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New Zealand Futurewatch 2025

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Authors: Dr. Sami Mahroum sami.mahroum@arcs.ac.at

Sponsors: The Government of New Zealand

Type: National foresight on scanning for new and emerging science and technologies, particularly biotechnologies that have implications for New Zealand's economy, environment or society

Organizer: The Ministry of Research, Science, and Technology.

Duration: Ongoing **Budget:** €350,000 (estimate) **Time Horizon:** Until 2025

Goals and Objectives

The goal of this initiative is to alert the government to new scientific knowledge and technology and understand the opportunities and risks that they present for New Zealand. The ambition is to find things that are new or unusual that may act as signposts to important changes on the horizon. Another aim is to think about the impacts of new science and technology in a way that include a range of perspectives in particular perspectives from outside the world of science and technology. This is intended to improve the Government's ability to anticipate and respond to new science and technologies from a context of broad reflection on New Zealand's future.

What Biotech can do for New Zealand

The 2000–2001 Royal Commission on Genetic Modification recommended that New Zealand develop a capability for what they called 'Biotechnology Futurewatch'. This was agreed by government through the New Zealand Biotechnology Strategy. This strategy includes the following statement:

'*Futurewatch activities scan, analyse and disseminate information on emerging developments to provide early alerts of new opportunities and issues. There is a need to strengthen futurewatch capacity to enable better and earlier identification of emerging biotechnologies that should be discussed by New Zealanders […] It will also provide the means to help improve the Government's capability to respond to new biotechnologies in the New Zealand context.*'

The first result of 'Futurewatch' is a report on global trends in biotechnology entitled 'Biotechnologies to 2025'. The conclusion of this report are summarised in the sections below. This activity however, links in with a range of other future-works across the government of New Zealand, and with the work of agencies and departments carrying out scanning activities.

The report was developed by a mix of people that included experts in global science trends, S&T policy advisers and futurist consultants. For the Science Discovery Scan (Chapter 9 of the report), a panel of scientists was convened by the Royal Society of New Zealand to identify major science trends based on their expert knowledge. A peer review process was used to check overall coherence and technical accuracy. A fold-out poster for dissemination was developed and tested in a work shop with policy advisers.

A Future of Converging Technologies

The 'Biotechnologies to 2025' report on the future of the biotechnology sector takes as a starting point that the future of the industry looks very different from today. Today, most biotechnology research and related business is focused, ulti-

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mately, on health- and wellbeing related knowledge and applications. The development of the sector however will be driven by two main forces:

- Technology convergence and
- Market applications.

Both synergy and convergence between technology platforms in the biotechnology industry are on the increase. For example the personalization of treatment through genomic medicine is forecast to be mirrored in developments in food and nutrition through advances in nutria-genomics. One area of growing importance is 'diagnostic technologies' such as DNA chips and bio-sensing devices. These are developing rapidly with applications across genomic medicine, nutria-genomics, food safety, environmental monitoring and bio-defense.

Increased investment in bio-defense technology is another driver of convergence. It will inevitably drive adoption across industry sectors and lead to technology spill-over into civilian use.

Main Results of the Report

'Biotechnologies to 2025' has identified important areas for technology development that will shape the biotech sector in the period leading up to 2025. Additionally it has identified influential market developments. We first take a look at the technology development areas and then we look at market applications.

Emerging Areas of Development

Health and Wellbeing - From Repair to Regeneration: The development of regenerative medicine that is accompanying a growing understanding of stem cells and the neurological system signals a shift from an emphasis on the replacement of tissues to a more biologically based method for the repair and regeneration of tissues.

Primary Production - From High-Volume Low-Value' to 'Low-Volume, High-Value' primary production: Primary industry products have traditionally been characterized by the production of high volumes for relatively low returns. Biotechnology is enabling a move towards more value added products being produced in the primary industries (for example, pharmaceutical proteins produced in livestock and plants).

Industry and Environment - From Non-Renewable Commodity Products To Renewables: The finite nature of fossil fuels, and oil shocks – coupled with advances in industrial biotechnology, both in the development of cost-effective technologies to convert biomass to its constituent parts and in the growth in scale of bio-processing capability – are driving a trend towards the increased production of commodity products (bio-fuels and bio-plastics) from renewable biomass, such as crops and trees.

The fourth important area of development is **'Security and Defense**'.

The developments in these four areas will open up new possibilities, produce demand for new solutions, and bring about entirely new markets based on new applications. Now we take a closer look at the potential application areas identified by 'Biotechnologies to 2025'.

Health and Wellbeing

DNA chips: DNA chips and genetic testing will become integrated into standard clinical practice as the genetic nature of more complex diseases is unraveled and diagnostic tools become cheaper. This has been forecast to occur in around 2012.

RNA interference (RNAi): The therapeutic application of gene silencing could theoretically be applied to any disease that is linked to an overactive gene or genes. The first filing of an investigational drug application based on RNAi technology occurred in August 2004. The earliest prediction for an RNAi drug to reach the market is around 2019.

Stem Cell Therapies: Stem cells are the cells 'most likely' to enable anticipated tissue engineering applications due to their innate ability to differentiate into other forms of tissue. The emergence of stem cell based therapies for the treatment of chronic diseases such as diabetes, Parkinson's and Alzheimer's and heart disease are forecast to emerge sometime between 2015 and 2025.

Neuro-prosthetics: Neuro-prosthetics use brain signals to operate devices such as artificial limbs or computer keyboards. It is also possible that wearers may regain the sense of touch with the use of such devices. Successes in the lab indicate that they may be available on the market soon after 2010.

Embryo Screening for Multiple Genetic Traits: Recent improvements to DNA amplification techniques mean that doctors will be able to screen pre-implantation embryos for multiple genetic traits.

Primary Production

GM Crops - Stacked Traits: The ability to genetically modify plants with multiple genetic traits is known as 'trait stacking'. GM crops with multiple genetic improvements will enable in the first instance, greater control over production traits, such as pest resistance.

More complex transformations will follow, targeting for example 'output traits' in plants such as increased yield of oils or sugars. Artificial chromosome technology and chloroplast

transformation are the two most promising technologies for achieving controlled 'stacked trait' transformations.

Marker–Assisted Selection: Breeding technologies for both plants and animals based on marker-assisted selection is likely to allow controlled, increasingly complex genetic traits in animal and plant reproduction, without the need for genetic modification.

Bio-pharming: The production of high-value proteins using plants or animals as bioreactors or 'factories' is forecast to occur between 2007 and 2020. An important market could be the pharmaceutical industry. The application of bio-pharming based on farm animals is expected to happen before it becomes possible using plants.

Industry and Environment

Bio-processing Technologies: Micro-organism- and enzyme-catalyzed industrial processing is being transformed by emerging techniques such as metabolic engineering. These techniques manipulate microbial cells to bypass cell processes in larger organisms.

Renewable Bio-Plastics: It is estimated that by 2010 10% of the global plastics market will be renewable and that sometime in the period 2020 to 2025 this will have expanded to 20% of the market.

Security and Defense

Diagnostics: National security needs are driving the development of live cell bio-sensing technologies and real-time lab-on-a-chip processing capabilities. This is particularly true in the United States. These technologies are anticipated to have spin-offs into civilian markets.

Antiviral Therapeutics: The development of antiviral therapeutics is being driven by bio-defense requirements as well as the emergence of diseases such as SARS and the Avian Flu. Approaches include targeting 'commonalities' between different viruses and attempting to counter viral pathogens in a generic way.

Observations on the Future

Are we at a Fork in the Road?

Sometime between 2008 and 2013 it is likely that there will emerge two key technological approaches for producing crop varieties with desirable complex and controlled output traits, such as enhanced nutritional value or drought resistance:

- Genetic modification
- 'Smart Breeding' techniques based on marker-assisted selection technologies.

Given the known uncertainty in consumer acceptance of GM technologies this highlights the possibility of a 'fork in the road' where different markets by region, by sector or both, may choose one production path over the other. This situation could have a follow-on effect on the rate of development in related biotechnology market segments.

Interdependencies: Synergy or Conflict?

Forecasts for the development of bioenergy, biofuels and commodity bio-based chemicals depend to a large extent on the assumption that forecasted future developments in GM crop applications will provide improved raw materials and crop yields to act as feedstock to fuel industry growth. If markets choose not to go down the GM road then there is a possibility that the large-scale development of bio-based industry may not occur as anticipated.

The possible development of a bioenergy sector based on GM crops will almost certainly create tension between different environmental values and goals. On the one hand the development of a bioenergy sector that contributes a sustainable energy resource is environmentally desirable. On the other hand if this outcome depends on the use of GM crop technologies to achieve increased crop yields and scale, it may present difficulties for those who consider GM technologies to be in conflict with environmental outcomes.

Regulatory Readiness: Are we Future-Proofed?

Anticipating emergent biotechnologies reveals a number of technologies for which New Zealand's legislative system may not yet be adequately prepared. The report 'Biotechnologies to 2025' identified a number of areas that may warrant further exploration. These include:

- Genetic testing, and developments in genomic medicine which raise issues related to ethics and privacy as well as particular cultural issues for Maori
- Neuro-prosthetics such as mind-controlled artificial limbs. These raise issues related to ethics and safety
- Bio-prospecting, and the need to ensure adequate protection of our native flora and fauna while also enabling opportunities for innovation
- Nano-biotechnology applications which may raise issues related to health, safety, ethics and privacy

The Emergence of a 'Possibility Space': Are we moving from Therapy to Enhancement?

The convergence of technologies emerging from different market sectors can enable totally novel outcomes. 'Biotechnologies to 2025' refers to what it calls 'possibility spaces'.

For example it indicates that a possibility space may open up around 2020 if there are:

- Incremental improvements in embryo screening and selection;
- Significant advances in gene therapy applications; and
- Meaningful results from the number of large-scale population-based national studies into the genetic and environmental determinants of disease.

The convergence of these three factors could enable a scenario whereby embryos could potentially be engineered to exhibit selected *desirable* genetic traits and lead to the creation of so-called 'designer babies'.

Readying for Uncertainty

This work has highlighted many areas in which technological development is almost certain. It has shown where research is currently focused. It has made it possible to anticipate incremental developments in knowledge and application, and to plan accordingly.

A more important aim of this futures work however is readying for **UNCERTAINTY** rather than certainty. For instance it has brought into focus areas of uncertainty such as:

- Whether and how social values and views about biotechnology may change, and
- If and when New Zealand may experience a serious national-level bio-related incident, such as an influenza pandemic or a foot and mouth incursion.

These and other uncertainties underline the need to be alert to science and technology developments and their surprises, as well as the need for flexibility to adapt in order to manage issues and take advantage of opportunities.

In this respect the New Zealand government has set up two initiatives following up on 'Future Watch':

- The Navigator Network and
- The Oxygen Group.

The Navigator Network

The Navigator Network is a scanning network. It supports a continuous scanning process carried out by contributors and users of scanning information. This approach is to be contrasted with the 'snapshot' approach adopted for the 'Biotechnologies to 2025' report.

Probably the most characteristic feature of this approach is that it recognizes scanning as a social process, involving people from a range of organisations and perspectives, the exchange of their knowledge and the development of new meaning. Another feature of the approach is its location. It is not located within any one organization but consists of a horizontal network spanning a range of government departments as well as the interface to the New Zealand national science system and its connections with global science. The initial focus of the Navigator Network is on food and agro-bio-technology, although the scanning will cover many other areas as well.

The Oxygen Group

The Oxygen Group is a unique initiative which taps into the voices and experience of younger scientists on new and emerging developments in science to provoke and inspire action toward a better future for New Zealand science. The role of the group is to advise the government on:

- Emerging science and technology trends,
- How these trends might impact on the future of science in New Zealand, and on
- How younger scientists can be more actively engaged in mapping the future of science in New Zealand and take a more active ownership and leadership of future science directions.

The members of the group come from a wide range of scientific disciplines including the biosciences and social science, the information technology or IT sector, the chemical and physical sciences, the geosciences as well as Mātauranga Māori or Māori knowledge.

Sources and References

- Biotechnologies to 2025: A report prepared for the NZ Ministry of Research, Science & Technology. January 2005.
- The Ministry of Research, Science & Technology: www.morst.govt.nz.
- Contact person: Ms. Katherine Silvester, Principal Adviser at the Ministry of Research, Science and Technology in NZ.
- The website of the Navigator Network can be found at www.navigatornetwork.net.nz.

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