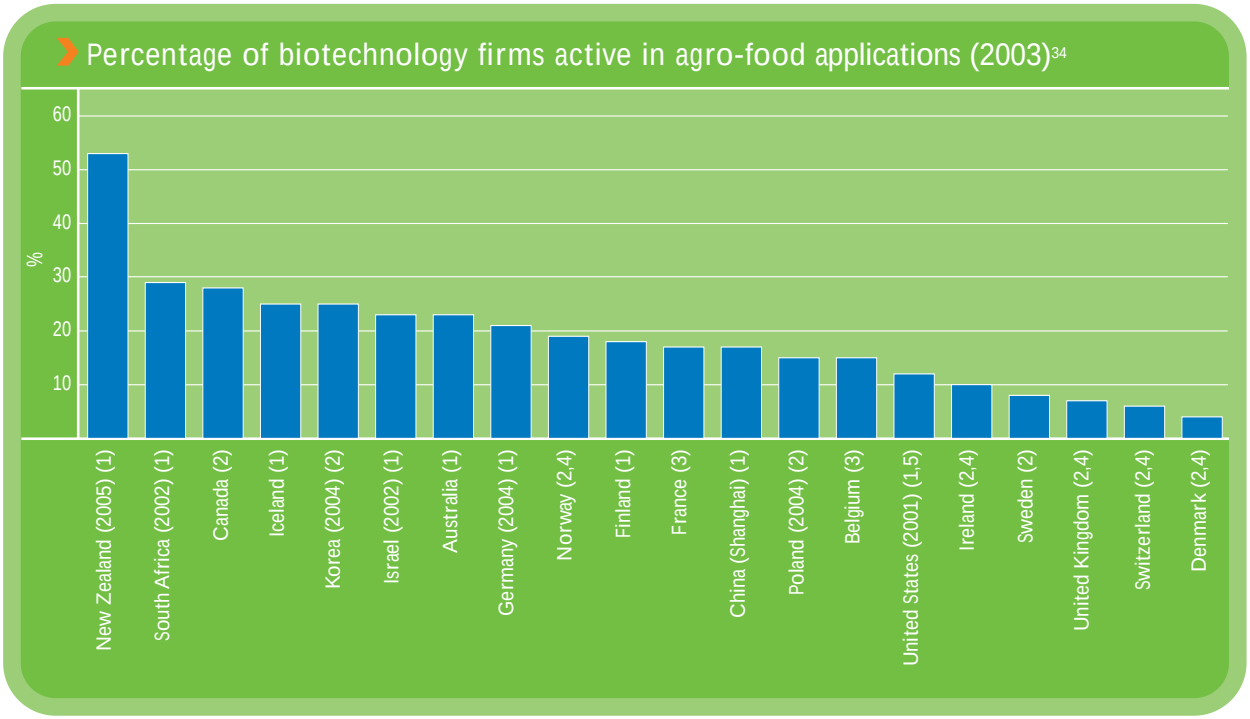
Despite the New Zealand biotechnology industry's small scale globally, revenues continue to grow incrementally – with biotechnology income for the 2005 financial year valued at $811 million.
Of this, the private sector contributed $515 million, the public sector $160 million and the higher education sector the remaining $135 million.

Biotechnology expenditure over the same period was valued at $642 million.

New Zealand biotechnology companies currently export to more than 60 countries. Major export markets include the United States, Europe and Australia. NZBio estimates that export earnings may reach the $1 billion mark around 2014.[33]

The biotechnology sector in New Zealand exhibits many unique characteristics due to a distinct research, industrial and environmental mix as well as its small size and distance from its major markets. Comparative international statistics show that New Zealand has a significantly higher percentage of biotechnology firms active in agro-food applications than other countries *(Figure 3)*. This is to be expected from what has always been the very strong biological base to the New Zealand economy. In short, the growth of the biotechnology industry is in great part a re-focusing of what New Zealand has always done.

Figure 3



[32] Statistics New Zealand (2005), *Biotechnology in New Zealand*,

[33] New Zealand Biotech Sector Overview (August 2005), *Asia Pacific Biotech Journal*

[34] OECD Biotechnology Statistics – 2006 p.28 (note: agriculture-derived processing is assigned to industrial-environmental applications)

Biomedicine is the major focus for the international biotechnology industry with the dual lure of improved health outcomes and the vast profits that can be made from successfully commercialising therapeutic applications. Final presentation to market is dominated by a handful of very large companies that have the financial clout to get drug candidates through the last stages of the clinical trials process and the sales force to market drugs to mass or niche markets.

There is, however, a growing trend within the pharmaceutical industry to outsource the discovery end of the research spectrum to R&D intensive biotechnology companies and public research institutions. This can only benefit New Zealand. New Zealand has established a significant track record in the areas of cancer and diabetes based therapeutics and carbohydrate based drugs with a substantial number of drug candidates currently in Federal Drug Administration (FDA) approved clinical trials (Table 1).

Table 1

Drug compounds developed in New Zealand in FDA approved clinical trial (as of November 2006)

Company	Partner	Drug	Indication	Phase
Antipodean Biotechnology		Mitoquinone	Parkinson's & Friedrichs ataxia	P I
Auckland Cancer Society		Amsacrine	Leukaemia	In Market
	Xenova	XR-11576	Cancer	PI
	Millennium	MLN-944	Cancer	PI
	Antisoma	DMXAA	Cancer	PII
	Pfizer	CI-1033 (Canertinib)	Cancer	PII
Proacta		PR-104	Cancer	PI
Industrial Research Limited	BioCryst	BCX-1777	Leukemia	PII (Orphan)
	BioCryst	BCX-4208	Cancer	PII
Protemix		Laszarin	Diabetes	PII/III
Neuren		Glypromate	Stroke	PII
		NNZ-2566	Neuroprotection	PI
Virionyx		PEHRG214	AIDS	PII

Recent successes include:

- The licencing of a drug candidate (BCX-4028) developed by the Carbohydrate Chemistry Team at Industrial Research Ltd (IRL) to Hoffmann La Roche for use in treating transplant rejection and auto immune diseases. Future milestone payments could exceed $500m.
- An FDA ruling that Neuren can advance its stroke drug candidate Glypromate directly into Phase III trial, without a planned Phase IIb trial.

3.3 Meeting the global challenge

Biotechnology research is an international endeavour and the vast majority of research breakthroughs and knowledge generated will occur outside of New Zealand. The markets for most of the products resulting from biotechnology research in New Zealand are also predominantly located offshore.

To capitalise from these international dimensions, New Zealand needs to maintain a broad base of research capabilities to adopt and adapt international biotechnologies for the benefit of New Zealanders, while also ensuring that applied biotechnology research is cognisant of, and connected to, global research partners and markets.

New Zealand's geographical isolation will always make this a challenge and limited resources means that partnership efforts need to be focused on countries and markets where New Zealand can gain the greatest value. The government has invested significant effort in tailoring international biotechnology research and market linkage initiatives in those areas that have the potential to maximise benefits for New Zealand.

The government's international research linkage initiatives take the form of bi and multilateral Science and Technology Cooperation agreements (STCs) with priority nations and fora[35] and the placement of Science and Technology Counsellors in strategic locations.[36] The formation of biotechnology research links forms an explicit part of some of these relationships, for example, the S&T Counsellor for Europe has the development of agriculture and biotechnology research linkages as a priority area. The Korea Focal Point Programme also has the field of biotechnology as one of its focus areas for exchange.

The government also recognises that different regions provide different market opportunities for New Zealand biotechnology products and services. Biotechnology trade and export promotion efforts are focused accordingly. For example, the:

- European and Japanese markets present opportunities for New Zealand developed innovative foods;
- South America and China present large emerging markets for New Zealand developed agricultural biotechnology innovations; and
- the United States is the dominant player in the international community in terms of markets and capital – notably for health biotechnology opportunities.

Australia is a particularly important international biotechnology partner for New Zealand. Significant efforts have been made to create more effective biotechnology research and industry partnerships with Australia to build critical mass at a regional level to benefit both countries.[37]

[35] For further information see: *Making the Connection – MoRST's International Linkages Strategy 2005-2007*: http://www.morst.govt.nz/Documents/work/international/NZ-International-Linkages-Strategy.pdf

[36] Science and Technology Counsellors are currently located in the United States and the European Union.

[37] Examples include the Australia-New Zealand Biotechnology Alliance: http://www.biotechalliance.org/ and the Australia-New Zealand Biotechnology Partnership Fund: http://www.nzte.govt.nz

3.4 A unique environment

New Zealand is an island nation with a very high level of endemic biodiversity. Evolution through a long period of isolation created unique flora and fauna. This isolation and slow evolution means that our native plants and animals are particularly vulnerable to introduced species.[38]

New Zealand also faces increasing environmental sustainability challenges. Not least, climate change and methane emissions from ruminants accounting for 49% of our greenhouse gas emissions. Nitrogen run-off from intensive dairying practices has also had a profoundly negative impact on the health of inland waterways.

Increasingly, New Zealand's international reputation and trade opportunities also depend on the ability to maintain a high quality natural environment. This extends to ensuring that primary industry develops in an environmentally sustainable fashion.

Biotechnology research has key roles to play in helping us characterise and protect New Zealand's indigenous genetic heritage, in the provision of tools to identify biosecurity threats before they encroach on our borders, and through research to help counter the environmental impacts of farming in areas such as ruminant biology and nitrogen fixing in pasture.

However, environmental biotechnology research is more than just managing risk; there are opportunities as well. These include the environmental and economic opportunities arising from developing techniques like the bioremediation of pollutants, lowering inputs into farming systems, leveraging bio-prospecting opportunities from New Zealand's marine or terrestrial environments, and deriving economic value from biosecurity expertise.

3.5 Societal values

Each nation holds a different set of values which influence views about emerging technologies. New Zealand is no exception. For example, New Zealanders place a high degree of importance on environmental issues. The New Zealand Values Survey[39] notes that New Zealanders prioritise the environment over economic growth.

Research undertaken to gauge the acceptability of biotechnologies to New Zealanders indicates that, similar to overseas findings, the issue is a complex one. Attitudes are shaped by a range of factors including world view, spiritual beliefs and values. One size does not fit all; different types of biotechnologies and end uses elicit different responses. For example, research has indicated that the use of genetic modification to fix environmental problems is more acceptable to New Zealanders than its use in agriculture.[40]

New Zealand's unique cultural mix also means that different groups within society can hold different sets of values about different biotechnologies. For example, research undertaken on Māori views on genetically modified organisms found that in general participants thought the movement of genes between different species resulting in the "mixing" of mauri[41] was detrimental.[42]

The government has responded to this uncertain environment with more open styles of governance for biotechnology than has previously been the case around emerging science and technology. This has led to the establishment of the Bioethics Council to ensure that the use of biotechnology has regard for New Zealanders' values; and the Dialogue Fund, a pilot fund to trial programmes to engage communities in discussion over science and technology related issues that are, or may become, a cause of tension between science and society.

Social research also has a very important role to play to help us understand how New Zealanders respond to emerging biotechnologies.

[38] *The New Zealand Biodiversity Strategy* (2000)

[39] Massey University, Centre for Social and Health Outcomes Research and Evaluation (2005), *The New Zealand Values Study*

[40] Cook, Andrew J et al. (2004), *New Zealand Public Acceptance of Biotechnology*, p. xiii

[41] Mauri can be defined as *the essential life force, the spiritual power and distinctiveness that enables each thing to exist as itself*

[42] Roberts, Mere (2005), *Walking backwards into the future: Maori views on genetically modified organisms*

3.6 Health status

New Zealand has a continuing burden of disease within its population – which is in part unique to New Zealand and in part common to other developed nations. Within the New Zealand population-base, for example, the prevalence of diabetes in Māori and Pacific populations is around three times higher than among other New Zealanders.

Biomedical research has central roles to play to unravel the underlying biological determinants of chronic diseases and the development of effective treatments to help combat them. There are wider benefits as well, the returns on investment in basic biomedical research not only advance healthcare but they also help develop this country's biotechnology industry.

Increasingly, New Zealand's ability to maintain a modern healthcare system and develop an indigenous health biotechnology industry will be linked to its ability to engage in, and interpret, such research.[43]

[43] Health Research Council, *Research Portfolio Strategy – Biological Systems and Technologies*

4 The strategic landscape

Section summary

- The government has high expectations of biotechnology and the positive contributions that it can make to New Zealand.
- Biotechnology research has a central role to play in achieving the government's economic transformation goals, fuelling the development of world class firms and driving the transformation of key existing sectors.
- Environmental sustainability is another strategic goal of government where biotechnology research has an important role to play - as a tool to assist in the protection and management of New Zealand's natural environment and industries.
- The government expects that biotechnology developments will be managed responsibly. Research has an important role to play in providing the evidence-base to inform responsible decision-making about emerging biotechnologies.
- New Zealand's approach to regulating new organisms, incorporating cultural, spiritual and ethical effects into decision making processes also provides important broader strategic context for biotechnology developments.
- Biotechnology is also strategically important to New Zealand's primary industries. Industry needs biotechnology research to drive compound productivity gains and develop value-added products. Growing strategic importance is being placed by industry on environmentally sustainable industry developments as an area for government and industry co-investment.

4.1 Government strategy

The government's biotechnology research investment does not exist in a vacuum and needs to be responsive to the strategic drivers influencing the surrounding landscape. At the highest level, the government recognises that most New Zealanders want to have a highly productive and skilled society with sustainable economic growth that maintains or improves quality of life and does not degrade New Zealand's natural environments.

RS&T is expected to contribute to government objectives, and the various government strategies provide a strong context for government's overall level and approach to investment in science, biotechnology research included.[44] Some of these strategies simply provide a degree of additional context for biotechnology research.

Others explicitly signal research directions which can only be achieved through investing in biotechnology research.

The following table summarises the government's high level and sector specific strategies which directly and indirectly influence biotechnology research investments and how biotechnology research is expected to contribute.

[44] See Science for New Zealand: *An overview of the Science System, 2006*, www.morst.govt.nz

Table 2:

Government strategy influencing biotechnology research

Type of Strategy	Strategy	Strategy description and the role of biotechnology research
High level strategies	Economic Transformation[45] (2006)	The government's agenda for economic transformation covers five themes which together provide high-level direction for its economic development policies. The themes are: • Growing globally competitive firms; • World class infrastructure; • Innovative and productive workplaces; • An internationally competitive city – Auckland; and • Environmental sustainability. Biotechnology research has a particular role to play in fuelling the development of New Zealand's biotechnology industry and the growth of globally competitive biotechnology firms. It also has important contributions to make to environmental sustainability through, for example, the development of cleaner bio-industrial processes.
	Growth and Innovation Framework[46] (2002)	The government's Growth and Innovation Framework (GIF) identified biotechnology as a sector with high growth potential for New Zealand. As a part of the GIF process the government convened a Biotechnology Taskforce to report on growth strategies for the biotechnology sector and make recommendations for further development. The Taskforce Report[47] recognised the critical role of basic biotechnology research as the "starting point" for biotechnology sector developments and the role that it plays enabling innovation across other important sectors of the economy.
	Sustainable Development Programme of Action[48] (2003)	While there is no explicit mention of the specific role of biotechnology research in the Sustainable Development Programme of Action it provides important "context" for biotechnology research developments. Biotechnology research will also make important contributions to achieving its goals. Biotechnology is a tool which can contribute to environmental sustainability, benefiting child and youth health and can be used for advanced renewable energy applications.
Government sponsored sector strategies	The New Zealand Biotechnology Strategy (2003)[49]	The overarching theme of the Strategy is "development with care". The Strategy is divided into three key streams: 1. Growing the sector: Grow New Zealand's biotechnology sector to enhance economic and community benefits; 2. Regulation: Manage the development and introduction of new biotechnologies with a regulatory system that provides robust safeguards and allows innovation; and 3. Community: Build understanding about biotechnology and constructive engagement between people in the community and the biotechnology sector.

[45] Cab Min (06) 7/22

[46] New Zealand Government (2002), *The Growth and Innovation Framework*, http://gif.med.govt.nz/

[47] The Biotechnology Taskforce (2003), *Growing the Biotechnology Sector in New Zealand – A Framework for Action*, http://www.nzte.govt.nz

[48] New Zealand Government (2003), *Sustainable Development Programme of Action*, http://www.beehive.govt.nz/hobbs/30199-med-susined-developm.pdf

[49] New Zealand Government (2003), *The New Zealand Biotechnology Strategy*, http://www.morst.govt.nz/publications/a-z/nz-biotechnology-strategy/

	Food and Beverage Taskforce[50]	The government has also recognised the important role of the food and beverage industry in New Zealand's economy. A Food and Beverage Taskforce has been commissioned to recommend actions that will help the industry adapt and grow in the future. As part of this process the Taskforce has considered the role of research and innovation in production improvement and new product innovation. The Taskforce report back signals that biotechnology research is likely to play an important part in strategic approaches to food innovation. A significant future opportunity for food and beverage biotechnology is seen to be the convergence between food and health. The government's response to the Taskforce's recommendations is pending (as of November 2006).
Government capability strategies	Biodiversity Strategy (2000)[51]	New Zealand's Biodiversity Strategy mentions biotechnology explicitly as both a threat and an opportunity. An opportunity as a source of new pest control methods, a way of extracting economic advantage from biodiversity, and as a potential threat to biodiversity via the release of genetically-modified organisms. The strategy identifies two main areas where research is required: (1) general information-gathering on indigenous biodiversity, particularly marine and freshwater biodiversity (for example, taxonomy, monitoring, distribution, patterns of gene flow, ecosystem function, management of threats); and (2) development of new technologies and techniques to combat threats from introduced pests. Biotechnology research enables us to better identify, understand, manage and conserve our biodiversity.
	Biosecurity Strategy (2003)[52]	The crucial importance of science in underpinning biosecurity policy formulation and decision making is strongly stated in the New Zealand Biosecurity Strategy. The Strategy highlights the need for science to have a strengthened contribution in the future. A Biosecurity Science, Research and Technology Strategy is currently under development to assist with the identification and prioritisation of science initiatives. This will help to ensure that investment in science for biosecurity leads to the best possible outcomes in improving the performance of the system. The contribution of biotechnology research (pest control technologies and biosensing devices) in this area is significant. Current strategic priorities for biosecurity management in New Zealand are directed at better pre-border management of incursion threats. Biotechnology, in the shape of better biological detection and analysis devices, will play a pivotal role in achieving this.
	Vision Mātauranga (2005)[53]	Vision Mātauranga is a Vote RS&T-wide policy framework designed to unlock the innovation potential of Māori knowledge, resources and people. It is designed to respond to distinctive needs of the Māori community and also to enable the development of distinctive contributions of Māori knowledge, resources and people to RS&T.

[50] Food and Beverage Taskforce (2006), *Smart Food, Cool Beverage: New Zealand's Future in the Food and Beverage Sector*: http://www.nzte.govt.nz

[51] New Zealand Government (2000), *The New Zealand Biodiversity Strategy*, http://www.biodiversity.govt.nz

[52] Biosecurity New Zealand (2000), http://www.biosecurity.govt.nz/bio-strategy/biostrategy.htm

[53] MoRST (2005), *Vision Mātauranga - Unlocking the Innovation Potential of Māori Knowledge, Resources and People*, http://www.morst.govt.nz/Documents/work/vm/Vision-Matauranga.pdf

		Vision Mātauranga presents four research themes, each of which can be enabled by biotechnology research or can drive innovation through the convergence of biotechnology research and indigenous knowledge: • Indigenous Innovation: Contributing to economic growth through distinctive R&D; • Taiao: Achieving environmental sustainability through iwi and hapa relationships with land and sea; • Hauora/Oranga: Improving health and social wellbeing; and • Mātauranga: Exploring indigenous knowledge and RS&T.
Government sector strategies	Tertiary Education Strategy (2002-2007)[54]	The Tertiary Education Strategy is a five-year blueprint for a more collaborative and cooperative tertiary system that contributes to New Zealand's national goals and is closely connected to enterprise and local communities. The tertiary education sector is of great importance to the development of New Zealand's underpinning biotechnology research capabilities. It also supports New Zealand's biomedical research capability. From a research strategy perspective, there has been an increased focus on research excellence in the tertiary sector. This has resulted in the establishment of the Centres of Research Excellence and the Performance-based Research Fund (PBRF). The growing emphasis on connecting the tertiary sector more explicitly with industry is also resulting in greater strategic alignment of the supply of skills to important industries which benefit from biotechnology research, like the primary sector.
	New Zealand Health Strategy(2000)[55]	One of the New Zealand Health Strategy's primary objectives is good health and wellbeing for all New Zealanders throughout their lives. Ongoing developments in the biomedical and drug development sciences will offer significant contributions to understanding, preventing and treating chronic diseases.
	New Zealand Energy Strategy (pending)[56]	In late 2005, the government announced it would develop a New Zealand Energy Strategy to provide long-term direction and leadership to put New Zealand firmly on the path to an energy system that supports economic development, while being environmentally responsible. The Government also emphasised renewed commitment to promoting energy efficiency and renewable sources of energy. This strategy remains forthcoming, but biotechnology research will potentially contribute to developments in biofuel and energy developments which would contribute to the government's renewable energy goals.
	New Zealand Waste Strategy[57]	The New Zealand Waste Strategy's goal to "[reduce] the damage to the environment from waste generation and disposal" can be enabled by a range of biotechnology research developing environmental bioremediation technologies, cleaner industrial "closed loop" bioprocessing processes or extracting greater value from biological industry waste streams.

[54] Ministry of Education (2002), *The Tertiary Education Strategy (2002-2007)*, http://www.tec.govt.nz/about_tec/strategy/strategy.html

[55] New Zealand Government (2000), *New Zealand Health Strategy*, http://www.moh.govt.nz/publications/nzhs

[56] Ministry of Economic Development, New Zealand Energy Strategy development process details: http://www.med.govt.nz

[57] Ministry for the Environment (2002), *The New Zealand Waste Strategy*, http://www.mfe.govt.nz/publications/waste/waste-strategy-mar02/

4.2 The biotechnology regulatory environment

The way that biotechnology is regulated in New Zealand also provides important strategic context. New Zealand's biotechnology regulatory system is generally considered well harmonised with other leading countries' processes, particularly in relation to the regulation of medicines, foods and agricultural compounds. New Zealand is distinctive, however, in how it regulates new organisms (which includes genetically modified organisms), in particular, the Hazardous Substances and New Organisms (HSNO) Act.

The HSNO Act does not exclude from formal approval any types of developments involving genetically modified organisms (GMOs). Some countries have exemptions or notification processes for research involving certain specified types of "low risk" genetically modified organisms. In addition, the HSNO Act requires consideration of "cultural, ethical and spiritual effects" in the risk assessment process.[58]

Since the HSNO Act came into force (in 1998), there have been a range of changes (both legislative and operational) to improve the efficiency and effectiveness of the application processes. These include adding a new type of release approval, removing duplications in processes between different regulatory processes, and reducing costs and information requirements for some types of "low risk" applications. There are, however, still concerns expressed by some researchers and biotechnology companies, as well as others, about the time and costs associated with regulation of new organisms in New Zealand. Work to address these, and any other biotechnology regulatory issues, forms the basis of the Biotechnology Strategy's regulation work stream and fall outside of the scope of this Roadmap.

4.3 Primary industry strategy and research priorities

The government's outcome-focused research investments relating to existing parts of the economy are largely driven by research priorities determined by large industry end-users. In the case of biotechnology research the end-users are mostly primary industry bodies. Many of the primary industry sectors invest in industry-good research through levies collected through the Commodity Levies Act.

These end-users can be segmented into the following indicative industry groupings: the pastoral sector (dairy, meat and wool, deer); arable; horticultural (includes fruit and vegetables); forestry; marine; and the food and beverage industry.

An analysis of primary industry research priority and strategy documents[59] shows a number of shared research priorities and relatively clear indications of which different "player" industries see the responsibility for research investment lying with (that is, government R&D investment, public-private co-investment or private sector R&D investment).

[58] A study of the biotechnology regulatory system, commissioned by MoRST, describes some of the strengths and weaknesses of New Zealand's biotechnology regulatory system: *Biotechnology Regulatory System Baseline Study* - http://www.morst.govt.nz/publications/a-z/biotechnology-regulatory-system-baseline-study/

[59] Primary sector research strategies prepared for the Foundation for Research, Science and Technology in 2004 were used in this analysis. These are not exhaustive but give a useful representation of broad primary industry research priorities.

Table 3 below shows a list of research priority signals, which party industry see as responsible for investment and the industries that have specifically indicated a particular area as a priority.

Table 3

Primary Industry Research Priorities

Research signal	Priority area for
For Government R&D Investment	
Biosecurity	Pastoral, Horticulture, Forestry, Marine, Arable
Human health and welfare	Food and Beverage
Biodiversity knowledge	Marine
For Co-Investment	
New products (includes foods)	Arable, Food and Beverage, Forestry, Marine, Pastoral
Increase productivity	Pastoral, Horticulture, Arable, Forestry, Marine
Environmentally sustainable Industry development	Pastoral, Arable, Forestry, Marine
Animal health and welfare	Pastoral
Food safety	Pastoral, Horticulture, Food and Beverage
For Private Sector R&D Investment	
Develop industry tools and markets	Horticulture, Pastoral

Industry's expectations of what it considers "public good research", to be funded by government alone, is research into understanding and protecting our natural environment and the subsequent competitive advantages that this bestows on industry and enhancing the health status of New Zealanders.

Industry considers that research into increasing primary production productivity, food safety, animal health and welfare, ensuring that industry develops in an environmentally sustainable way, and bearing the risk of investing in research into value-added product developments with as yet untested markets, should be undertaken as a co-investment between government and industry. This expectation has been borne out via a number of the research consortia recently established between government and industry groups.

The areas where industry considers the research investment responsibility of the private sector alone are largely at the market driven end of the spectrum. This includes the development of industry tools and markets, for example, research to understand consumer attitudes and preferences.

5 Biotechnology Research in New Zealand

Section summary

- The government currently invests $195 million per annum on biotechnology research. At 25% of total government R&D investment this is proportionally the highest share of government funded biotechnology research in the OECD.
- There is roughly a 50-50 split between research supporting basic and basic-targeted research on the one hand, and more outcomes-focused applied research and support for commercialisation on the other.
- The relative size of this investment means that a number of research funding and investment agencies are involved in allocating research funding; the largest investment agency being the Foundation for RS&T (72%).
- The bulk of the government's research investments are directed towards achieving economic outcomes – fuelling competitive advantages within existing industries and building completely new industries.
- Biotechnology research has benefited from recent new investments in "cross-institutional" research configurations, like the Centres for Research Excellence and Research Consortia schemes.
- An analysis of current research investments shows that:
  - New Zealand possesses world-class niches in biomedical research and drug development research. This research is mostly prioritised on the basis of research excellence.
  - Plant and animal biotechnology research is largely consolidated around the key species critical to New Zealand's primary production sectors.
  - Opportunities exist to integrate underpinning research platforms in some areas.
  - Biotechnology research is critical to the value-added product end of food and nutrition research. A gap exists between the potentially transformational research being currently undertaken and industry's ability to pick it up in the future.
  - Investments in marine biotechnology are comparatively low at 2% of the total. To capitalise from opportunities in this area there is a need to build both research capability and industry's capacity to utilise research.
  - Industrial biotechnology offers future opportunities for research, but improved coordination is required to harness the value proposition for New Zealand.
  - Although the government has invested in social and environmental impacts research to support improved decision-making, end-user feedback indicates that there is fragmentation between research providers as well as a need for better strategic oversight of this area.

Research is a critical driver of biotechnology development and its application. Biotechnology research:

- grows our understanding of biological systems which form the basis of all biotechnology applications, for example, fundamental biomedical research on different disease states;
- applies biotechnological tools to create new knowledge and solve problems – for example, genomic research to support animal breeding and enhanced productivity in the primary sector;
- improves science services that rely on biotechnologies – for example, forensic tests; and
- enables scientists to keep at the forefront of their disciplines and able to connect with overseas science teams to both contribute and create new knowledge.

The government's investments in biotechnology research are broad. There is no one 'biotechnology fund' for public research and no intention to create one. Rather, biotechnology research is supported through a wide range of funds managed by a range of agencies.

As for other areas of research, most funds are available as grants obtained through a contestable funding process, although there is a trend toward longer term negotiated contracts.[60]

5.1 Current investment levels

In 2004-05, just over $195 million[61] was invested by government research funding and investment agencies (FIAs) in biotechnology related research.

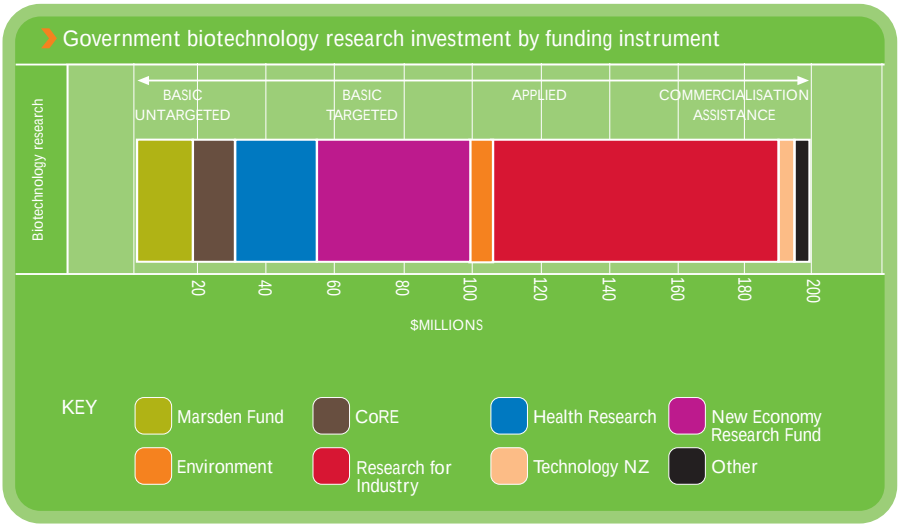
At 25% of total government R&D expenditure, New Zealand has, proportionally, the highest share of the government R&D funding invested in biotechnology research in the OECD.[62]

Investments in biotechnology research span the spectrum from basic, to applied research, through to funding for research commercialisation.

Figure 4 illustrates the continuum of key funding instruments and schemes comprising the government's total investment. While at a project level, there is variation within each funding instrument that complicates the picture, roughly half of the funding is expended on basic-untargeted and basic-targeted research with the remainder made up of more outcome focused-applied research investments and support for commercialisation.

Figure 4

Total government biotechnology research investment by funding instrument



[60] For more information on current changes to New Zealand's RS&T system see: *A More Effective and Stable Funding Environment for Science* Cabinet Paper available on the MoRST website – www.morst.govt.nz

[61] Gilbertson (2005): *Analysis of New Zealand Government Investment in Biotechnology R&D 2004/05 Funding Year* (partially updated by MoRST, March 2006)

These figures do not include PBRF data.

[62] OECD (2006) *Biotechnology R&D Statistics*, p. 16

5.2 Who is allocating biotechnology research funding?

The breadth of the government's investment in biotechnology research means that a number of funding agencies are involved in allocating research funding *(see Table 4)*.

Table 4
Biotechnology research funding agencies, percentage of funding and investment profile

Funding Agency	$m	%	Investment profile
Foundation for Research, Science &Technology (FRST)	140	72%	FRST is the government's primary investor in biotechnology research. The bulk of FRST's biotechnology research investments are outcome focused and directed towards achieving economic and environmental outcomes; mostly to underpin the development of New Zealand's primary production and food sectors.
Health Research Council of New Zealand (HRC)	23.8	12%	The HRC is the government's primary funder of health research and also awards a range of scholarships and fellowships. The HRC's biotechnology research investments are primarily focused on supporting investigator-led research and teams with a focus on research excellence.
Royal Society of New Zealand (RSNZ)	15.7	8%	The RSNZ manages the Marsden Fund. The Marsden Fund is New Zealand's premier basic research fund. It funds excellent basic research across the board, including biotechnology research.
Tertiary Education Commission (TEC)*	12.2	6%	TEC administers the Centres of Research Excellence (CoRE) scheme. The CoRE scheme funds world-class research. CoREs are primarily, but not exclusively, inter-institutional research networks, with researchers working together on a commonly agreed work programme. Four of the current seven CoREs have a basis in biotechnology research.
New Zealand Trade & Enterprise (NZTE)	3.1	1.5%	NZTE administer the Australia New Zealand Biotechnology Partnership Fund. The fund is designed to facilitate and accelerate trans-Tasman biotechnology industry collaboration. While not specifically a research fund it does support some research collaborations which are accounted for in this figure.
Ministry of Agriculture & Forestry (MAF)	1.0	0.5%	MAF's Sustainable Farming Fund supports projects which contribute to the improved financial and environmental performance of the land-based productive sectors. This includes a proportion of applied biotechnology research contributing primarily to biosecurity management practices.

*TEC totals represent the Centres of Research Excellence funding only, not the Performance Based Research Fund.

5.3 What outcomes is the government currently seeking from its biotechnology research investments?

The government is seeking a range of different outcomes from its biotechnology research investments. At a high level, these correlate broadly to the expectations the government holds for the RS&T system as a whole.

At this level, biotechnology research contributes directly to achieving the government's four strategic goals for research:

- Economic: Biotechnology research contributes directly to increasing the competitiveness of New Zealand industries and sectors and generating new biotechnology firms.
- Environment: Biotechnology research enhances our understanding and management of our natural environment.
- Social: Biotechnology research helps to improve the health status of New Zealanders.
- Knowledge: Biotechnology research creates new knowledge through research and science activities with a focus on excellence.

The government's basic biotechnology research investments (through the Marsden Fund and tertiary sector funding instruments like the CoREs) are focused on research excellence and result primarily in "knowledge" outcomes. In practice this translates to researcher training and development, and contributions to knowledge through research excellence. It also results in New Zealand being connected to, and able to translate and benefit from, advances in the global pool of knowledge.

Much of the government's biotechnology research is, however, targeted more explicitly towards achieving public good economic, environmental and social outcomes. FRST and the HRC are the funding and investment agencies which set the most explicitly targeted outcomes from the research investments they manage. This has largely come about through portfolio review processes undertaken by FRST and HRC, and their responses to various strategic signals from government and industry.

5.3.1 FRST's horizons model

FRST uses a "horizons" model to balance their research investments across groupings of their investment portfolios. The rationale behind this approach is that public good research should span a spectrum, from supporting existing sectors and environmental management practices, to research aimed at creating new and diversified opportunities for future economic developments.

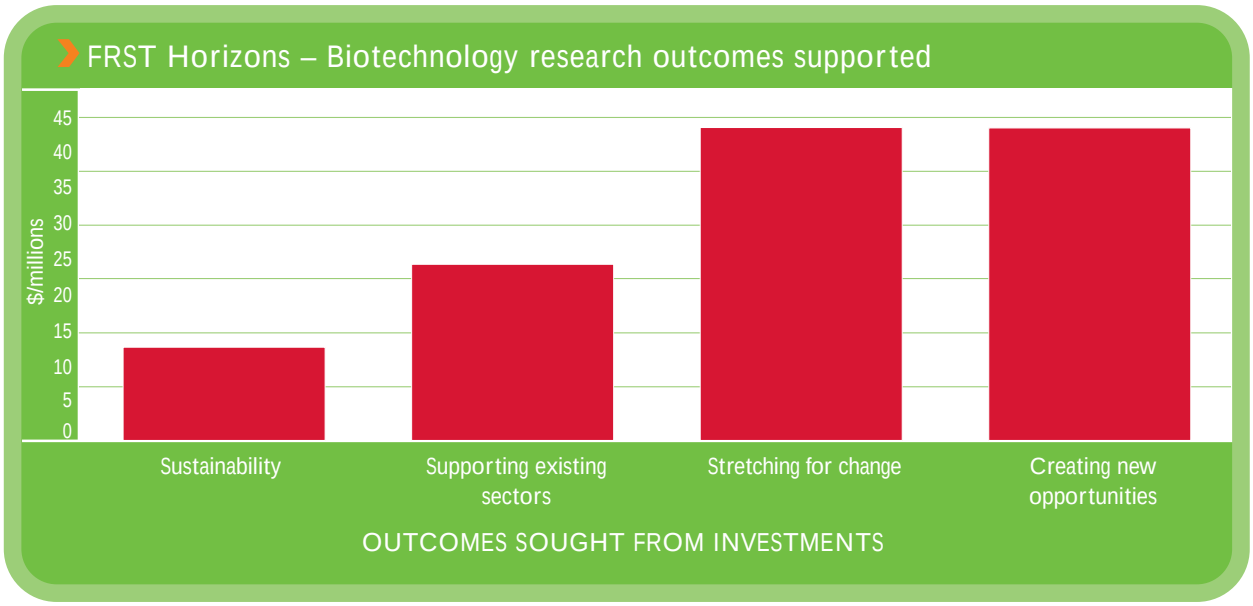
The horizons model encompasses four areas:

- Horizon 0 – Sustainability: research aimed at ensuring the sustainable development of New Zealand's natural environment and primary industries.
- Horizon 1 – Supporting existing sectors: research aimed at ongoing improvements to productivity and management approaches in existing economic sectors.
- Horizon 2 – Stretching for change: research aimed at stretching the capabilities of existing sectors so that there is innovation and greater added value.
- Horizon 3 – Creating new opportunities: research that falls outside, or beyond existing sectors and approaches, and which is aimed at creating new opportunities for New Zealand's future.[63]

[63] FRST (2005), *Progress and Achievements Report*

Using these horizon categories, FRST's biotechnology research investments (2004-05) are directed proportionally towards achieving the following outcomes *(Figure 5)*:

Figure 5



Using this breakdown, the bulk of government investment is directed at stretching existing sectors for change and creating new opportunities with smaller proportions given to supporting the current activities of existing sectors and to environmental sustainability.

These proportions partly reflect a strategic re-prioritisation (since 1999-2000) of research supporting New Zealand's primary production sectors. Emphasis has shifted from the traditional productivity enhancement areas of research to a greater research focus towards developing value-added products and economic diversification.

Much of the research being directed towards creating new economic opportunities is being invested through the New Economy Research Fund (NERF). A recent evaluation of NERF found that 63% of its investment to date is being directed towards biotechnology research.[64]

The evaluation report raises concerns that this weighting towards biotechnology research, in isolation, may impact on future opportunities which could be derived from the convergence of biotechnology with other enabling areas of science and technology like ICT and nanotechnology.[65]

[64] ABT Associates (September 2005), *Evaluation of the New Economy Research Fund*, p.40

[65] ibid, p.51

5.3.2 The HRC's portfolio-based investment framework

The HRC is the main funder of New Zealand health research. The HRC's priorities have traditionally been driven primarily by investigator-led research excellence, but it is becoming more targeted in its investment processes. The HRC instituted a portfolio-based investment framework[66] in 1999, and many of its goals can potentially be delivered by biotechnology research. Biotechnology research is spread across the HRC's Biological Systems and Technologies, Communicable Diseases, and Non-Communicable Diseases Portfolios.

Although health related biotechnology research in particular areas may contribute to achieving the government's strategic health objectives (like reductions in the incidence and impact of cancer and cardiovascular disease), research is not prioritised on this basis alone. Biomedical research is a global endeavour and many of the positive health benefits that New Zealanders will experience from biotechnology will come from research performed offshore.

The priorities for the HRC's biotechnology research investments, therefore, remain mostly focused on research excellence. This way, beneficial outcomes to the health status of New Zealanders, contributions to global knowledge, and a heightened opportunity to capture economic benefits are all potentially addressed.

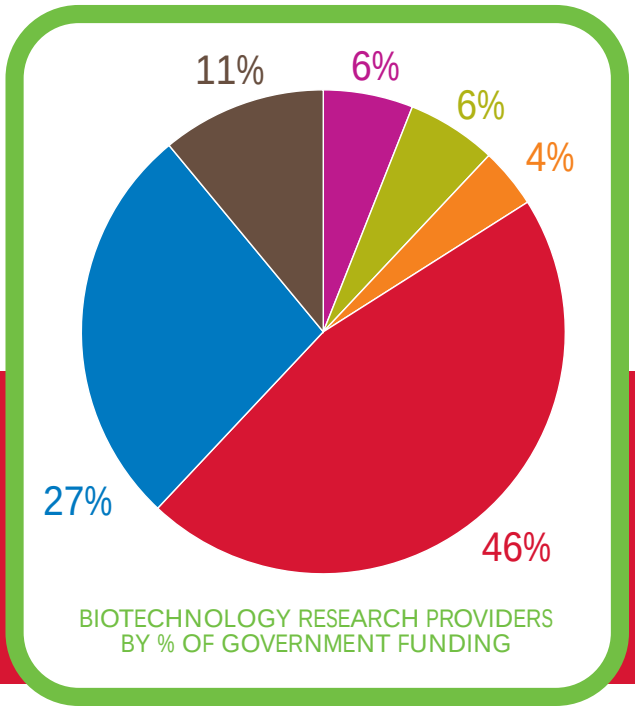
5.4 Key research providers

With very few large, or even medium sized, private companies within this sector biotechnology research is largely carried out by public sector institutions in New Zealand *(see Figure 6)*.

A very high proportion of the funding comes from government grants. Private sector R&D expenditure accounts for only 36% of total expenditure.[67]

Figure 6

Biotechnology research providers by % of government funding



KEY

- University
- Private Sector
- Public-Private Partnerships
- Centres of Research Excellence
- Research Associations
- Crown Research Institute

[66] Health Research Council (2005), *Investment Strategy* 2005-06

[67] MoRST (2006), *Research and Development in New Zealand* – A Decade in Review p.90

The core public sector biotechnology research providers in New Zealand are the Crown Research Institutes and the Universities. Distinct regional clusters have developed around research institutions or in some circumstances reflect local industry bases, for example:

- biomedical research clusters are co-located with the campuses of the two main medical schools at the universities of Auckland and Otago; and
- a Palmerston North-based plant biotechnology research cluster – encompassing Massey University, Hortresearch, AgResearch and Crop and Food Research – on the Grasslands Campus.

Over the past few years other "cross-institutional configurations" have emerged to stimulate research collaboration across research institutions and to link research more effectively to industry end-users through co-funding, notably:

- the Research Consortia funding scheme to bring researchers and industry end-users together through co-funding arrangements (nine of the ten current consortia have some basis in biotechnology research); and
- Centres of Research Excellence to encourage the development of world class research in New Zealand (three of the seven current CoRES are based on biotechnology research).

Private sector R&D providers receiving government R&D funding in this area are largely supporting the development of the primary production sectors. Key recipients of funding include Fonterra and PGG Wrightson.

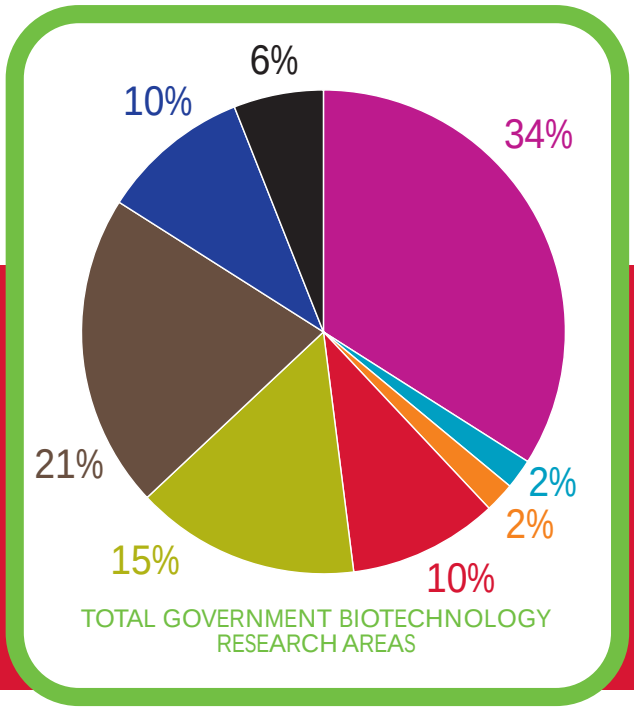
5.5 Current research investment areas

This section draws on a background paper prepared by MoRST[68], the advice of an Advisory Group, feedback gathered from key stakeholders at regional workshops (May 2006), and through a formal submission process (September 2006).[69]

This section is broadly structured on the categories of research identified in the Biotechnology Taskforce Report. Using this framework, Figure 7 (below) shows the total government investment in biotechnology R&D broken down by research area.

Figure 7

Total government biotechnology research by key research area



[68] MoRST (2006), *The New Zealand Biotechnology Research Landscape*

[69] The summary of formal submissions is available on the MoRST website: www.morst.govt.nz

These categories are not those used by any funding agency to allocate funds but were developed by government agencies[70] based on the Taskforce categories to indicate broadly where the investments in biotechnology are being made. There are considerable areas of overlap between different categories therefore it is not possible to present in aggregate figures.

Annex 3 provides a more comprehensive breakdown of total government biotechnology research investment broken down by key research area and sub-area.

Discussion of each research area is structured as follows:

- research strengths;
- current investment levels and trends; and
- any issues or gaps identified.

The need to improve funding processes to progress research commercialisation as an issue which cuts across a range of research capabilities is also discussed in this section.

5.5.1 Biomedical science and drug development research

Research Strengths

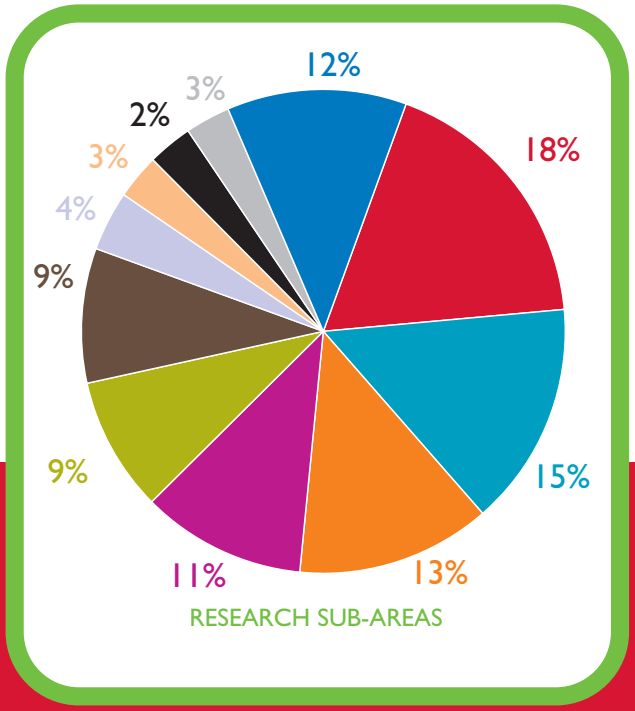
Global investments in biomedical research and drug discovery are considerable and New Zealand cannot compete effectively in all areas. However, biomedical and drug discovery research in New Zealand is characterised by pockets of world-class research excellence.

New Zealand has significant research capabilities in bioengineering; diabetes and cardiovascular disease; cancer and oncology; glycotherapeutic drug development; neuroscience; asthma; and osteoporosis and bone health.

Research funding is largely allocated around these strengths:

Figure 8

Biomedical and drug discovery breakdown by research sub-area



[70] MoRST, FRST, NZTE and Statistics New Zealand developed a statistical framework to categorise the biotechnology research conducted in New Zealand based on the Biotechnology Taskforce categories.

Current investment levels and trends

The government currently invests 34% of total biotechnology research funding on biomedical and drug discovery research.

Most research funding is at the early stage, with investments primarily prioritised by science excellence and researcher track record. Funding into biomedical research has increased over the past few years via an increase in health research funding in the 04-05 Budget, and new biomedical research investments directed towards human-related technologies through NERF.

With the bulk of biomedical research innovations occurring offshore, New Zealand needs to maintain a broad base of biomedical research capability to adopt and adapt research and technologies for New Zealand conditions. The medical schools within the tertiary sector play a vital role in maintaining this baseline capability.

As was shown in section 3.2, the health biotechnology industry sector in New Zealand is strengthening. A number of New Zealand companies have developed drug candidates out of government funded basic research.

These are progressing through the clinical trials process (some relatively advanced at Phase II and III). Reflecting this maturation, the government has also recently started to make significant investments in a number of health biotechnology companies to assist with later stage research commercialisation. This is done through schemes like Technology New Zealand.

Issues or gaps?

Despite a growing critical mass, future challenges exist for New Zealand if it is to effectively leverage biomedical research strengths and capture economic benefits from highly competitive global markets. A remaining "pressure point" identified by sector representatives is access to pre-seed financing to commercialise biomedical and drug development research. The government has recognised this funding gap by setting up the Pre-seed Accelerator Fund (PSAF) in 2003-04 and further boosting its funding in 2006-07. An interim review of the PSAF fund indicated that nearly 40% of PSAF projects have their main area of application in the area of medical and health technologies (the highest, at 22%) and biotechnology (16%).[71]

[71] FRST (May 2005), *Evaluation of the Pre-seed Accelerator Fund*, p. 9

New Zealand's growing drug discovery expertise

Professor Vern Schramm (left) and Dr. Richard Fumeaux.

New Zealand's human pharmaceutical research community has an increasingly strong track record of success, with 13 molecules in the US's Food and Drug Administration-approved clinical trials or on the market in 2006 alone.

Two companies, Crown Research Institute, Industrial Research Limited (IRL) and Proacta Therapeutics, have been particularly prominent in developing new drug leads.

Industrial Research Limited

Since 1994 the Carbohydrate Chemistry Group at IRL has been working with the Albert Einstein College of Medicine (Einstein) in New York to develop new drug compounds that affect how cells use carbohydrates. That year, Professor Vern Schramm, who leads the Einstein's Biochemistry Department drew a molecule that he thought would make a great drug candidate on a napkin in a New York bar. His problem was that he could find no one in the US to make it and find out. His companions in the bar, Drs Richard Furneaux and Peter Tyler of IRL, already world leaders in carbohydrate synthesis, took on the challenge and were successful.

Processing facilities at IRL.

In 2006 that molecule, now called Forodesine, was the subject of a multi-million dollar sub-licensing deal with European-based Mundipharma for the treatment of certain leukaemias. A closely related drug also developed by IRL and Einstein, BCX-4208, was sub-licensed to major multinational pharmaceutical company Roche for the treatment of autoimmune diseases and transplantation in November 2005. In addition to royalty payments that may be realized from commercial sales, both of these sub-license agreements provide for potential future clinical, regulatory and commercialisation event payments that could exceed $US700 million. The Roche deal was the 5th largest biotechnology deal in the world for 2005.

These licensing deals were made by IRL and Einstein's licensee, BioCryst Pharmaceuticals, located in Birmingham, Alabama.

Both drugs work by interfering with the way rapidly dividing cells produce DNA. The pivotal Phase IIB clinical trial of Forodesine began in January 2007, while the Phase II clinical trial of BCX-4208 is expected to begin in 2007. Forodesine has been granted Orphan Drug Status by the US Food and Drug Administration, which allows it to be fast-tracked through the approval process because it aims to treat a relatively rare condition for which there are few available treatment options.

IRL and Einstein are developing the next generation of these compounds to treat a wider range of diseases including malaria.

Visit www.irl.cri.nz/carbo

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Proacta Therapeutics

Proacta Therapeutics is a recent spin-out from the University of Auckland. Their anti-cancer drug, PR-104, which is designed to treat solid tumours, is currently undergoing human clinical trails at Waikato Hospital in New Zealand, the University of Auckland, the Peter MacCallum Cancer Centre in Melbourne, Australia and several sites in the United States, including UCLA.

PR-104 is one of a new generation of pro-drugs. These are drugs that are not activated until they reach the cancer itself, avoiding the side-effects that accompany most cancer drugs.

Proacta CEO Paul Cossum says, "PR-104 is only activated once inside the tumour, killing only cancer cells and leaving healthy cells unaffected. This is in stark contrast to current chemotherapies that kill any fast growing cells including gut lining, hair follicles and bone marrow." PR-104 becomes active in tissue that is starved of oxygen which occurs in tumours as their growth outstrips their blood supply, but not in normal tissue. "We estimate that more than 65% of the 10 million people currently diagnosed with cancer every year have these types of tumours," Dr Cossum says.

PR-104 is the latest drug to be developed by Proacta's founders Professors Bill Denny and Bill Wilson of the Auckland Cancer Society Research Centre (ACSRC). It was developed in collaboration with Professors Martin Brown and Amato Giaccia at Stanford University in the US. The ACSRC has a history of success in developing anticancer drugs. In addition to PR-104 it has four in trial with international commercialisation partners and one, Amsacrine, on the market through major multinational pharmaceutical company Pfizer.

Investors in New Zealand, Australia and the US were so impressed by the potential of PR-104 and the track record of the company founders that Proacta has raised more than $US47m to get the drug through Phase II trial. Investors include international pharmaceutical and biotechnology companies Roche and Genentech as well as venture capital investors.

Visit www.proactatherapeutics.com and www.health.auckland.ac.nz/cancer

5.5.2 Animal and plant biotechnology

Research Strengths

Plant and animal biotechnology research capabilities are largely consolidated around important species for the New Zealand agriculture, horticulture and forestry sectors. As a consequence New Zealand has extensive plant biotechnology research strengths and knowledge of the biology of industrially significant plants, grasses, trees and crops (both arable and horticultural).

Figure 9

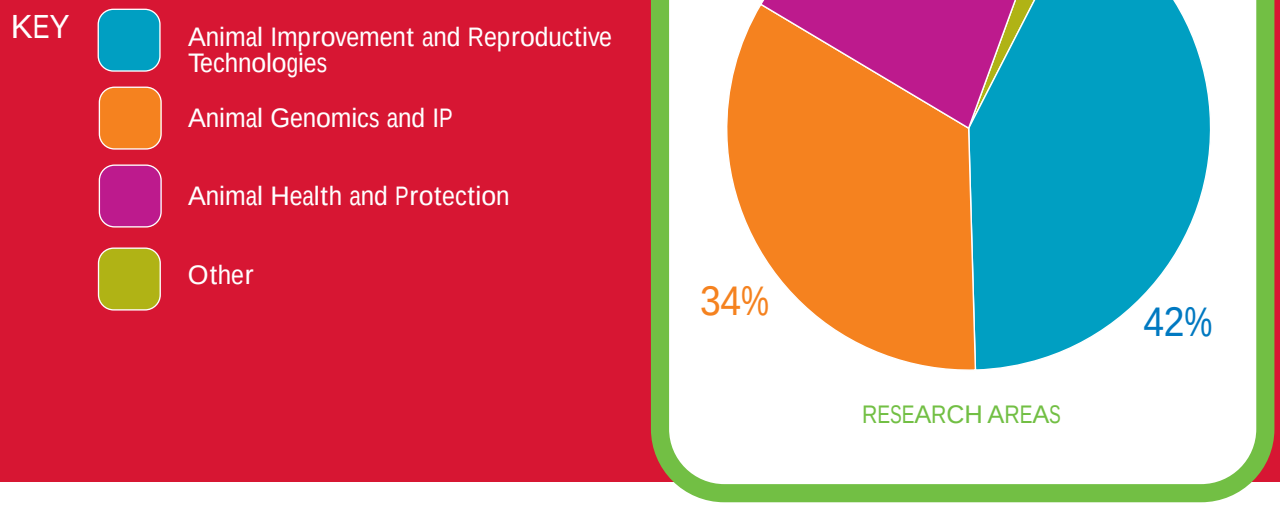
Plant biotechnology research by research area

Notable examples include: kiwifruit, apples, ryegrass, clover and pinus radiata. This includes access to unique germplasm collections and expanding genomic databases.

New Zealand also has significant research strengths in large animal biology. We are regarded as being world-leading in overall knowledge of sheep and dairy cattle. Particular research strengths are in animal genomics and reproductive and cloning technologies.

Figure 10

Animal biotechnology research by research area



Current investments and trends

Public investments in animal and plant biotechnology research play a vital role in underpinning the development of New Zealand's land-based primary production sectors and account for 40% of total biotechnology research investments.

A significant proportion of plant and animal biotechnology research is invested in underpinning platforms like genomics research (29% and 34%, respectively). Research co-investment trends between industry and government over the past 3-4 years have resulted in increased investment in plant and animal biotechnology. Nine of the ten current research consortia have some basis in plant or animal biotechnology research that supports New Zealand's primary production sectors.

Research directions for applied agricultural biotechnology research investments (as with other research supporting industry sectors) are set in consultation with industry end-users. For example, the Pastoral 21 initiative, where a pastoral industry collective is working proactively with government to set industry RS&T targets and co-investment goals. In response to this, Budget 06-07 included new research investment aimed at increasing productivity and partnership research within the pastoral sector.[72]

Issues or gaps?

FRST recently completed a domain review[73] of government's current research investments in plant biotechnology.

[72] Budget announcement 06-07: http://www.morst.govt.nz/Documents/publications/budget/MoRST-Budget-2006.pdf

[73] The purpose of a domain review is to direct future FRST investment strategy. A domain review analyses and assesses the Foundation's investments across a topic area. They are not in depth reviews of individual research programs and contracts.

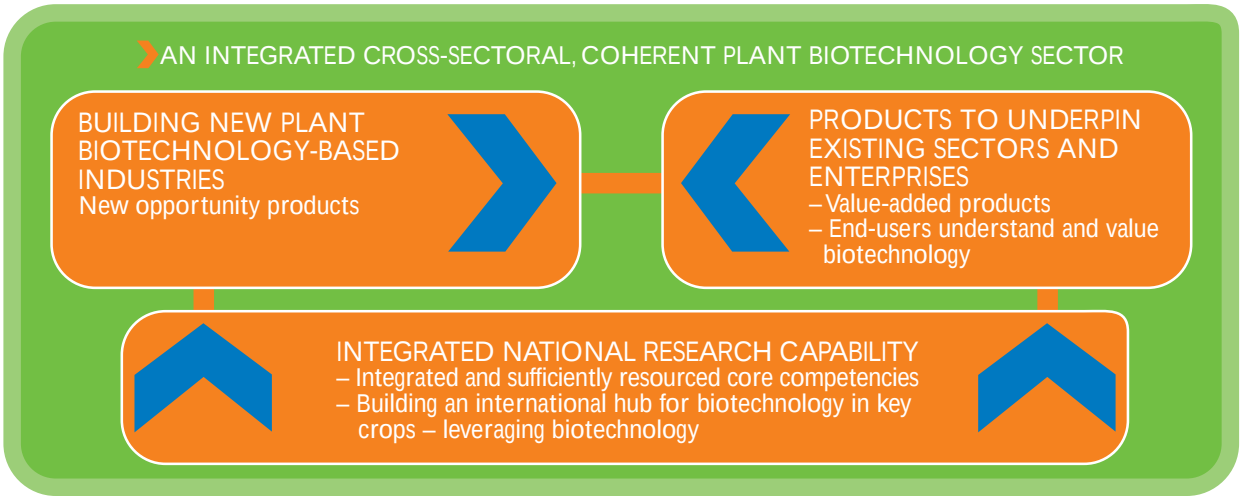
The review found that although it is not necessary to "radically overhaul" plant biotechnology research there are opportunities for it to be "better strengthened and aligned".[74] The review's recommendations are multi-faceted, but an overarching theme is the need for better integration:

- through enhanced linkages between research and industry;
- through better collaboration between research organisations; and
- at the research platform level, through the development of a national crop-based "hub" involving shared research data and facilities.

This review articulated a vision for plant biotechnology research in New Zealand to 2016 *(Figure 11)*.

Figure 11

A vision for plant biotechnology research in New Zealand to 2016[75]



There are future opportunities to consider how animal biotechnology research could benefit from enhanced integration in this manner.

There is also a need to improve the flexibility of public-private partnership models. The current research consortia model is most successful in highly organised "homogenous" sectors with a central producers group.

However, one size does not fit all. Highly fragmented "heterogeneous" industries and sectors find it more difficult to set joint research priorities, organise a co-funding arrangement and benefit from it.[76]

[74] FRST (2006), *Plant Biotechnology Domain Review – Report of the Strategic Decision Group.*

[75] Ibid, p.9

[76] Kaye-Blake, William (2006), *Successful Biotechnologies – Three Case Studies* (commissioned by MoRST and available on the MoRST website: www.morst.govt.nz)

Smart Sheep Science

New Zealand is a world leader when it comes to science involving animal genetics, with the likes of research consortium Ovita – which boasts the world's largest database of sheep pedigree and genetic history, and the largest sheep DNA library – at the pinnacle of their field.

Ovita invests in scientific research and develops new products and services for the benefit of New Zealand's sheep farmers, and also develops knowledge that can be licensed for other applications such as animal and human pharmaceutical markets.

Ovita was formed in 2001 by Meat New Zealand, The New Zealand Wool Board and Crown Research Institute AgResearch to manage a $90 million investment into biotechnology research focusing on sheep biology, physiology and genomics. The government is also an investor in Ovita through the Research Consortia scheme, investing $8 million per annum over five years (2002-2007).

In the past five years, Ovita and spin-out company Catapult have launched five products onto the market to enhance sheep fertility and growth, and filed twelve new patent applications. These products include DNA tests for genes that lead to musclier, more fertile and less fatty sheep. The knowledge that underpins these products is based on many years of research and development by AgResearch scientists.

80,000 sheep were tested with Ovita's genetic diagnostic products in 2005 alone, and the DNA testing business recently expanded into Australia, the UK and Europe.

Also in the development pipeline are tests for resistance to internal parasites, improved meat quality and facial eczema. Parasite research is continuing within Ovita spin-out company Paraco Limited, which is developing a novel worm-killing medicine and a vaccine candidate for controlling gastro-intestinal parasites in livestock. The muscle growth and development research venture, focused on applications in humans and based on the myostatin molecule, is also continuing within another spin-out company called Orico Limited.

Visit www.ovita.co.nz

ROADMAPS for SCIENCE

5.5.3 Food and nutrition

Research strengths

One of the key future global trends in food research is for functional foods and nutraceuticals. For example, nutrigenomics, the customisation of diet by genotype to optimise health benefits, may become a market trend in the future.

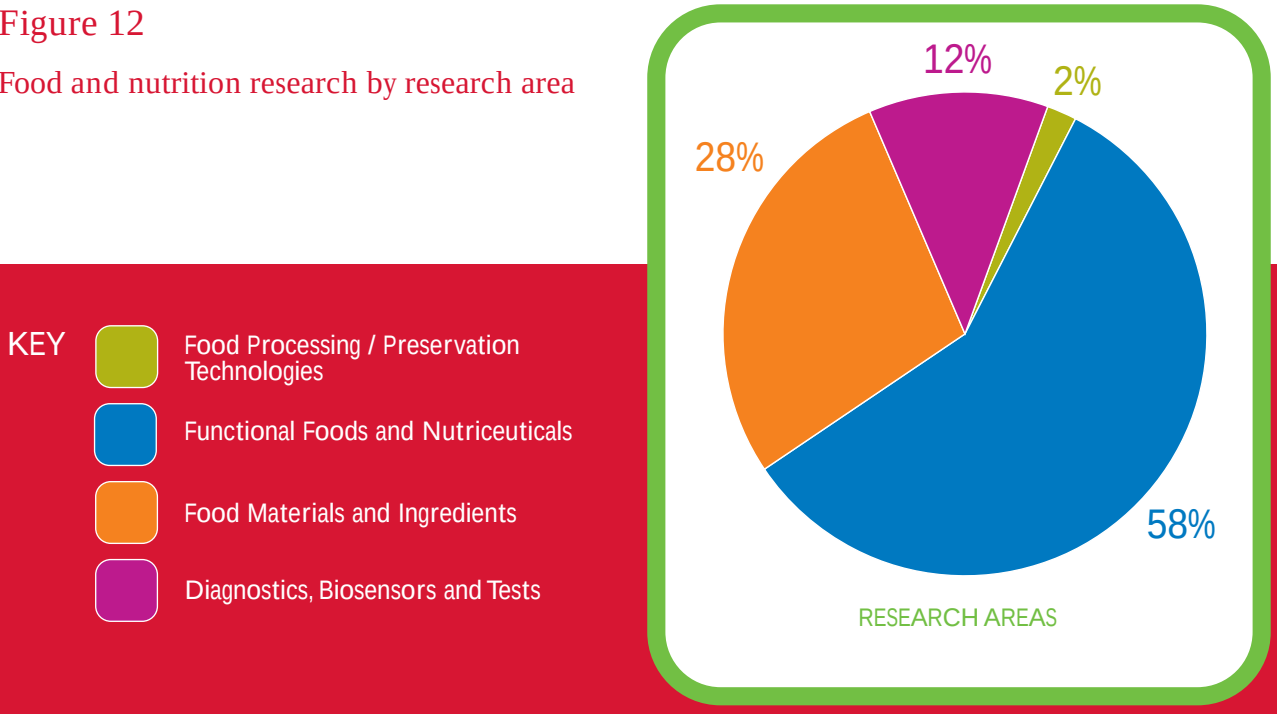
New Zealand has significant research strengths in functional foods and nutraceuticals and food and nutrition research in New Zealand is well placed to capitalise on these global trends. Longer-term these advanced food concepts have the potential to create the next growth step-change for New Zealand's food and beverage sector.

Current investment levels and trends

Biotechnology research into value-added food and nutrition accounts for $19 million per annum, or around 10% of total government investment in biotechnology. *Figure 12* shows that the bulk of current investments are directed towards functional foods and nutraceuticals (58%), followed by research into food materials and ingredients (28%) and food safety research (12%).

Figure 12

Food and nutrition research by research area



Issues or gaps?

The impact of biotechnology research on the wider food and beverage sector is considerably greater than the value-added end of the food and nutrition research spectrum. The potential impact is even larger if you use a broad "farm-to-fork" frame to consider the impact of biotechnology research on quality improvements to our agricultural and horticultural exports.

Despite the potential of much of the value-added food and nutrition research being undertaken in New Zealand, recent work undertaken for the Food and Beverage Taskforce indicates that in such a diversified, fragmented industry sector a gap does exist. The gap is between the potentially transformational research currently being undertaken and the industry's capacity to pick it up in the future. Part of the reason for this gap is that industry tends to favour R&D investments into cost-reducing process innovation over margin-enhancing, biotechnology-driven product innovation.[77]

5.5.4 Marine biotechnology

Research strengths

New Zealand has marine biotechnology research strengths in:

- aquaculture production using genetic techniques to underpin selective breeding in commercial shellfish species; and
- the discovery and extraction of marine bioactives for health and industrial purposes.

Current investment levels and trends

Marine biotechnology research constitutes only 2% of the total government biotechnology research expenditure. Of this 43% is spent on research into marine bioactives; the remaining 57% goes on research to underpin the aquaculture industry.

Issues or gaps?

That marine biotechnology funding is small compared to the land-based primary production industries is not surprising. Despite the comparative advantages New Zealand enjoys in the marine environment (including the breadth of biodiversity and relative size of our Exclusive Economic Zone and coastlines), harnessing marine species for industrial purposes beyond "catching fish" is still at a very early stage of "domestication".

There is considerable scope for the future expansion of activities and a notable overlap with the food and beverage sector.

The government's marine biotechnology research investments are currently exclusively directed towards applied research. There is a perceived basic-targeted research "funding gap".

Like the food and beverage sector, the seafood industry is diverse and fragmented. It is dominated by the larger, traditional seafood companies with a proliferation of smaller enterprises in the aquaculture and value-added products end of the spectrum. This creates a difficult environment for biotechnology research to be taken-up and utilised by industry.

The establishment of Seafood Innovations Ltd (SIL), a new research consortium, is starting to make some progress linking research and industry in co-funding arrangements. In recognition of structural issues, among other factors within the seafood sector, FRST approved a revised consortium model for SIL, whereby co-investment is sought from industry stakeholders on a project-by-project basis.

[77] MoRST (2006), *Current Food and Beverage Research in New Zealand*

5.5.5 Industrial biotechnology

Research strengths

Industrial biotechnology is a very broad research area. It encompasses bio-energy production, bio-production and manufacturing technologies and bio-based product development like bio-polymers.

Areas of research strength in New Zealand (traditionally labelled as "fibre" research) utilising wool, wood and non-food crops are beginning to gain critical mass. This is resulting in emerging research strengths in areas like advanced industrial biopolymer development. Industrial biotechnology applications are also starting to emerge out of research underpinning some of New Zealand's plant food crops (see Case Study p.45). Significant bio-processing research capabilities leveraged from the dairy industry also fit into this category.

Current investment levels and trends

Around $12 million of government research funding is currently invested on bioprocessing research. A small portion of bioenergy research ($1.2 million) is also funded through Vote RS&T. Current industrial biotechnology research capability mostly focuses on improving biomanufacturing systems (45%) and developing novel biomaterials (40%).

FRST has recognised the emergence of this sector and its potential by signalling that industrial biotechnology proposals be considered in the 06-07 investment round.

Issues or gaps?

Sector feedback has identified areas of opportunity for New Zealand to capitalise from emerging international industrial biotechnology developments. Notably, niche bio-based products and processes, the extraction of greater value out of under utilised primary industry waste-streams, and the potential, if proven economically viable, for indigenous biofuel production.

However, despite this, potential areas of niche research opportunity research capabilities in this area are not well described or promoted as a whole. Greater coordination will be required to understand and harness the value proposition that industrial biotechnology offers to New Zealand.

5.5.6 Environmental biotechnology

Research strengths

The government's environmental biotechnology research investments can be divided into three broad areas of strength:

- fundamental research contributing to knowledge about ecological and evolutionary processes;
- research underpinning biodiversity and biosecurity management in New Zealand; and
- research directed towards technology development with dual economic and environmental outcomes for example, bioremediation technologies.

Current investment levels and trends

Environmental biotechnology research investment currently stands at 11% of the total expenditure. Biodiversity ecology and evolution (53%), and biosecurity and pest control technologies (31%) account for the majority of the total *(see Figure 13)*.

‘Nature Identical’ Scents and Flavours

We are often told to stop and smell the roses - at HortResearch they have really taken that advice seriously.

HortResearch, a Crown Research Institute, is working on identifying the exact enzymes involved in producing flavours and fragrances in both fruit and flowers. This could revolutionise the way such compounds are created for foods, cleaners, cosmetics or perfumes.

The company has filed international patent applications on the use of an enzyme that makes a compound that smells like the heady scent of red roses and another enzyme that creates the fragrance of green apples.

Various industries presently use either extraction techniques from harvested raw ingredients or synthetic solutions to mimic nature's flavours and fragrances in products ranging from ice cream to shampoo.

Neither approach is ideal. Chemical synthesis leaves an environmental footprint, largely because of its use of fossil fuels in the manufacturing process. What's more, chemical synthesis can never truly recreate nature; the flavour or fragrance will typically be slightly different to that found naturally in fruits and flowers.

While extraction from raw ingredients produces natural tastes and smells, it is often an expensive and wasteful process that produces only limited quantities of product.

Over many years, HortResearch has developed extensive fruit enzyme and flavour/fragrance compound databases. They have also developed techniques that help determine which specific enzymes create each compound, and how those compounds combine to create a flavour or fragrance.

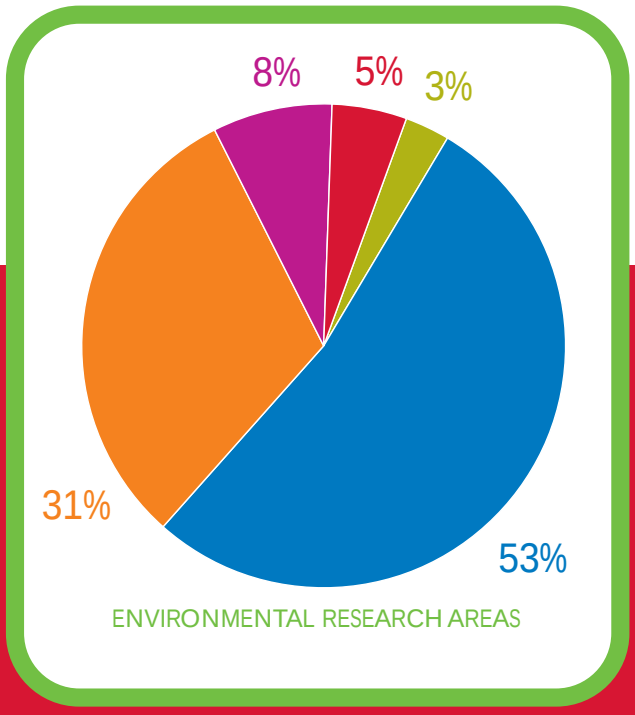
Once the relevant enzymes have been identified, researchers at HortResearch use biofermentation techniques to produce the desired compound. Biofermentation processes have long been utilised in baking bread, making beer, wine, cheeses, yoghurts and antibiotics. During biofermentation useful compounds end up floating in the airspace above the bacterial brew where they can be harvested.

The harvested compounds have exactly the same molecular make-up as those from plants in the wild. They are, as the scientists say; ‘nature identical’. To prove the concept, HortResearch has recently recreated a natural fruit compound called alpha-farnesene. This compound and its derivatives are responsible for the distinctive aroma of green apples.

ROADMAPS for SCIENCE

Figure 13

Environmental biotechnology research breakdown by research area



There has been a consolidation of basic and underpinning environmental biotechnology research capability over recent years with the establishment of CoREs, the National Centre for Advanced Bioprotection Technologies, and the Allan Wilson Centre for Molecular Ecology and Evolution. Similarly, the awarding of longer-term outcome-based investment (OBI) funding to Landcare Research's biosystematics databases and research programme has begun the process of providing greater stability to areas of critical public good research.

Environmental technology development is considered to be a growth area for New Zealand.

Issues or gaps?

While there has been a degree of consolidation of underpinning research capability in this area, there still remains a need to focus investments particularly in outcome focused areas. Sustainable development is becoming increasing important to New Zealand, as evidenced by the level of strategic importance being attached to it by government and industry. This will be a research area which will require improved oversight and funding levels will need to be revisited if New Zealand is to achieve its strategic goals.

National Centre for Advanced Bio-protection Technologies

New Zealand's unique island ecology and dependence on agriculture and horticulture means protecting our environment from destructive foreign pest organisms is vital.

This means the National Centre for Advanced Bio-Protection Technologies, which is at the forefront of biosecurity research, plays an important role in New Zealand's future.

The Centre, hosted by Lincoln University and partnered by Massey University, Crop & Food Research and AgResearch, is one of seven Centres of Research Excellence (CoREs) that were established in 2002 to encourage the development of world-class research in New Zealand, in this case agricultural biotechnology and bio-protection. The Bio-Protection Centre also undertakes applied research and has formed a number of partnerships with government agencies and industry.

The Centre performs a range of research projects, from molecular biology to conservation biocontrol, computer modelling and field trials, to assist New Zealand's plant-based industries and natural ecosystems. This includes developing sensor and DNA-based diagnostic technologies to detect unwanted pests at the border, and bioprotection techniques which are acceptable to Māori growers by incorporating Māori perspectives and tikanga (customs and traditions) into effective modern bio-protection strategies.

The Centre has also had commercial successes. Four biocontrol products have been commercialised by Centre researchers in association with partners Agrimm Technologies Ltd. The latest of these, Sentinel®, is used to control the fungus Botrytis in wine grapes and tomatoes. It has been developed from a new strain of Trichoderma, a fungus that prevents harmful fungi from infecting crops.

A key resource of the Centre is the New Zealand Biotron, a climate simulator in an enclosed two-storey building where researchers can study interactions between plants, pests and the environment. With independent manipulation of above-ground and below-ground conditions, the impacts of extreme weather, like frosts or hot sunlight, can be studied in experiments that closely mimic field conditions. The facility will allow study of hosts, pests or pathogens that cannot be released into the open. This will be increasingly important for the study of potential biocontrol agents or pests that pose biosecurity risks.

For more information about the National Centre for Advanced Bio-Protection Technologies visit www.bioprotection.org.nz

ROADMAPS for SCIENCE

5.5.7 Research to support the effective development and management of biotechnology

Following on from the recommendations of the Royal Commission on Genetic Modification the government has directed research investments towards the societal implications and environmental impacts of emerging biotechnologies.

This research mostly aims at contributing knowledge to support:

- the ethical and safe regulation of New Zealand developed and imported biotechnologies;
- the prevention and management of adverse impacts; and
- the socially and environmentally responsible development of biotechnologies.

Research strengths

New Zealand researchers are currently building research strengths in developing models to understand the impacts of genetically modified crops on agricultural eco-systems and the social context shaping attitudes and values towards emerging biotechnologies within New Zealand.

Current investment levels and trends

Investments in this area currently make up 2% of the total investment in biotechnology research. Proportionally, current investments are weighted towards environmental impacts research (87%) and investments are distributed across a range of research providers.

Issues or gaps?

End-user feedback suggests that the current configuration of environmental and social impacts research has resulted in some fragmentation between research providers and the need for better connectivity with the largely government sector users of this research. This in turn suggests that there is a need for greater strategic oversight to shape the future direction of this research investment area.

5.5.8 Research commercialisation – streamlining processes

The long lead time to market with biotechnology products requires long-term research investments. An issue which has been identified is the need for more streamlined research funding processes at both an intra and inter-research funding and investment agency level.

The government's research funding output classes and schemes span the research spectrum and are managed by multiple funding and investment agencies. The vertical nature of these funding pots can inhibit the progression of the best ideas along the pathway towards commercialisation.

The recently completed New Economy Research Fund (NERF) evaluation also pointed out a perceived gap between the basic-targeted research funded by NERF and access to follow-on research funding that bridges the gap to commercialisation.

Furthermore, there is a degree of confusion about the degree of overlap between NERF and the more applied Research for Industry (RFI) fund.[78] To add weight to this observation, as of 2005-06, 40% of NERF funding is directed towards applied or experimental research and 32% of RFI is directed towards basic research.

There is scope here for further RS&T system policy work to investigate options for tackling these issues. There is also scope for future improvements both between, and within, research funding agencies to streamline the progression of the best research towards commercial application coupled with the appropriate review mechanisms to filter quality. One particular area identified is the need to investigate whether health biotechnology research funding processes are appropriately aligned between the HRC and FRST.

[78] ABT Associates (September 2005), op-cit, p.67-68

6 Directions for Biotechnology Research

Section summary

- Previous sections identified the international and national biotechnology research landscapes and New Zealand's strategic economic and social goals. Drawing on this material this section presents the government's perspective on the preferred future directions for biotechnology research in New Zealand.
- This section:
  - affirms some existing directions and trends; and
  - highlights areas where changes, improvements or greater future emphasis will be need to be made.

6.1 High level objectives

Biotechnology research is of critical importance to New Zealand, with a central role to play in achieving the government's economic transformation goals.

Transforming New Zealand's economy will come about by both building new strengths based on our primary sector, and by developing new areas of competitive advantage that capitalise on global demands. Government funded research must continue to maintain New Zealand's existing competitive advantages while also helping establish new areas by investing in opportunities arising from "science-led" research which have the potential to build completely new industries. Research is the life-blood of New Zealand's biotechnology industry and ensures that there is a supply of innovations to drive new biotechnology enterprise creation.

New Zealand's natural environment faces increasing challenges including adjusting to climate change, a biosecurity management system under increasing pressure from the globalisation of trade and travel, and balancing the need to increase on-farm productivity and lower environmental impact. Biotechnology research has a growing role to play to help find solutions to these challenges, as well as open up new opportunities based on our natural resources.

Research has an equally important role to play in ensuring the responsible development and management of biotechnologies in New Zealand. Research knowledge underpins high quality decision making and informed debate about the environmental and societal implications associated with new biotechnologies.

The global nature of biotechnology research has important implications for New Zealand. Given that the vast majority of biotechnology research and applications are, and will always be, developed off-shore, New Zealand must maintain research that allows it to remain connected to the global network of biotechnology RS&T. This ensures a continuing ability to scan, adopt and adapt this pool of global knowledge for New Zealand needs. This is important for a number of areas including the healthcare system, the development of critical science services (like forensics), and the adaptation of offshore research developments for New Zealand's unique primary sector conditions. With limited resources, it is also important for New Zealand to focus partnership efforts on targeted countries and regions.

Government has the following four main objectives for New Zealand's involvement in biotechnology research:

- Biotechnology research should contribute to economic transformation, through higher productivity, higher value products and diversification of the economy.
- Biotechnology research should assist in protecting the natural environment and developing environmentally sustainable industries.
- New Zealanders should benefit from biotechnology developments which will improve their health and wellbeing.
- Biotechnology research undertaken in New Zealand should be developed and managed responsibly.

Using these over-arching objectives as starting points, we have identified a set of directions for biotechnology research. Where appropriate these directions are supported by immediate actions to aid their implementation.

6.2 Biotechnology research directions

At the highest level, the current balance of the government's biotechnology research investment is "about right". For example, there is a good balance between supporting biotechnology research for New Zealand's core business of food and agricultural production (approximately 50% of research investments) and the development of new knowledge and enterprises based on global biomedical opportunities (30% of research investments).

Our own analysis and consultation with key stakeholder groups, therefore, leads the government to conclude that there does not need to be any radical shifts in funding priorities. Consequently, this Roadmap does not recommend any significant re-prioritisations of *existing funding* between different research areas or portfolios. Biotechnology research requires long term investment (often at least 10-15 years) to reap benefits, and major short-term shifts in priorities can lead to wasted effort as research projects are started up and shut down to meet these changes.

However, there are some areas where New Zealand needs to improve, either the way its biotechnology research system operates, or in how it responds to future opportunities or challenges. Specifically, improvements need to be made to:

- better integrate underpinning research platforms which support strategically important research areas;
- improve linkages between research and end-user communities (industry and government);
- develop more appropriate public-private co-funding arrangements for currently fragmented industry sectors; and
- improve funding processes between and within research funding and investment agencies (in particular, building greater flexibility into processes as projects move from basic to applied and into commercialisation stages).

Furthermore, to bolster New Zealand's efforts in emerging areas of importance, the overall balance and level of research investment will need revisiting in some areas. These emerging areas include:

- adding value in the marine and the food and beverage sectors;
- taking advantage of significant opportunities emerging from global industrial biotechnology developments; and
- using biotechnology research to address environmental sustainability challenges.

The government recognises that identifying areas of future opportunity and challenge may have potential budgetary implications. If additional funding is required to achieve these directions, government funding decisions will be made as part of the annual Budget process.

Table 5 provides a summary of the statements of research direction detailed in section 6.2.1 – 4. These statements are divided into:

- directions to achieve the explicitly stated strategic outcomes that the government seeks from its biotechnology research investments (namely; economic and environmental outcomes and research to support the responsible management of biotechnology); and
- cross-cutting directions which have implications for, and underpin, all areas of biotechnology research (for example, strengthening international linkages, research infrastructure requirements and collaboration and multi-disciplinary research).

Biotechnology is a broad area of research and there are cross-over areas with other Roadmaps developed by MoRST. These cross-over areas are also signalled in the directions.

Table 5.
Summary of Directions: Biotechnology Research Roadmap

Directions: Economic	Direction 1
	The government will continue to support and partner with industry, providing biotechnology research that enables industry participation and helps develop and transform bio-based industries in New Zealand.
	Direction 2
	Additional effort is required by government and industry to leverage transformational biotechnology research opportunities in the marine and food and beverage sectors.
	Direction 3
	Enhanced coordination is required for New Zealand to benefit from emerging industrial biotechnology opportunities.
	Direction 4
	The government will continue to support New Zealand's best biomedical and drug development research.
	Direction 5
	The government will work to improve research funding processes to progress biotechnology research more smoothly along the pathway to commercialisation.
Directions: Environmental	Direction 6
	The government will maintain long-term research capabilities to underpin and enhance biodiversity and biosecurity management in New Zealand.
	Direction 7
	Additional biotechnology research is required to help New Zealand meet emerging sustainable development challenges.
Directions: Research to support the effective management of biotechnologies	Direction 8
	The government will support research to inform quality decision-making on the environmental impacts and societal implications of emerging biotechnologies within the New Zealand context.
Directions: Cross-cutting	
International linkages	Direction 9
	The government will focus additional efforts on building international relationships for New Zealand biotechnology research in the Asian region.
Research platforms	Direction 10
	The government will work to consolidate underpinning biotechnology research platforms to better support key areas of research strength where there will be significant benefit to New Zealand.
Collaboration & inter-disciplinary research	Direction 11
	Greater focus on collaboration and inter-disciplinary research is required.

6.2.1 Directions: Economic

Direction 1

The government will continue to support and partner with industry, providing biotechnology research that enables industry participation and helps develop and transform bio-based industries in New Zealand.

The government wants to ensure that all New Zealand's key bio-based industry sectors are receiving maximum benefit from its biotechnology research investments. This includes the primary and the food and beverage sectors. To do this effectively government, research and industry need to work closely together. This ensures that the government's biotechnology research investments are taken up by industry where it exists, and the resulting products are acceptable to and valued by global markets.

Investing in higher risk, science-led research which extends the horizons of industry and provides the engine for a transformed future economy and new industries is another important role for government funded R&D.

Achieving this range of outcomes requires public investment to retain a balanced portfolio of applied research that maintains and extends New Zealand's comparative industry advantages and excellence focused earlier stage research with the potential for more transformational outcomes.

Different outcomes require different approaches to setting research direction. For applied research investments, research and investment agencies need to set research directions and targets in partnership with industry. From this comes an expectation that research proposals supporting industry development will also be assessed on their connections with end-user groups both through the setting of research targets and/or co-funding commitments. The rationale for this approach is to actively involve industry end-users in the process so there will be more likelihood they will gain direct benefits from the research.

Research priorities for earlier-stage biotechnology research with the potential to build new industry and transform existing industry need to be primarily based on internationally competitive research excellence.

However, the government also recognises that a greater degree of flexibility needs to be built into the research prioritisation and assessment process as research opportunities transition from early stage to more applied. This is because different industry groups may be at differing levels of maturity in terms of their capacity to co-invest, or in their own ability to take up and progress the results of research (for instance, research may be needed to prove to industry the value of "new animals" or "new crops"). FRST have started to build this increased flexibility into their investment processes as part of a "sector development" initiative.[79]

The government also has an important role to play in stimulating private sector investment in biotechnology R&D. Public-private research co-investment schemes act as an incentive to achieve this. Co-investment schemes also build important linkages between research and industry.

Although the Research Consortia scheme has improved links between research and industry, a consistent theme in this Roadmap is that, in reality, one size does not fit all across all industries. Fragmented, heterogeneous industry sectors do not currently absorb and benefit from biotechnology research as well as centralised, vertically integrated industry sectors. Notable examples of fragmented sectors identified in this Roadmap are the marine and food and beverage sectors (see Direction 2 below). The Seafood Innovation Ltd research consortium, in part due to sector diversity, has been predicated on a different co-investment model than the other research consortia.

The government will continue investing in public-private co-funding partnerships with industry. It will also continue working to ensure the most effective models are adopted to support different types of industry groupings.

[79] FRST (2006), *Investment Signals for the Leveraging New Zealand's Natural Resources Investment Process 2006-2007*, p.19-20

Short-term actions:

Research funding and investment agencies to:

- retain a balance in research funding, to maintain New Zealand's competitive advantages and develop new, transformational areas from them;
- set research priorities for applied biotechnology research in partnership with industry;
- build greater flexibility into research assessment processes for research where there is the potential for transformational outcomes, but an absence of current industry end-users; and
- set research priorities in new and developing areas based on research excellence.

Research organisations to highlight biotechnology opportunities by further developing linkages with relevant industries and user groups, and supporting researchers engaging with industries.

Direction 2

Additional effort is required by government and industry to realise transformational biotechnology research opportunities in the marine and food and beverage sectors.

Development of the Roadmap identified two key sectors for New Zealand where there are significant opportunities for biotechnology research to add value over the short-to-medium term: the marine and the food and beverage sectors.

Food and Beverage

From a research capability perspective New Zealand is well equipped to extract greater benefit in the food and beverage research area. Particular opportunities exist in the area where food and health converges. However, more research and policy work is required to leverage these opportunities. In particular, there is a need to address a current mismatch between "science-push" and "market-pull" at the value added end of the food and beverage spectrum.

Further work is needed by government, research and industry to transfer cutting edge research to the New Zealand based food and beverage industry. This finding is consistent with the recommendations in the recently published report of the Food and Beverage Taskforce.[80]

The Government response to the Food and Beverage Taskforce report is forthcoming.[81] Any related food and beverage research actions in its response to that report will be incorporated into the actions arising from this Roadmap.

Marine

New Zealand's marine-based industries and environment have the potential to provide future economic opportunities for New Zealand. These opportunities are multi-faceted. Based on experience with land-based primary production, biotechnology research will drive productivity improvement in the aquaculture industry. The potential of the aquaculture industry was recently highlighted in a strategy jointly developed by industry and government. As the world's fastest growing primary industry this sector presents significant opportunities for New Zealand to extend existing competitive advantages.[82] Marine biotechnology will also provide opportunities for New Zealand researchers to develop bioactive compounds from the marine environment for medical and industrial purposes.

It should also be noted there is a strong cross-over with the issues signalled for the food and beverage sector. The early stage of marine's development may also mean that New Zealand's established plant and animal research strengths, (for example, genomics research

[80] The Taskforce report recommends that there is a need to develop linking "vehicles to focus R&D on commercial problem solving" and provide greater incentives for collaboration through encouraging "the consolidation of infrastructure, knowledge, production processes, distribution and marketing" of which research is an important component.

[81] As of November 2006

[82] *The New Zealand Aquaculture Strategy* (2006), p.2

expertise underpinning plant and animal productivity enhancement) could be applied more broadly to the marine environment.

A range of issues exist across-the-board in the marine sector. Additional marine biotechnology research investment in the short-to-medium term needs to be directed towards building basic-targeted biotechnology research capability to support the long-term transformation of the sector. Ongoing work is also required to help industry build the capacity to take up research.

Actions:

Marine

- Government, research funding and investment agencies, research organisations and industry: to continue efforts to build better linkages between research and industry.
- In the short to medium-term, any additional funding available for marine biotechnology could most usefully be directed towards building basic-targeted research capability that could underpin the long-term transformation of the marine sector.

Food and Beverage

- MoRST to undertake further food and beverage research policy work (this action will be determined by the government's response to the Food and Beverage Taskforce recommendations).
- Government, research funding and investment agencies, research organisations and industry: to continue efforts to build better linkages between research and industry.

Direction 3

Enhanced coordination is required for New Zealand to benefit from emerging industrial biotechnology opportunities.

Internationally, significant industrial biotechnology market opportunities are beginning to present themselves – notably for commodity-based products like biofuels. But a growing consumer appetite in developed nations for environmentally sustainable products and cleaner industrial processes, coupled with maturing science and technology in the area, also present significant opportunities for New Zealand science. For example, existing research strengths and platforms underpinning primary production sectors could be re-oriented towards industrial biotechnology opportunities.

New Zealand does not, however, currently have a clear understanding of the complete picture of New Zealand's research and industrial capability in this broad area. In the short-term, therefore, we need to build a greater understanding of the value proposition from industrial biotechnology and how to best benefit from longer-term developments. In the short-term, improved coordination between government agencies, research organisations and industry will help.

Roadmap Crossover – Roadmaps for Science: Energy Research

Industrial biotechnology, in the area of bioenergy research development, is an area of convergence with the government's Energy Research Roadmap. The Energy Roadmap describes critical research capabilities that New Zealand needs to maintain in the bioenergy area to benefit from rapidly moving international developments. It stresses the importance of keeping options open and the flexibility to move in a number of directions, for example, into niche technology development or New Zealand-specific resource assessment and implementation.

The future direction of this area (including research) will also be shaped by the New Zealand Energy Strategy which is currently under development.

Short term actions:

- MoRST and New Zealand Trade and Enterprise to undertake a survey of New Zealand's industrial biotechnology research, to determine existing industrial biotechnology capability in New Zealand and identify emerging needs.
- NZBio to develop a Special Interest Group for industrial biotechnology.
- Research funding and investment agencies to implement the Directions for bioenergy research signalled in the Energy Research Roadmap.

Direction 4

The government will continue to support New Zealand's best biomedical and drug development research

New Zealand has developed a number of world-class biomedical research groups. These have been built on sustained public investment and the research excellence of the teams involved. The fruits of some of these areas of research have started, or are in train to reap commercial benefits.

The field of biotechnology offers the promise of huge improvements in healthcare through, for example, more selective drug targeting, genetic testing and regenerative therapies. For these benefits to be realised, discoveries made through biomedical research need to be commercialised to make them into treatments that can be used for patients. Given the size of the New Zealand market and the expense of developing biotechnology products, this will generally mean targeting problems with an international as well as New Zealand impact. This means that New Zealand research has to be internationally competitive.

Investment in research excellence will also result in health benefits for New Zealanders by providing the expert skills and knowledge needed to adapt international health biotechnology products to New Zealand conditions. With such a small part of the world's biotechnology research happening in New Zealand it is likely that the major health benefits from biotechnology to New Zealanders will come from offshore research.

Strengthening trends in the global biopharmaceutical industry to outsource early stage R&D present opportunities for New Zealand. However, the challenge remains one of guiding excellent research opportunities through to the point of research commercialisation. Connecting effectively with regional or global markets and partners is a critical part of this process.

Over the past few years a number of New Zealand biomedical research groups have developed effective connections with the global marketplace. Future investment in later stage research investments should be concentrated around research that builds on or leverages off these links. This is especially so for collaborations which vertically integrate basic discovery, development and early commercialisation by groups with proven track records.

Government funded biotechnology R&D investments are an important part of sustaining and building areas of research strength. Its research investments need to be based primarily on internationally competitive research and researcher track record if critical mass is to be built and for New Zealand to be internationally competitive.

Short term actions:

Research funding and investment agencies to:

- set biomedical and drug development research priorities on internationally competitive research excellence.
- focus later- stage research investments on research that builds on strong international links.
- work on building collaborative partnerships within New Zealand that cover the entire basic-to-market application spectrum.

Direction 5

The government will work to improve research funding processes to progress biotechnology research more smoothly along the pathway to commercialisation.

The long lead times to development with biotechnology related products require long-term research investments. The government has important roles to play supporting research commercialisation activities in partnership with industry to grow the biotechnology industry in New Zealand. This includes the provision of funding to progress biotechnology research that can be commercially used from basic-to-applied-to-prototype development and addressing any funding gaps that are inhibiting the progression of biotechnology research to achieve commercial outcomes.

The establishment of the Pre-seed Accelerator Fund (PSAF) has begun to fill what was a particularly important funding gap for the biotechnology industry in New Zealand. Preliminary reviews of this funding scheme indicate that nearly 40% of projects funded to date have a basis in biotechnology research. The government has scheduled an evaluation of the PSAF scheme for completion by 2008-09. This evaluation will identify any aspects of the scheme's implementation which require further improvement.

The need remains, however, to improve continuity of funding between funding portfolios and instruments and to improve inter-agency alignment between funding agencies which support complimentary research commercialisation activities. For example, recent evaluations indicate that there is degree of confusion amongst the research community, and overlap between the outcomes that are being sought from both the NERF and RFI output classes within Vote RS&T. There is scope for further RS&T system policy work to investigate options for improving these issues.

There is also scope for future improvements both between and within research funding agencies to streamline the progression of research to achieve commercial outcomes. This needs to be coupled with the appropriate review mechanisms to filter quality to ensure that the research with the greatest likelihood of commercial application is supported. This work has already started. For example, FRST recently introduced systematic review processes to manage their research investments, in terms of assessing their scientific quality, working out their fit with national priorities, and assessing their delivery of outcomes to date. One area identified which requires further consideration in the short-term is whether health biotechnology research funding processes are well aligned between the HRC and FRST as projects move towards commercialisation.

Work is also underway more broadly to identify where greater coordination and alignment is required between the government agencies that support research commercialisation and business support for firms. This includes work to develop coordinated and seamless delivery between operational funding agencies to improve the performance of existing funding mechanisms which support business R&D.

Short term actions:

- MoRST to evaluate the implementation of the Pre-Seed Accelerator Fund by 2008-09.
- MoRST to continue to work on RS&T system policy settings to ensure that Vote RS&T is structured to maximise commercial outcomes from research.
- MoRST to work with research funding and investment agencies to develop improved internal and cross-agency funding processes to further streamline the progress of biotechnology research ideas towards commercialisation.

6.2.2 Directions: Environmental

Direction 6

The government will maintain long-term research capabilities to underpin and enhance biodiversity and biosecurity management in New Zealand.

Effectively managing New Zealand's indigenous biodiversity and biosecurity regime is highly important for New Zealand. It requires long-term underpinning research and the curation and management of indigenous biodiversity data, including genetic data. Much of this data is currently housed within nationally significant databases and collections, for example, biosystematics collections.

Policy work currently being undertaken by MoRST aims to put in place a funding regime that is better tailored to support "backbone" science investments[83] of New Zealand science. The backbone concept takes the view that there are sets of research assets which are required over the long-term to support a broad range of RS&T activities. Work is currently underway to define the criteria and protocols for investment in research backbone. Biotechnology research assets underpinning biodiversity and biosecurity are being included within this process.

Biosecurity New Zealand in partnership with MoRST is currently developing a Biosecurity Science, Research and Technology Strategy. The completion of this strategy will more clearly articulate the biosecurity research that the government requires. Recent changes to New Zealand's RS&T system to introduce longer-term, negotiated research funding to areas of critical public good research is also taking research underpinning biodiversity and biosecurity management into account.

The Environment Research Roadmap provides more detailed directions for biodiversity and biosecurity research, particularly with regards to data management, which also apply to biotechnology research (see box below).

Roadmap Cross-over – Roadmaps for Science: Environment Research

The Environment Research Roadmap recommends that research effort is concentrated around a series of broad research areas. This includes global environmental change, the sustainable use of land, water and coasts and sustainable urban design.

Both Roadmaps have complementary roles to play addressing specific environmental sustainability challenges. For example, in the case of climate change, environment research focuses on investigating the physical aspects of climate change and climate modelling projections whereas biotechnology research will play an important role in helping provide solutions for New Zealand specific challenges, like agricultural methane emissions.

Areas identified for concentrated research efforts which cross over with this Roadmap are biodiversity and biosecurity. The Environment Research Roadmap signals the need for a more integrated, systems-based approach to managing biodiversity and biosecurity data and information systems. This also includes the need for biodiversity agencies and science providers to work together to assess the needs for long-term research that underpins biosystematics research capabilities, collections and databases.

Short term actions:

- MoRST to consider biodiversity and biosecurity management requirements as part of ongoing policy work to define the criteria and funding management needs for research backbone.
- FRST to include this research area as part of the longer-term negotiated funding processes.
- FRST to take account of the research directions set in the government's upcoming Biosecurity Research Strategy and the Environmental Research Roadmap.

[83] Backbone investments within Vote RS&T include essential infrastructure, nationally significant databases and collections, and functions related to core tasks of government such as the Measurement Standards Laboratory.

Direction 7

Additional biotechnology research is required to help New Zealand meet emerging sustainable development challenges.

Both the government and the private sector have signalled environmentally sustainable development as an area of critical strategic importance for New Zealand:

- The government has clearly signalled that science needs to play an important role in responding to potentially highly significant emerging environmental challenges (like climate change and biosecurity management).
- Sustainable development is also high on the list of strategic priorities for the primary production sectors (land and marine-based) which are also facing challenges to remain competitive and environmentally sustainable with limited resources.

Global trends indicate that biotechnology RS&T will have a growing role to play in meeting future sustainability challenges and that this is also where many of the emerging market opportunities will lie. In order for New Zealand to respond to this evolving national and international landscape in a timely manner, additional research effort will need to be directed towards addressing targeted sustainability challenges. Biotechnology research, while not the only type of research needed, will have a central role in meeting these challenges. This is particularly the case in areas like biosecurity management, food safety and the development of solutions for agricultural greenhouse emissions through research into ruminant biology. Developing biotechnological solutions to these challenges will also provide market opportunities for New Zealand research, for example, through the development of sustainable food production systems.

Short-term actions

Government agencies, including research funding and investment agencies, to work with primary sector industry organisations in developing shared strategies and undertaking jointly funded projects to address their sustainability needs.

6.2.3 Directions: Research to support the effective development and management of biotechnologies

Direction 8

The government will continue to support research to inform quality decision-making on the environmental impacts and societal implications of emerging biotechnologies in the New Zealand context.

Ongoing social and environmental impacts research is required to ensure that emerging biotechnologies are responsibly developed and managed in New Zealand. End-user feedback indicates there is currently a lack of strategic oversight and a degree of fragmentation between research providers in these research areas. Additional work needs to be undertaken to ensure that research to support decision-making is well coordinated and targeted to meet the strategic needs of the end-user community and society at large.

Short term actions:

MoRST to hold a workshop (2007), with government departments, research funding and investment agencies and researchers, to better co-ordinate existing and future work on environmental impacts and societal implications of biotechnologies.

6.2.4 Direction: Cross-cutting issues

Direction 9

The government will focus additional efforts on building international relationships for New Zealand biotechnology research on the Asian region.

Being well connected internationally is critical to the development of biotechnology research in New Zealand. New Zealand's geographic isolation means that the country faces particular challenges in staying tapped into global networks. International research linkages play a central role in developing biotechnology research in New Zealand, resulting in scientific collaborations, new sources of research investment and access to specialist research facilities. International research linkages also facilitate the development of international business and commercialisation linkages as New Zealand researchers use the business networks of their off-shore collaborators.

While many of the most fertile international research linkages are at the research group to research group level, the government also has a role to play in developing and facilitating international research relationships. For example through development of bi-lateral and multi-lateral science and technology agreements.

Recent efforts from government have focused on building research and industry links to important markets for biotechnology like the United States, the European Union and Australia. These have taken the form of a biotechnology alliance and partnership fund with Australia, focused delegations to the European Union and the inclusion of a science delegation to the US Biotechnology Industry Association's annual conference. The government will continue to build on these efforts.

International trends in biotechnology research activity are, however, indicating an increase in investment in the Asian region. Nations like China, India, South Korea and Singapore have been rapidly scaling up biotechnology research investments and infrastructure development. These sustained efforts present opportunities for New Zealand research groups and organisations to build stronger biotechnology research links with this region and help meet emerging market opportunities in the North Asia region. There are a number of synergies between areas of biotechnology research strength in New Zealand and growing investments in Asia.

Recent initiatives like the inclusion of biotechnology as a focus area in the Korean research mobility funding programme and the International Investment Opportunities Fund's focus on developing co-funding relationships with South Korea and Japan signal government's efforts in facilitating links with North Asia. Over the short to medium-term the government will also be actively building New Zealand's research relationship with China.

MoRST is also updating its International Science and Research Linkages Strategy. The current strategy focuses exclusively on developing bi-lateral and multi-lateral relationships. The updated strategy will take broad thematic research areas into account like biotechnology and food and nutrition research. This will provide further clarity and focus for the government's priority nations for building biotechnology research links.

Short term actions:

- MoRST to focus additional effort on building and facilitating New Zealand's research linkages with China.
- MoRST to update the government's International Science and Research Linkages Strategy to reflect thematic areas of research focus, like biotechnology research.

Direction 10

The government will work to consolidate underpinning biotechnology research platforms to better support key areas of research strength where there will be considerable benefits to New Zealand.

There are opportunities to better integrate underpinning research platforms and infrastructure (for example, genomics platforms, high throughput technologies and analytical capability) in New Zealand that have application across a number of areas of biotechnology.

This is particularly the case within broad research investment areas where there is fragmentation in research capability and the potential for duplication of effort between research organisations. Downstream, the effective consolidation of underpinning platforms will have the potential to free-up research funding for re-investment in more value-added research.

This view was confirmed by the findings of FRST's recent Plant Biotechnology Domain Review.[84] It recommended that within the government's plant biotechnology research investments there are opportunities to "integrate" national research capability at this underpinning level.

Beyond plant biotechnology, other broad areas of research capability could also benefit from the further consolidation of biotechnology research platforms. Rolling review processes, like FRST's science domain reviews, will help identify future areas where further consolidation of underpinning research platforms could offer significant benefits to New Zealand.

The implementation of plant biotechnology domain review recommendations provides an opportunity to "pilot" this direction. MoRST will work closely with FRST on the wider RS&T system implications involved. In the short-term (2007-08), the initial phase of work will involve defining the implementation pathway of this pilot in greater detail with FRST and the wider RS&T sector. This will include an assessment of how this will be incorporated into the ongoing negotiated funding roll-out.

Short term actions:

- FRST, with MoRST, to implement the recommendations of the Plant Biotechnology Domain Review to better integrate national plant biotechnology research platform capability in New Zealand.
- Research funding and investment agencies through ongoing review processes to investigate the case to better integrate other areas of underpinning biotechnology research capability and infrastructure.
- Research Organisations to continue to explore ways of working more collaboratively to share the costs and access to critical research infrastructure.

[84] FRST (June 2006), *Plant Biotechnology Domain Review – Report of the Strategic Decision Group*

Direction 11

Greater focus on collaboration and inter-disciplinary research is required.

Research funding and biotechnology science trends internationally and within New Zealand show a shift towards funding interdisciplinary research teams and research at the convergence of disciplines. Research occurring at areas of convergence between disciplines also drives innovations and the most significant "step changes" in knowledge.

Collaboration between researchers and research institutions also avoids duplication of effort and resources and helps build critical mass. It facilitates greater sharing of infrastructure, building of inter-disciplinary teams, and the development of stronger links between basic and more applied research. Establishing effective inter-disciplinary teams requires a range of factors and takes time. Funding and investment agencies and research organisations have roles to play in encouraging such teams to develop in the first instance, and then supporting them over the long-term.

Recent reviews and evaluations[85] have suggested that the RS&T system is not supporting research convergence as well as it might and greater effort is required to build and appropriately fund effective inter-disciplinary teams. One particular area of emerging opportunity for New Zealand identified by the Nanoscience and Nanotechnologies Roadmap (see box below) is greater focus on research at the interface between bio and nanotechnology.

Roadmap Cross-over – Roadmaps for Science: Nanoscience and Nanotechnologies

The Nanoscience and Nanotechnologies Roadmap signals the need for greater emphasis on building capabilities in bio-nanotechnologies. Strengthening research capability in New Zealand at the interface between biotechnology and nanotechnology is desirable because of the importance of primary production to the economy, the strengths we have in biotechnology and the added benefit nanotechnologies may contribute, and because of strong national support for good environmental management.

Short term actions:

- Research funding and investment agencies and research organisations to continue to prioritise and effectively support and maintain inter-disciplinary research teams; and
- Research funding and investment agencies to take account of the research direction in the Nanoscience and Nanotechnologies Roadmap which signals the need to strengthen research capability at the interface between bio and nanotechnologies.

[85] The Evaluation of NERF and the Plant Biotechnology Domain Review

7 Putting this Roadmap in place

This Roadmap has been approved by the Minister of RS&T who will retain stewardship of the Roadmap and, supported by MoRST, will ensure the directions are communicated and actions taken where appropriate.

The Minister of RS&T will instruct FRST and the HRC to take account of the relevant directions in the Roadmap in their future investment decisions. MoRST will work with FRST and the HRC to develop an implementation plan.

The Minister of RS&T will encourage organisations in the wider science system to take account of the directions in the Roadmap.

MoRST will maintain leadership for coordinating policy development and strategic activity to ensure responsible management and development of biotechnology research in New Zealand.

This Roadmap is a statement of the government's position on biotechnology research in New Zealand and is expected to remain current for 5-10 years. It is, however, inevitable that unforeseen developments and events will occur and that some of these may in time alter the outlook of the Roadmap.

MoRST will maintain oversight of the Roadmap, advising the Minister of RS&T on the progress of implementation as well as the ongoing relevance of its directions. MoRST will maintain a Roadmap advisory group to provide feedback on progress and arising issues. The Minister of RS&T will consider the need for an update to the Biotechnology Research Roadmap by 2011.

Annex 1

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Annex 2

Continuum of public research investment schemes in biotechnology research

Research Type	Research funding and investment agency	Research scheme and/or output class and description
Investigator Lead (Basic and Basic-Targeted Research)	Royal Society of New Zealand	The Marsden Fund The Marsden Fund supports excellence in research and researchers. The fund's objectives are: • to enhance the underpinning research knowledge base in New Zealand, and contribute to the global advancement of knowledge; • to broaden and deepen the research skill base in New Zealand; and • to undertake research that is investigator driven.
	Tertiary Education Commission	Centres of Research Excellence (CoREs) The Centres of Research Excellence (CoREs) were established in 2002/03 to encourage the development of world-class research in New Zealand, by providing incentives for researchers in the tertiary education sector to conduct research that is excellent, contributes to New Zealand's future development, and incorporates knowledge-transfer activities. The Centres of Research Excellence are primarily, but not exclusively, inter-institutional research networks, with researchers working together on a commonly agreed work programme. Each CoRE is hosted by a university and comprises a number of partner organisations including other universities, Crown Research Institutes and wānanga.
	Health Research Council	Health Research The HRC is the major government-funded agency responsible for purchasing and co-ordinating health research and fostering the health research workforce in New Zealand.

	Foundation for RS&T	New Economy Research Fund (NERF) NERF supports researcher-led innovation aimed at developing capability and knowledge in new areas or applications where industries are emerging or yet to emerge, in order to underpin new high-technology business opportunities. The focus of NERF funded research is on targeted basic research and human capital development that will underpin new enterprises and new sectors.
Outcome-focused (Targeted Research)	Foundation for RS&T	Environmental Research This output class supports public good research, science and technology that enhances understanding and management of New Zealand's environment. The research contributes to the understanding of species, habitats and ecosystems, and the human, pest and other influences to which they are exposed. Research outputs provide the knowledge that underpins the management, protection and enhancement of natural ecosystems. Research on sustainable use of ecosystems and the productive sector's environment is also included as is the attention to the social impacts of new technologies.
	Foundation for RS&T	Research for Industry (RFI) The RFI output class supports public good research, science and technology to increase the competitiveness of New Zealand industries and sectors. Research portfolios aim to lead to new products, processes and services that enhance the competitiveness of these industries and sectors. Of relevance to biotechnology research, one of RFI's key areas of focus is research whose primary objective is to advance food and fibre-based industries and related sectors through innovation. Research Consortia Research consortia (also funded out of the RFI output class) to facilitate public/private research partnerships that provide early user engagement and increase private investment in New Zealand. Research investment is made through user-led research consortia in partnership with research providers. They are industry-led, collaborative ventures established to fund and manage research. The consortia programme has been successful both in boosting private sector investment in science, and in increasing collaboration between researchers and investors.

Outcome-focused (Targeted Research)	Ministry of Agriculture and Forestry	Sustainable Farming Fund The purpose of the Sustainable Farming Fund (the Fund) is to support projects, including research projects that will contribute to improving the financial and environmental performance of the land-based productive sectors. The Fund aims to help the land based sectors solve problems and take up opportunities to overcome barriers to economic, social and environmental viability. It does this by bringing together "communities of interest". These are groups of people, including researchers drawn together by a shared problem and/or opportunity, in the sustainable use of resources.
	Foundation for RS&T	Pre-seed Accelerator Fund (PSAF) Pre-Seed Accelerator funding seeks to accelerate the commercialisation of new knowledge from publicly funded research carried out by public sector and not-for-profit research organisations, by bridging the gap between generating such knowledge and producing a first prototype or similar development so that the commercial prospect is "investor-ready".
	Foundation for RS&T	Technology NZ Technology New Zealand assists companies undertaking research and development (R&D) projects which result in new products, processes or services. The role of Technology New Zealand is to support companies wanting to overcome specific technical barriers which are likely to be part of the R&D phase.
	New Zealand Trade and Enterprise (NZTE)	Australia New Zealand Biotechnology Partnership Fund The Australia New Zealand Biotechnology Partnership Fund (ANZBPF) is designed to facilitate and accelerate trans-Tasman biotechnology industry collaboration. The rationale behind the scheme being that by developing greater regional critical mass, Australian and New Zealand biotech companies obtain better access to global market opportunities. While not strictly speaking a research scheme, ANZBPF supports some late-stage research projects and partnerships.

Annex 3

Statistical Framework for Biotechnology Research and 2004/05 Government Funding Investment by Area

Major Area	Definition	Sub category	Sub category definition
Animal-based biotechnologies	Utilises or engineers biologically-derived products to improve animal products, and create solutions to livestock related problems.	Animal genomics and IP	Animal genomic work including mapping and markers where there is a generic focus, capability building, and IP related to those activities.
		Animal health and nutrition	New vaccines, therapeutics, and other products to diagnose, treat and vaccinate animals for various diseases (also includes animal feeds).
		Animal improvement & reproductive technologies	Applied genetics and reproductive technologies including cloning.
		Animal products (non food)	By-products from animals (eg blood products/ colostrum/ skin) and fibre.
		Biopharming	Development of transgenic animals for the production of biopharmaceuticals or therapeutics.
Plant-based biotechnologies	Utilises or engineers biologically-derived products to make better or more useful plants, crops or trees and solutions to agricultural and horticultural problems.	Plant genomics and IP	Plant genomic work including mapping and markers where there is a generic focus, capability building, and IP related to those activities.

		Plant improvement	Production of new cultivars using genetic manipulation or marker assisted selection.
		Plant health and protection	Plant improvement specifically focussing on protecting against diseases, pests and weeds.
		Plant growth	Cell wall biotechnologies and molecular and genetic means to control plant growth.
		Biopharming	Development of transgenics for the production of biopharmaceuticals or therapeutics.
Innovative foods and human nutrition	Applies biotechnology to the production, processing of food products and nutritionally-based health solutions.	Food materials and ingredients	General food materials and ingredients.
		Food production technologies	On-farm production biotechnologies that specifically relate to the food value chain.
		Functional foods and nutriceuticals	New added value products, processes and services that specifically offer diet and health solutions.
		Diagnostics, biosensors and tests	Diagnostic tests and biosensors involved in food quality, food safety and food processing.
		Food processing/preservation technologies	Processing technologies and improving quality and shelf life.

Bioprocessing technologies and biomanufacturing	Applies biotechnology to industrial manufacturing and includes fermentation, extractions, purifications and separations of biological products.	Biomanufacturing	Industrial (non-food) processing and manufacturing includes textiles, speciality chemicals, biopulping and biobleaching.
		New materials	New materials including polymers and chemicals produced from biomaterials sources (such as plants and other fibres).
		Process monitoring	Industrial sensors (non food) and process technologies underpinning biomanufacturing
		Extremophiles / enzymes	Investigating the possible uses of extremophiles/ enzymes.
Environmental	Utilises biotechnology processes and applications for environmental outcomes.	Bioremediation	Applications for management and treatment of waste.
		Mitigation technologies	Applications to reduce amount and impact of pollution.
		Biosecurity and pest control technologies	Novel technologies and applications to manage/ control pests and diseases.
		Environmental indicators	Monitoring ecosystems and measuring environmental health.

		Biodiversity, Ecology & Evolution	Improved understanding of taxonomic relationships and ecosystem/ecological diversity or dynamics [to better manage biodiversity].
Marine biotechnology	Uses biotechnology to develop marine derived products	Aquaculture	Broodstock genetics, fish health and nutrition.
		Marine-sourced bioactives	Bio extractions of compounds from algal, fish and marine plant sources.
Biomedical science and drug discovery	Uses cells, genes, proteins, enzymes, antibodies or other biological components to prevent, diagnose, and fight infections and other diseases, as well as to correct genetic disorders.	Oncology/cancer	
		Diabetes and Cardiovascular disease	
		Neurological muscular diseases	
		Immunological diseases	
		Infectious diseases and parasitology	
		Osteoporosis and bone health	
		Medical diagnostics and devices	
		Biomedical imaging and bioengineering	
		Reproduction	
		Brain/neural studies	Non-disease oriented. Memory, learning, consciousness.
		Small organic compounds	Contributing to drug design/testing.

		Miscellaneous	Wounds/Healing, traditional medicines, bioactives.
Impacts and Integration of emergent Technology		Environmental	All research on impacts on the environment.
		Social	Research that focuses on the human dimension.

Government funded research by each Major Area and Sub category 2004-05

Major Area	Sub category	Total
Animal-based biotechnologies	Animal genomics and IP	9,439,988
	Animal health and nutrition	6,172,465
	Animal improvement and reproductive technologies	11,665,802
	Animal products (non food)	60,000
	Biopharming	620,057
Animal-based biotechnologies total		27,958,312
Biomedical science and drug discovery	Biochemistry	1,484,344
	Biomedical imaging and bioengineering	1,838,534
	Brain / neural studies	5,662,596
	Diabetes and cardiovascular disease	9,431,961
	Immunological disease	5,474,714
	Infectious diseases and parasitology	2,139,614
	Medical diagnostics and devices	6,807,409
	Miscellaneous	4,780,274
	Neurological / muscular disease	8,055,852
	Oncology / cancer	10,899,988
	Osteoporosis and bone health	2,783,638
	Reproduction	2,104,357
	Small organic compounds	561,172
	Stem cells	461,939
Biomedical science and drug discovery total		62,486,392
Bioprocessing technologies and biomanufacturing	Biomanufacturing	5,146,766
	Extremophiles / enzymes	577,500
	New materials	4,652,792
	Process monitoring	1,163,478
Bioprocessing technologies and biomanufacturing total		11,540,536

Environmental	Biodiversity ecology & evolution	10,776,877
	Bioremediation	1,545,839
	Biosecurity and pest control technologies	6,294,047
	Environmental indicators	960,100
	Mitigation technologies	583,336
Environmental total		20,919,901
Impacts and Integration of emergent Technology	Environmental	2,518,672
	Social	401,229
Impacts and Integration of emergent Technology total		2,919,901
Infrastructure total		369,280
Innovative foods and human nutrition	Diagnostics, biosensors and tests	2,217,500
	Food materials and ingredients	5,393,507
	Food processing/preservation technologies	358,000
	Functional foods and nutriceuticals	11,167,897
Innovative foods and human nutrition Total		19,136,904
IP and Commercialisation Assistance Total (includes NZTE and TBG)		5,150,808
Marine biotechnology	Aquaculture	2,529,000
	Marine-sourced bioactives	1,933,500
Marine biotechnology total		4,462,500
Misc total		2,141,612
Plant-based biotechnologies	Biopharming	1,257,100
	Plant genomics and IP	11,637,197
	Plant growth	7,001,168
	Plant health and protection	6,628,537
	Plant improvement	12,956,520
Plant-based biotechnologies total		39,480,522
Sector Development total		98,333
Grand total		195,905,299

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