Genomic Futures for Aotearoa New Zealand

genomics aotearoa

Mā te whakaatu,
kā mōhio

Through discussion,
comes awareness

Mā te mōhio,
ka mārama

Through awareness,
comes understanding

Mā te mārama,
ka mātau

Through understanding,
comes knowledge

Mā te mātau,
ka ora

Through knowledge,
comes wellbeing

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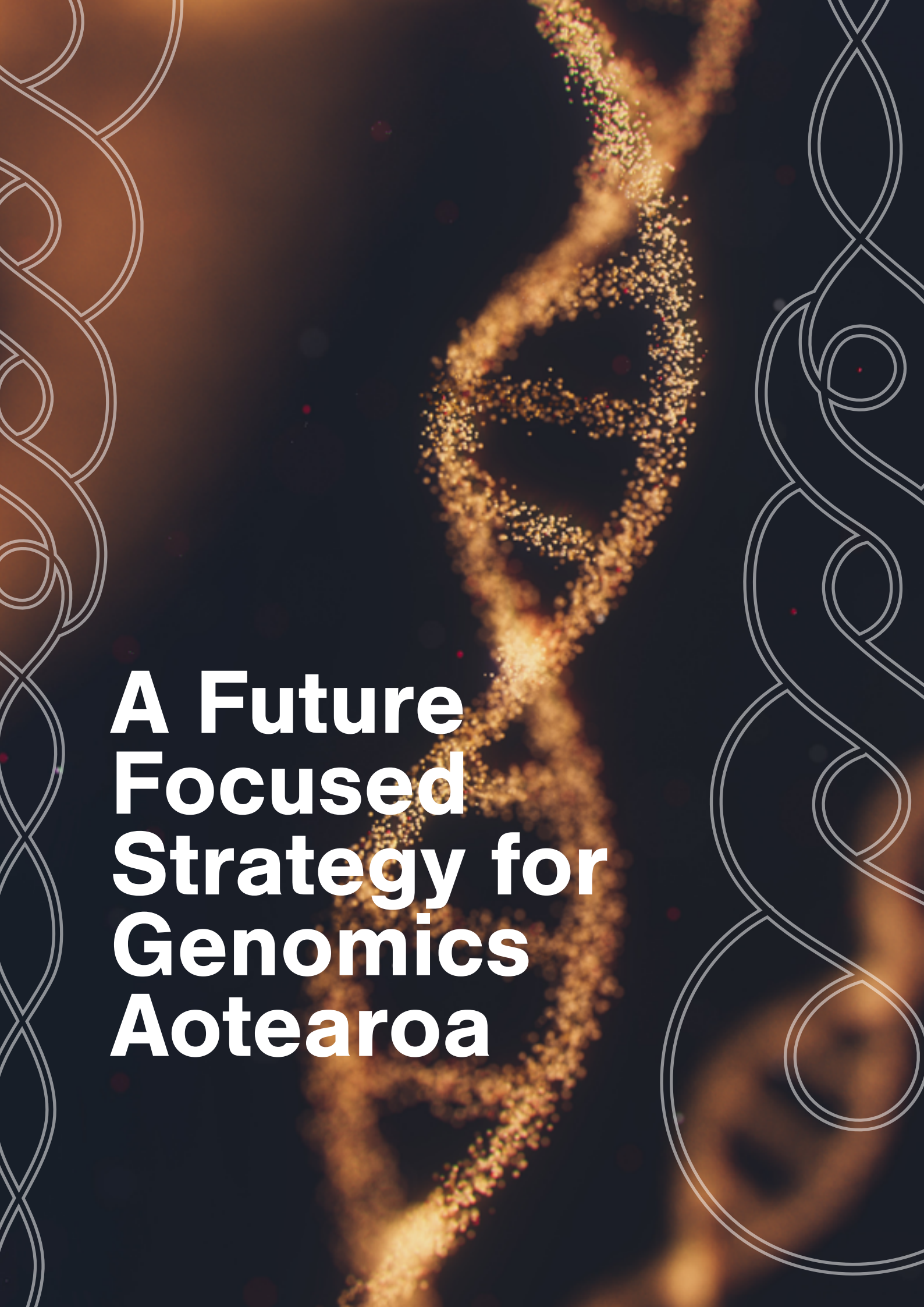


A Future Focused Strategy for Genomics Aotearoa

Executive Summary

Vision

Maximising Aotearoa New Zealand's potential through genomics.

Purpose

Genomics Aotearoa will work with communities* to build capacity and capability in genomics to support our environment, create economic opportunity, and enhance our health and well-being.

We will deliver a national genomics infrastructure that addresses the critical challenges currently facing Aotearoa New Zealand through collaborative partnerships that reflect a Te Tiriti o Waitangi/The Treaty of Waitangi (Te Tiriti) based approach.

Genomics Aotearoa's role

- Developing capability and capacity in genomic science.
- Development of new knowledge and new tools supporting Aotearoa New Zealand's aspirations.
- Supporting translation of genomic/genetic technologies to industry.
- Developing infrastructure that supports research and translation.
- Delivering communication and outreach in genomics to support uptake and trust, and provision of advice to policymakers.
- To take international leadership in aspects of genomics of importance to Aotearoa New Zealand and its people.

Developing infrastructure through research missions

We will continue to focus on research missions as a way to build capability, tools, and technology.

- Mitigating for and adapting to changing environments – biodiversity and biosecurity assessment and monitoring, environmental quality assessment, and improved management of both taonga and introduced species.
- Advancing equitable health and wellbeing – effective delivery of precision healthcare and reduced inequity, including through the development of ancestry-informed tools for clinical genomics.
- Growing sustainable food production in changing ecosystems – improved breeding schemes for primary production systems, effective genetic improvement via culturally appropriate genomic tools.

Measures of success

- A national genomics infrastructure developed through sustained and meaningful partnerships with Māori, that promotes and enables Māori-led genomics research programmes.
- Increased capability and capacity in genomics across science, industry, government, and throughout the wider community.
- Responsible and effective management and utilisation of genomic data through trusted systems.
- The principles of Indigenous Data Sovereignty are upheld, and mana kaitiaki and mana rangatira are supported and enabled.
- Improved outcomes across focus areas: better environmental management, reduced inequity and increased health and well-being through genomics-informed healthcare, and improved production outcomes for biology-based industries.
- Increased and broad use of genomic technologies across a range of sectors, and greater understanding, acceptance, trust, and uptake of genomic technologies and information by the peoples of Aotearoa New Zealand.

Given the range and scale of these activities, we will need to determine how deep, and how broad, a national genomics infrastructure should be. Meaningful delivery across all of these areas would require investment at a level significantly above the first tranche of Genomics Aotearoa funding.

*Broadly "communities of interest" – research communities, local and central government agencies, NGOs, businesses, iwi, hapū and whānau Māori.

SECTION 1

National Genomics Strategy

1. Introduction

All life descends from a past common ancestor, shaped by environment and ecology. Information is passed down this long unbroken chain of life; information that is carried in DNA. In Te Ao Māori, life descends through Ranginui and Papatūānuku the atua or gods of sky and earth. The whakapapa, or lines of descent, link all life, including humans, to our natural world.

These views direct us to a more holistic, systems view of the world. Life is shaped not just by what it is but by its past, its relationships, and its interactions. Historically, such broad views of life were often difficult for science to encapsulate because of a lack of insight, but that insight can now be provided by genomics.

Genomics encompasses a collection of tools and techniques for determining, analysing, and interpreting genetic data at the whole-genome level. Genomics has been made possible through the development of techniques to read the genetic code of organisms, and the computer power to process that information (bioinformatics) to make it useful. Genomics (including bioinformatics, and more broadly, genomic data science) is a relatively new and fast-moving area of science.

Genomics is crucial to Aotearoa New Zealand's future. Our unique past, peoples, ecosystems, and organisms, have left us with biological challenges to our environment and personal health, and our means to grow food sustainably. We must invest in smart genomic ways to help address varied and difficult biological problems.

If genomics is to be beneficial to Aotearoa New Zealand, we need to have a national genomics infrastructure that is accessible to those who need it, and one which is able to adapt to keep pace with ongoing developments.

This strategy considers those important biological challenges facing Aotearoa New Zealand and the Pacific. It is born of the many and varied insights provided by our scientists and our communities, and highlights the opportunities for genomics to improve our health, environment, and economy. It recognises our past, considers where we are now, where we are headed and what may be required from genomics to realise that future.

2. Outlook

Looking towards the future, climate change, globalisation, and the demands of an ever-increasing world population will create challenges and opportunities for Aotearoa New Zealand. We are striving to be better custodians of the natural environment while at the same time enjoying an ever-improving standard of living and a thriving economy. We also have an expectation to live longer, healthier lives, and achieve a sustainable food supply which has reduced impact on the environment.

We are also faced with the internal challenges of alleviating inequities (particularly access to food, housing, and medical care), honouring the principles of Te Tiriti o Waitangi /The Treaty of Waitangi (Te Tiriti), recognising our place in the Pacific, and keeping pace (or catching up) with the standards of living in the rest of the developed world.

"Genomics is crucial to Aotearoa New Zealand's future."

Genomics can underpin a culturally cognisant approach to achieving a low-emission, more circular economy, by providing tools that respond to cultural needs and improve the efficiency of our primary production systems, giving us the means to enhance and protect our conservation estate, and unlocking genomics-led personalised medicine that improves healthcare while redressing our health inequities.

3. Genomics and Te Tiriti partnership

For a country with a rich diversity of flora and fauna, and an economy strongly driven by biological production systems, genomics offers a host of enticing opportunities. In Aotearoa New Zealand, the potential benefits of genomics are real and tangible, however when assessing these as part of a national genomics strategy, it is important to consider them in the context of our nation's founding document, Te Tiriti.

Te Tiriti provides a critical framework for partnership with Māori, as well as specifying the responsibilities that underlie that partnership. Of particular relevance to genomics is Te Tiriti's guarantee of tino rangatiratanga over all taonga. The Waitangi Tribunal further affirmed Māori kaitiakitanga over the genetic material of taonga species, stating the kaitiaki relationship with taonga species is entitled to a reasonable degree of protection including a careful balancing of all interests. With this in mind, genomics has an important role to play from a Te Ao Māori perspective. It is a technology that can process a tiny sample from an organism and reveal deep and valuable data about that organism's DNA, and in turn, about its whakapapa and its respective interconnections within the natural world. While genomics is an invaluable tool for scientific discovery, there is potential for data misuse, a risk in restricting data access, and the subsequent exacerbation of inequities.

In developing a national strategy for genomics in Aotearoa New Zealand it is crucial that we honour Te Tiriti through approaches recommended by the Waitangi Tribunal and adopted by the Crown, including a partnership approach that actively seeks to embed Te Tiriti principles, applies genomic technologies, in collaborative partnerships, where kaitiakitanga is required, acknowledging and incorporating appropriate tikanga and mātauranga. This responsibility relates not only to the generation of genomic data, but also to how it is stored, shared, analysed, and protected, and what narratives are created from its use.

The following sections outline many of the challenges facing our nation, and explore the potential benefits and solutions that the well-considered application of genomics could provide. Meaningful partnerships with Māori will be critical to achieve these goals. That means that in many cases Māori would not only be partners in leading and driving the research but would also be able to realise benefits that are generated.

Although many such research partnerships already exist, achieving this at a national scale will require the investment of resources in relationship building, the establishment of trust, the development of shared goals, capability building, and the co-design and execution of genomics-driven research. And that research must yield real-world benefits that are shared by the scientific community, by iwi, hapū, and whānau partners, and by the wider community of Aotearoa New Zealand.

To be truly effective, a national genomics strategy that works with the aspirations of indigenous people and Te Tiriti would enable world-leading genomics research that encompasses inclusive partnerships and delivers meaningful benefits for Aotearoa New Zealand.

"Genomics will help us not only to detect change, but also better understand the functioning of our environments."

4. Opportunity

Detailed, actionable, and rich information is the gift of genomics – granular interconnected information to solve biological conundrums. This valuable information reflects our evolutionary past but also links to genealogical connections, within and between the natural world and human communities. The following sections outline many of the challenges facing our nation and explore the potential benefits and solutions that the well-considered application of genomics could provide.

4.1. Environmental monitoring and understanding

Genomics can provide an important tool for supporting mātauranga Māori and detecting and monitoring change, as well as providing detailed information that will be crucial to future environmental monitoring. Our ecosystems, both productive and natural, will continue to respond to the impacts of climate and human activity. In the future, we will be using genomics to monitor impacts such as changing biodiversity in many environments across Aotearoa New Zealand.

This monitoring is already happening[1], using eDNA technologies, and as the technology continues to improve and become more affordable, we will develop novel ways to carry out this work across multiple environments. Large volumes of detailed genomic information, from soil, air, and water, will allow us to monitor change, detect threats, track biodiversity, assess ecosystem services, and maintain biosecurity, in near real-time, and at scale. Such technologies are, even now, being developed to monitor changes in geothermal activity, giving early warnings about volcanic and earthquake events (not yet published but see[2] for baseline studies). Local and traditional knowledge systems will work in sympathy with these new technologies.

Aotearoa New Zealand has committed to both the principles of Te Tiriti and the United Nations Convention on Biological Diversity (www.cbd.int/convention/text). These commitments will be hard to achieve without basic data on taonga species and environments. Reference genomes of all our endemic and taonga species, working alongside international efforts, will provide critical information to aid conservation efforts. Effective environmental monitoring requires baseline data and long-term datasets. It is crucial we start generating this information now, to enable the delivery of a desired future state.

Genomics will help us not only to detect change, but also better understand the functioning of our environments. Novel genomic approaches for collecting baseline information and monitoring change will allow targeted and timely beneficial intervention for areas such as pest suppression, precision agriculture, and the containment, control, and eradication of invasive pest species. Genomics will enhance our ability to understand the impacts of land-use in a detailed way, pointing us toward the reduction of greenhouse gas emissions and pollution as well as supporting mitigation of, and recovery from, adverse events. Some of these interventions may require the application of tools such as gene-editing, and genomics can help in monitoring and ensuring the safety of these technologies.

One powerful example of the impact of genomics is the generation of whole genome data for all living kākāpō[3] which has led to an outpouring of new ideas and tools to improve species conservation, including tracking via genomics[4], improving diet[5], informing the kākāpō breeding programme, understanding the impact of human intervention[6], and the tracking of disease[7]. More broadly, genomics is set to greatly assist conservation managers to understand when human intervention is required[3]. These are currently research tools, but this work has shown their additional value in a conservation setting, in the hands of conservation managers and Te Tiriti partnerships. These tools should be applied across all our threatened taonga species.

4.2. Health and wellbeing

The medical benefits talked about so optimistically twenty years ago with the first sequencing of the human genome are now being realised. On all fronts in the health sphere, it is clear that using genomic information for cancer diagnosis and monitoring, immunotherapies, identification, and treatment of rare genetic disorders, identifying genetic markers for heart disease, and population-scale screening, will reduce health-system costs and improve patient care (for examples see[8–11]). In the future we will be using genomics to monitor infections in hospital patients (providing rapid point-of-care diagnosis of infection) and to select the best antibiotics for treatment, reducing cost, antibiotic overuse, lost workdays, and the spread of infection. The technology to do this already exists[12,13], and the Covid-19 pandemic gave insight into the power of genomics to understand and fight disease spread during Aotearoa New Zealand's suppression phase.

"Genomics will provide the information required for health and well-being intervention."

From cancer to developmental and chronic disease, many conditions have at their heart a genetic basis, which can be better understood through genomics. Clinical researchers imagine a future in which the health system is predictive, not reactive. With the detailed information genomics can bring, population-level genome sequencing will provide the means to predict and improve our future health, allowing better prevention, more accurate screening, and rapid and personalised treatment of disease. Genomics will provide the information required for health and well-being intervention, especially with the advent of gene-editing in health care, a revolutionary therapy that is already underway in Aotearoa New

“In order to maintain our international position, our primary producers must be enabled to reduce their environmental impact, while developing new non-polluting sources of food and fibre.”

Zealand[14,15]. Effective use of these technologies will require both socialisation and trust.

The opportunity exists to deploy genomics in health in a way that places genomics-based tools at the service of communities, allowing them to determine their best use to improve outcomes while alleviating inequities. Genomics Aotearoa’s recent work in this area underpins this opportunity through the *Variome* project - delivering an understanding of genetic variation in Māori, and the *Rakeiora* project - setting out processes and tools to work with Indigenous genomic data for genomic medicine purposes. Both are cited as providing key underpinning infrastructure in Manatū Hauora’s recent Precision Health: Long-term Insights briefing[16].

Internationally the WHO, in a report on genomics in health in 2022[17], made 15 recommendations grouped into four categories as a route map to extending the benefits of genomics-informed health care. These are:

1. Promoting genomics through advocacy.
2. Implementation of genomic methodologies.
3. Collaboration of entities engaged in genomics.
4. Attention to the ethical, legal, and social issues raised by genomics.

Such activities will need coordination, from both research and health system perspectives, and rely on trust in the system itself.

4.3. Producing more with less

Genomics already supports our leading primary production industries, and its impact is seen in reduced animal stocking rates, reduced environmental impact, and reduced management costs, without a reduction in production volume [18,19]. These same genomics-informed approaches to primary production which are now being used to reduce greenhouse gas emissions[20], and develop more efficient grasses[21,22], will be rolled out to the wider industry as they become more precise and effective. These technologies can be expedited into other primary industries, for example, forestry[23–25]. In the future, they will also incorporate the impact of environmental factors, tracked by gene expression and epigenetics[26]. Precision agriculture requires biological data. Genomics, coupled with advanced and efficient phenotyping, is the only technology that can provide that data quickly, cheaply, at scale, and with acceptable quality.

Current breeding technologies are slow to realise improvements, because of the rates of reproduction of the species involved. The international future of animal and plant breeding technologies will thus involve genetic technologies such as gene-editing[27,28]. As it stands, such methodologies are being actualised outside Aotearoa New Zealand[29]. In order to maintain our international position, our primary producers must be enabled to reduce their environmental impact, while developing new non-polluting sources of food and fibre. Genetic technologies will enable this transformation,

and genomics will monitor impacts. We need to establish centres of knowledge, engagement, and capability to ensure we can deliver on this need in an Aotearoa New Zealand nuanced way.

The technologies of intervention, such as gene-editing, will be crucial to this future, but will also need to be used in a context of benefit, social acceptance, and appropriate governance. Māori leadership in building relationships and in discussions around environmental management, in particular for gene-centric research, will be essential.

Genomics will underpin our switch to a future low-emission circular economy through:

- accurate plant and animal phenotyping and breeding for low emissions; including the potential to use new breeding technologies and selection to accelerate the precision and the rates of gains.
- genetic improvement to support adaption to climate change.
- genomics to reduce dependency on synthetic pesticides by developing new and advanced solutions for pests, weeds, and diseases.
- new genomic monitoring technologies for rapid, early detection of incursions to support post-border biosecurity responses.

All the content_id:30574995 tools developed in environmental monitoring and human health can be rolled out for plant, animal, and environmental health, with genomics as the underpinning technology that will support Papatūānuku over time. The ambitions of the one-health[30] approach to production and human health will only be achieved with the widespread use of genomic information to monitor biological health (including humans), track infections, and improve biosecurity.

4.4. Genomics and data

Our projected future has implications that may be uncomfortable for some. The widespread use of data implies sharing or access to these data, by public and private enterprises. Understanding how data can be stored, shared, and protected to achieve the best possible outcomes from their use will be crucial. Aotearoa New Zealand will need an effective data commons that holds this information, and enables mana kaitiaki. Such a data commons will link genomic information to other data, such as Land Information Management Systems (LIMS), museum collections, regional council databases, and international collections, so that these data can be combined to enable precise data-informed decision-making and also help realise our Te Tiriti obligations across all relevant institutions. For this future to deliver the foreseen outcomes, we need to ensure that genomics will be used with due attention to equity, privacy, ethics, and the principles of, and rights under Te Tiriti. We will be required to use genomics and manage the vast amount of data produced, in ways that support Te Tiriti principles, including partnership and tino rangatiratanga for mana whenua.

4.5. Technology

Genomic technology is developing rapidly on multiple fronts in response to growing need and demand:

1. **Reduced sequencing cost.**
   About-to-be-implemented technologies (ultimagenomics.com) will reduce the current cost of sequencing 10-fold, and costs will continue to drop. It is realistic to imagine a near future where sequencing cost becomes negligible.

2. **Distributed sequencing.**
   Some Oxford Nanopore sequencers are already cheap and able to be deployed outside labs (nanoporetech.com). This company intends to miniaturise their technology to something that plugs into a mobile phone (nanoporetech.com/products/smidgion) or tablet (nanoporetech.com/products/minion-mk1d). These are achievable goals within the near future, with a real possibility of hand-held sequencers being commonly and easily used.

3. **Greater precision and repeatability.**
   Each generation of DNA sequencing and bioinformatic analyses is producing more advanced, more detailed, more precise, and more robust data.

We will need new data technologies to support widespread sequencing, from data compression and new analytical pipelines, to the widespread use of Artificial Intelligence (AI) (as per our current research[3]). Storing, curating, and interpreting this ocean of data in ways that are consistent with Te Tiriti will be a major challenge, and therefore we need to increase our pace of enabling and empowering Māori leadership.

"Genomic technology is developing rapidly in response to growing demand."

Our imagined future will see inexpensive and nimble sequencing underpinning all the future applications discussed above. In the same way that cheap cameras and GPS in mobile phones produced unexpected outcomes, we expect unforeseen opportunities to arise. It will be important for us to align technologies to a communication approach that supports Te Tiriti partnership and future collaborative opportunities.

This future comes with risks. Those unexpected outcomes from mixing technologies are not always of benefit to people and have the potential to exacerbate underlying inequalities. Ensuring we navigate our way to beneficial, rather than detrimental outcomes is an enormous challenge. Strong leadership and governance will be required.

> **"Aotearoa New Zealand-specific outcomes will require strong national research and translation capability."**

5. Seven key principles for this genomic future

Genomic technologies are challenging and powerful. As discussed, they have the power to change the way we deliver healthcare, enhance primary production, and understand and protect our environment. Because of this, we must have clarity around the principles we adopt in order to deploy a genomic future that recognises and provides for Māori interests and Te Tiriti based partnership. Such principles (not ranked) could be:

1. Delivering for Aotearoa New Zealand

The industries, people, and environment of Aotearoa New Zealand are unique. While much genomics research of relevance will be carried out overseas, it is vital to ensure that the specific aspirations of Aotearoa New Zealand communities, policymakers, end-users, and researchers are delivered on. This is particularly relevant to partnerships through Te Tiriti and tino rangatiratanga.

2. Building capability and capacity

Aotearoa New Zealand-specific outcomes will require strong national research and translation capability, inclusive of Maori aspirations, with appropriate investment. To take full advantage of future advances in genomics, training at all levels and across all communities including Māori, from schools upwards, is required to ensure Aotearoa New Zealand has the people and systems we need.

3. Delivering equitable outcomes

Inequity exists in Aotearoa New Zealand. Genomic technologies should be implemented with respect for Te Tiriti principles and in partnership with communities of interest which will reduce inequity while improving outcomes.

4. Embedding Te Ao Māori

Deploying genomics in the service of Te Ao Māori will enable deeper appreciation of whakapapa and mātauranga Māori as well as Māori values and perspectives in the use of genomics. It will also build trust with mana whenua, Māori organisations/end-users, and Māori researchers.

5. Ensuring privacy and data sovereignty

In all communities, issues of privacy, data security and data sovereignty are important, but these are paramount for Māori[31]. In using and storing data the conditions agreed by contributors (especially mana whenua where appropriate) must be respected. As this is an evolving component, ways to balance data sovereignty, privacy, cultural expectations, democratisation, public benefit and permissioned access will be needed.

6. Democratising technology

Genomic science which is accessible rather than technocratic, obscure, and complex is likely to democratise technology. Familiarity enhances understanding and trust. Communication and the language to achieve uptake are imperative for working with communities, including hapori Māori.

7. Transparency and Trust

Researchers and leaders should be honest and transparent in connecting to individuals, iwi, hapū, whānau and all communities. They should communicate, explore, and articulate the benefits and risks of both action and inaction to enable communities and individuals to make informed decisions.

6. Where are we now?

Aotearoa New Zealand, through genetic technologies, will benefit from more precision in health, primary production, the environment, and conservation sectors. These gains will come from the rich, dense data delivered by genomic science, its analysis, and the implementation of that knowledge. For this technology to provide benefit, it will need to be developed or modified for Aotearoa New Zealand to ensure it delivers for our unique environments, peoples, and biological heritage, aligns to Te Tiriti, and supports the aspirations of this nation.

"There is strong support from our leading primary production industries for the use of genomic selection."

Aotearoa New Zealand needs a more vibrant research sector in genomics, and far more capability in the functional aspects of genomics that underpin genetic technologies. The activities of Genomics Aotearoa and others are developing such capability, as well as providing infrastructure that supports research and translation. Through CRI partnerships, relationships with Māori end-users, and existing researcher-end-user relationships, we are beginning to see the implementation of genomic technologies in some newer industries, for example, the wine industry through the Bragato Institute and the apiculture industry through Future Bees Ltd. Likewise there is strong support from our leading primary production industries for the use of genomic selection, in particular Beef + Lamb New Zealand Genetics. Recent indications that genomics is being seriously considered by the Department of Conservation (DOC) and the long-term investment from Predator-Free 2050, underscore the potential for increasing uptake in conservation and environmental management. Similar sentiments for primary production are highlighted in the Productivity Commission Report[32].

Some of our health laboratories have been adopting genomic approaches, mainly on a research basis, and these have been supported by Genomics Aotearoa-funded projects. For example: the generation of a clinically accredited exome sequence analysis service run by Canterbury Health Labs is directly attributable to the Genomics Aotearoa project *Extending Whole Genome Analysis into Healthcare*.

The Genomics Aotearoa Indigenous Genomics Platform is beginning to demonstrate the value of placing genomic tools and skills in the hands of Māori communities to use for their own benefit. These grounded projects have been strongly supported by Genomics Aotearoa, with staff, technologies, and database support being crucial.

There is untapped potential for the use of genomics in environmental management and water quality testing (including testing drinking water). Recent challenges include the *Campylobacter* outbreak in Hawkes Bay

in 2016[33], and the recent *Cryptosporidium* outbreak in Queenstown, the rise in nitrogen and phosphate in some waterways, and the risk to health from contaminated flood waters in the upper North Island in the aftermath of Cyclone Gabrielle. Regional councils are beginning to take up these technologies, including pilot projects[34] but opportunities to use even current technologies are being missed or underutilised.

"Across all sectors, end-users expressed a need to use genomics research to enable good decision-making to achieve positive outcomes."

Within health, the system in general has not engaged with genomics in the way that has occurred in other OECD countries. Manatū Hauora is only now exploring the adoption of precision health technologies (including genomics) in a just published Precision Health: Long-term Insights briefing[17]. Based on this, it is apparent that specific policy covering clinical genomics is some way off, however, the use of gene-editing in a medical context is underway.

Even in animal breeding industries the clear benefits of genomics-informed breeding are yet to translate to whole-scale uptake.

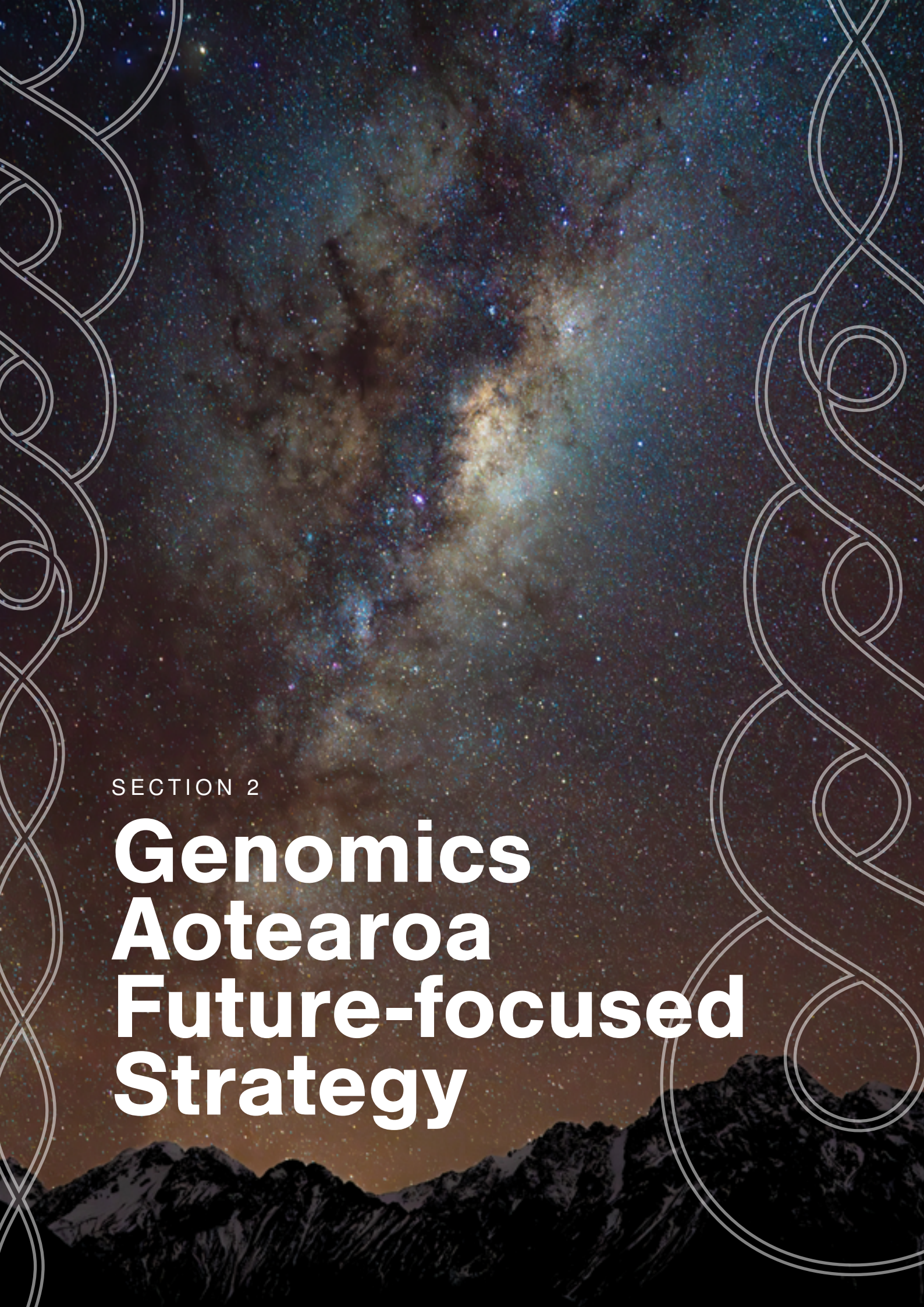
With regards to gene-editing, there are perceived and real (including legislative) barriers to uptake and implementation. Given the great potential identified, we need to reconsider the barriers to implementation.

Extensive end-user and researcher engagement by Genomics Aotearoa has identified significant opportunities and aspirations, while also highlighting several challenges. Across all sectors, end-users expressed a need to use genomics research to enable good decision-making to achieve positive outcomes. End-users want cost-effective solutions that can provide timely results that are relevant to their needs.

Outreach to our wider community is yet to be satisfactorily achieved. Genomics and data science are not taught in schools, and teacher training doesn't encompass these areas. This is despite the transformative impact these technologies are likely to have on students' lives. Similarly, medical schools teach very little genetics and genomics, and our agricultural training is only just beginning to highlight these technologies. The current genomics capability in Aotearoa New Zealand only partially meets current end-user and researcher needs, and where it fully meets them, it is likely to be constrained by future demand.

7. What is needed to realise this future?

- Aotearoa New Zealand is a developed country that relies on biology to pay its way in the world. To protect its environment and to look after the health of its people, a genomic future will require strong leadership to help us to navigate the challenges and opportunities of genomic science, while at the same time achieving our commitment to Te Tiriti.
- Capability and capacity in genomics, bioinformatics, gene-editing, and genetic technologies within the science, health systems and industry.
- New research into genomic technologies supporting Aotearoa New Zealand's goals in environmental monitoring, environmental management, biosecurity, and primary production.
- Data supporting the management of our taonga species and environments.
- The capability and capacity to be internationally competitive in genomics research and genomics-informed research.
- Equitable access to genomic solutions for marginalised communities across health and wellbeing.
- Better collaboration between researchers and end-users.
- Data governance and infrastructure, including a data commons that allows access and data integration while ensuring kaitiakitanga, privacy, and data sovereignty.
- Simple and effective data integration and visualisation for decision-makers.
- Outreach:
  - Public awareness and engagement.
  - Trusted advice to policymakers.
  - Education – from primary school upwards.
  - Transferability – uptake of outcomes across communities (including the South Pacific).
- The infrastructure needed to build national capability.
- The capacity to provide quality consultancy and advice to Māori and other communities, to industry, and to local and national government.
- Development, testing, and effective use of Artificial Intelligence, in the implementation of genomic solutions.
- Legislation that supports and regulates genomic privacy, data governance, and genetic technologies.



SECTION 2

Genomics Aotearoa Future-focused Strategy

Summary

Our vision: Maximising Aotearoa-New Zealand's potential through genomics

Our purpose: We work with communities to build capacity and capability in genomics to support our environment, create economic opportunity, and enhance our health and well-being.

Our research missions will apply genomics and bioinformatics to:

Mitigate for and adapt to changing environments - biodiversity and biosecurity assessment and monitoring, environmental quality assessment, and improved management of taonga species.

Advance equitable health and wellbeing - effective delivery of precision healthcare and reduced inequity.

Grow sustainable food production in changing ecosystems - improve breeding schemes for primary production systems, effective genetic improvement.

Our Role

- Develop capability and capacity in genomic science.
- Develop new knowledge and new tools to support Aotearoa New Zealand's aspirations
- Support the translation of genomic/genetic technologies to industry.
- Develop infrastructure that supports research and translation while upholding Te Tiriti principles.
- Deliver communication and outreach in genomics to support uptake and trust and providing advice to policymakers.
- Take international leadership in aspects of genomics of importance to Aotearoa New Zealand and its people.

Our Principles

- Our science meets Aotearoa New Zealand specific needs, complemented by international research.
- Genomic technologies are implemented in a way that reduces inequity.
- Te Ao Māori is embedded in genomics through a deeper appreciation of whakapapa and mātauranga Māori.
- Privacy and data sovereignty are balanced with cultural expectations, democratisation, and permissioned access.
- The technology we develop is accessible by all.
- Trust is built through transparency of benefits and risks.

Our measures of success

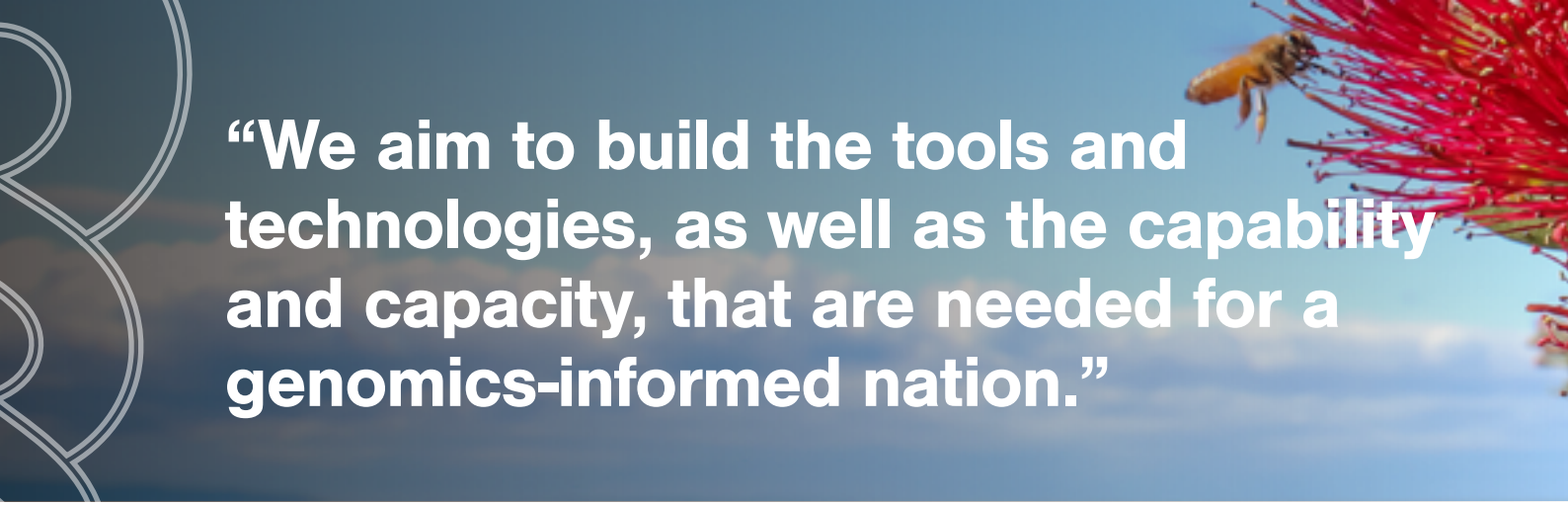
Delivery of a national genomics infrastructure that promotes and enables genomic research in Aotearoa New Zealand.

Increased capability and capacity in genomics across science, industry, government, and throughout the wider community.

Pathways to responsible and effective management and access to genomic data which uphold the principles of Indigenous Data Sovereignty.

Improved outcomes across our focus areas: environment, health, and primary production.

Greater understanding and acceptance of the use of genomics in Aotearoa New Zealand.



“We aim to build the tools and technologies, as well as the capability and capacity, that are needed for a genomics-informed nation.”

1. Preamble

MBIE has specifically asked that Genomics Aotearoa develop a strategy to “identify our national genomic infrastructure needs and provide researchers and end-users with a clear line of sight on the purpose, direction and intended outcomes of the Platform.”

We recognise the key challenges facing the world, including climate change, overpopulation, food security and those arising from globalisation. On this basis we will strategically align our activities to ensure that the solutions we develop, and the people we train, will be fit-for-purpose in meeting those challenges. Through our high-quality exemplar projects, we will provide the leadership in genomic science and infrastructure which will promote research to combat these complex global challenges.

We aim to build the tools and technologies, as well as the capability and capacity, that are needed for a genomics-informed nation. In the past six years we have focused on building capability and capacity amongst our scientists – we now need to push that capability out to transform the ways in which we manage our health, environmental and primary production sectors in the face of rapid global change.

2. Genomics Aotearoa’s evolution

Genomics and bioinformatics are now core skills central to all life sciences. In phase one of the government investment in this science, New Zealand Genomics Limited (NZGL) delivered sequencing infrastructure, when this technology was rare and expensive. With the advent of accessible, relatively cheap sequencing, the focus of investment in phase two turned to building the infrastructure with which to interpret and implement the outcomes of this data. Our role has been to turn niche skills into ubiquitous skills with which to empower our research community.

To this effect, Genomics Aotearoa has focused on building an infrastructure of people, constructing a national bioinformatics platform, creating collaborative, and culturally aligned research relationships, developing a data repository, and generating the Indigenous Genomics Platform. Our tactic of using high-quality research projects as exemplars to build all of these has been very successful, but we need to ensure the sustainability of this approach and most importantly, we need to support better translation into outcomes for Aotearoa New Zealand.

In our next phase, Genomics Aotearoa needs to fill the gaps in the implementation of genomics, introduce and develop the key technologies that will build our vision of a genomics and data-rich future, ensure we continue to build capability and capacity, and continue to nurture the end-user relationships that will support effective translation and, in particular, align to our Te Tiriti partnership obligations.

3. What needs to be done?

Aotearoa New Zealand's science community is continuing to improve its capacity in genomics and bioinformatics. The number of bioinformatically trained staff being employed by universities, businesses, and Crown Research Institutes (CRIs) is increasing, as are the number of genomics-focused science grants being funded. There is a gap, however, between the highly skilled tool developers and the tool users, which is problematic. Too much science is being undertaken using inappropriate tools, or tools used incorrectly, because scientists can apply them, but do not understand them. For example, AI provides a huge opportunity, yet few of our genomic scientists are engaging with it. Increased use and access to these technologies will be transformative given the amount of data being generated. Aotearoa New Zealand will need to incorporate AI, as well as other data science and computational approaches into its genomics toolkit if we are to remain at the forefront of international trends and practices in this space. We need to ensure we are tool developers, not just tool users.

Genomics and data science are only starting to be taught in schools, and therefore we face a long-term problem. This problem is echoed in other fields, such as medicine, where genomics training is limited. For the effective implementation of these technologies, it is vital for there to be significant input into curricula at all levels to ensure familiarity with this science and its potential applications. Capability needs to go beyond the science system for comprehensive implementation to occur. Similarly, exposure and uptake by Māori through collaboration and/or partnerships is imperative to meet Te Tiriti responsibilities, including tino rangatiratanga.

Access to sequencing technologies, either on or offshore, is no longer a problem. The only technology we do not have in New Zealand is that offered by Pacific Biosciences, and this can be accessed in Australia if needed. Oxford Nanopore Technologies sequencing platforms are becoming ubiquitous, but with technology and analysis tools both evolving rapidly, we still need to improve researchers' bioinformatic capabilities to ensure ongoing benefit from these powerful tools.

Implementation

Established primary production industries have, or are taking up, genomics as a technology, either with CRI partners (such as Beef + Lamb New Zealand Genetics) or within their own capacity (e.g., Bragato Institute (bri.co.nz), Livestock Improvement Corporation(lic.co.nz)). Other industries, such as beekeeping, have engaged with genomics in the past few years, but only after research investments have built key technologies. In health diagnostics, some providers are making tentative steps towards genomic diagnosis, but a lack of capability, and a lack of clinical infrastructure, has made progress slow. In environmental management, DOC is using genomics when supported by research scientists, and providers such as Wilderlab (wilderlab.co.nz) have made some progress in implementing environmental monitoring. Such activities need to increase in scale, and new environmental monitoring methods need to be developed. Human capacity generated by Genomics Aotearoa is beginning to move into these sectors, but we are only at the start of the journey. We need to increase our links with industry, including the Māori economy, to ensure the workforce we develop has the skills and ability to transition between academic, CRI, industry, and government roles, or to work within different sector interests, including Māori.

Base-line data sets to understand our uniqueness

Many of the biological problems that challenge us as a nation are unique. Our biology, peoples, and geography mean that off-the-shelf solutions are often not able to provide the answer. Even our primary production systems, while superficially resembling Europe's, are unusual and uniquely managed. To support our future needs, it is critical that we understand this biological uniqueness. New knowledge is needed on genetic diversity in our peoples, genetics of our taonga species, and an understanding of our environments and how human activity affects them. Such baseline data is significantly lacking, especially as we are moving into an era of rapid biological change and declining biodiversity. In particular, we need to recognise the mātauranga Māori and develop ways in which genomics can support the traditional management and kaitiaki /managers in their responsibilities.

Bespoke tools for Aotearoa New Zealand

This uniqueness means that we need to develop our own tools and technologies to solve our unique biological challenges. Examples such as effective wasp control (of little concern to the rest of the world), or tools to support Māori crop growers, or conservation of our taonga species, will all need to have local, bespoke solutions. New, world-leading tools and technologies will need to be developed that use AI and genetic technologies for the benefit of our people and environment. There is also an opportunity to incorporate tikanga Māori or cultural best practices in the development of such tools, which will ultimately improve their uptake by end-users. Such niche tools can only be developed, tested, and implemented here, hand-in-hand with end-users.

The use of genomics by Māori businesses, communities, and organisations is in its inception, triggered in part by Genomics Aotearoa projects. Clearly, more Māori capability, especially in genomics-informed leadership, is needed to build trust and familiarity with these technologies.

Genomics is all about data. If we are to use genomic data effectively, we need infrastructure. Aotearoa New Zealand desperately needs its own data commons infrastructure. A home-grown data commons that balances access and data integration with kaitiakitanga, privacy, and data sovereignty, is crucial in allowing the integration of data in novel ways to support informed decision-making. The joint Genomics Aotearoa and NeSI (New Zealand eScience Infrastructure) development of the Aotearoa Genomic Data Repository (AGDR) provides for storage of genomic data from non-human taonga species and is an exemplar of a Te Tiriti-guided data storage platform, with strong emphasis placed on enabling kaitiakitanga and ensuring data sovereignty. While the AGDR is intended primarily for the management and sharing of genomic data, integration of this resource into a broader national data commons would be a logical next step to ensure its ongoing growth and protection.

Aotearoa New Zealand's policy settings are not equipped for a future genomic age. Policy around data use, including sovereignty, integration, reuse, and privacy, is not well established. Nor are our policy expectations around the use of genomics for taonga species. While we have developed some guidelines, specific policy guidance is needed in light of the WAI 262 claim, but especially because we see our future as a collaborative approach to genomic contribution and uptake to support Māori aspirations in applying this science in their activities.

4. What happens if we do nothing?

Genomics Aotearoa's work to consolidate, coordinate and support the genomics sector has been very successful, but there is still more to do. Without a lead agency in this area, history shows us that the field will become more fragmented and siloed. The opportunity to fine-tune this most important science in the service of Aotearoa New Zealand would be greatly diminished, and the full benefits of genomics would not be realised.

Loss of Genomics Aotearoa's coordination role would have a massive impact in several key areas. An example would be the loss of an effective pipeline for early career researchers (ECRs), including Māori and Pacific Peoples, leading to slower implementation of genomics, reduced availability of capability and capacity, and impaired careers. We need to build on what Genomics Aotearoa has already achieved in this area.

Loss of our current data repository, the Aotearoa Genomic Data Repository (AGDR)[35] would be a serious problem for the genomics community and a significant step backwards in Te Tiriti relationships. Currently, it is the only option available for researchers who want to make genomic data accessible, while at the same time respecting the principles of Māori Data Sovereignty and Te Tiriti. Prior to the establishment of the AGDR, publication requirements for non-human genomic data sharing meant depositing genomic data into fully open international repositories, which was considered a violation of Māori Data Sovereignty[31]. Through establishing the AGDR, we have provided a powerful example to the international scientific community of how Indigenous data rights can be upheld.

Finally, Genomics Aotearoa has been doing considerable work to build relationships with Māori communities. This needs to be strategically valued so our Māori communities can continue to explore genomic technologies and build their own capability. This would strengthen the trust and the nascent relationships that will be crucial to the implementation of genomics, especially in the area of environmental monitoring.

The need for continued coordination, infrastructure and capability building in genomics and bioinformatics for Aotearoa New Zealand is clear given the investments our international partners are making. Genomics has the potential to be transformative for this country, socially, economically, and environmentally. We need a lead agency to ensure this potential is realised.

"There is also an opportunity to incorporate tikanga Māori or cultural best practices in the development of such tools, which will ultimately improve their uptake by end-users."

“Genomics Aotearoa is poised to deliver and support the development of many of the key changes needed to develop an Aotearoa New Zealand genomic future.”

5. What is Genomics Aotearoa’s role?

Genomics Aotearoa is poised to deliver and support the development of many of the key changes needed to develop an Aotearoa New Zealand genomic future, including supporting the country’s Te Tiriti responsibilities. A national genomics research infrastructure cannot possibly do everything, and strong partnerships with existing and new stakeholders will be needed to ensure that the benefits of the genomic revolution are delivered equitably to communities within Aotearoa New Zealand.

We will specifically focus on delivering across the following areas:

Capability building

In the past few years, our role has been to develop capability, both by developing home-grown talent, and attracting world-leading early-career scientists to Aotearoa New Zealand. We see this as key to the development of national capability and capacity. With all our staff, we take a ‘train the trainer’ or ‘train the teacher’ approach, such that our activities are amplified, and we have scale to make an impact.

We will continue to broaden our capability and capacity building. This means an expansion of our science training activities focusing not just on researchers, but also on building capacity with Māori and Pacific Peoples, the medical fraternity, central and local government, industry, and community groups. We also aim to support internships to give our early career scientists a taste of working in industry or government roles, and to give policymakers a better understanding of genomic science and what it can achieve. We will also help to build genomics and data science knowledge into school and university curricula, and work with partners and collaborators to assess the need to develop micro-credentialling as part of our training.

We will continue to grow our Indigenous Genomics Platform (IGP), putting genomic science into the hands of Māori communities, iwi, hapū, and whānau, and building local capability and capacity. We aim to build broad Māori leadership in genomics, ensuring culturally appropriate use and uptake of the benefits of these technologies. This includes the Genomics Aotearoa Board, which will continue to have wide representation, experience and knowledge in Te Ao Māori. In growing our IGP we will explore opportunities to embed Te Ao Māori through establishing an Indigenous Foundation; the following section provides an example of what this may look like.

An Indigenous Foundation

To help guide the future use of genomics in Aotearoa New Zealand, an Indigenous Foundation will be established as an extension of the current Genomics Aotearoa IGP. Embedding Te Ao Māori and Te Tiriti partnerships into a Genomics Aotearoa strategy provides a unique cultural lens. This cultural lens would support the ability of genomics to reduce inequities with respect to Māori; increase understanding of genomics for Māori; facilitate informed decision-making by Māori communities; improve genomics social acceptance and provide subsequent opportunities for Māori participation; growing capability and capacity of hapū, iwi and whānau.

The current IGP initiative was established in 2022 as a separate funding pool to support projects that address Māori need and are led or co-led by Māori. However, the much broader intent is to fully support:

- More Māori involved in genomics
- Clear effective pathways to working with Māori
- Benefit to Māori from genomics

To fulfil these outcomes, we will take a consolidated approach to genomics research and engagement with Māori that promotes ground-up/community-based research whilst also supporting research at higher level, and provides opportunity for outreach, education initiatives, and information-sharing. The Indigenous Foundation enables informed and reciprocal participation that builds relationships of trust, resulting in communities being able to select genomics research of specific interest and benefit to their respective hapū, iwi, or whānau. The Indigenous Foundation, underpinned by Te Ao Māori would incorporate cultural concepts as guiding principles. Additionally, key tangible components are necessary to ensure desired outcomes are achieved and genomics translates to real benefit for communities.

Key support components may include the following:

1. An Indigenous Genomics Platform

A dedicated platform that offers an interface with which Māori may engage. This interface would consist of access to genomics expertise; access to funding for projects that address identified needs and aspirations; information to build community knowledge and participation; data repository facilities; and a forum that offers general genomics advice and guidance.

2. Māori engagement fora

In depth and ongoing engagement that comprises diverse Māori representation is required to successfully identify Māori needs, and to track progress in fulfilling those needs. A comprehensive engagement programme that fully supports relationship building and assists communities to identify research of specific benefit. Such engagement also supports the ability of Māori to express rangatiratanga and utilise genomics where it assists in fulfilling kaitiaki responsibilities. Engagement should provide a medium for reciprocal knowledge exchange where genomics researchers may also engage and learn.

3. Wānanga

Engaging in conversations about genomics research and technology with Māori communities, as well as education and information provision to assist informed decision-making is vital to ensuring more Māori are involved in (and receive benefit from) genomics. Reluctance and fear to engage with genomics exists in many communities. This is likely due to insufficient opportunities to develop knowledge and understanding, a factor which some consider is exacerbated by academic institutions and research hierarchies that have seen limited knowledge transfer to communities and ordinary citizens. The delivery of genomics-focused wānanga to hapori Māori will build awareness and increase knowledge. More importantly,

wānanga also provide a safe space for potentially difficult conversations concerning genomic technology and cultural issues to occur. For example, gene-editing and increasing genomics social acceptance require informed and reciprocal dialogue, as do sensitivities regarding whakapapa and genomics.

In a similar way, a renewed Genomics Aotearoa intends to build a strong foundation for engagement with pacific peoples. Meaningful participation will be achieved by working through established relationships and with groups such as Le Vā, Pasifika Futures, the Pacific Committee of the Health Research Council, the University of the South Pacific, and the South Pacific Regional Environment Programme (SPREP).

New knowledge and new tools

One of our key innovations has been to ensure that the early career researchers working with us have world-leading research projects. Our projects aim at Horizon 3 Knowledge, aspiring to provide societal value through new knowledge and impacting the broader economy. This is vital to future capability, as it builds the national and international standing of our researchers, ensuring they have excellent reputations before they move on in their careers. This crucial aspect of our work ensures Aotearoa New Zealand gets internationally competitive genomic scientists with appropriate cultural experience, as well as developing new knowledge, tools, and technologies vital to supporting our future.

We aim to develop a collaborative hub of capability in gene-editing and genetic technologies, as a means to boost home-grown innovation in modern biology.

We have developed a mission-led research approach (see pages 28-29) that ensures our work respects whakapapa and mātauranga and produces high-quality engaged scientists, new knowledge about our biological systems, leading-edge tools and technologies, and makes progress on the key biological issues facing our country.

Supporting translation

The beneficial impact of genomics will only occur with its effective translation. To support this, we will work to develop an improved understanding of the needs of end-users, as well as nurturing improved trust in genomic technologies. We will optimise the translational capacity of projects, and encourage end-user involvement in projects at their inception. We will have dedicated fora at which end-users can interact with our researchers and indicate their needs and find ways to develop these into projects. A communications plan will be developed to specifically meet the aspirations of Māori and Pacific Peoples in their use of genomics.

Our early career researchers will be well supported to work closely with end-users to ensure they understand their needs. This will also assist in fostering career opportunities within end-user organisations.

Development of technology is not enough to ensure implementation. We need to build trust in genomics as a technology, with more investment to support end-user implementation. Policymakers need to be informed about the risks and benefits of genomics, and all these components need to work within the requirements of Te Tiriti. Our end-user

engagement has clearly indicated that the impact of policy on implementation is an issue for industry. We aim to support the development of policy and guidelines as a trusted source of objective information. We will work at the science/policy interface as a trusted, engaged, informative, accurate, and timely source of information about genomic science and genetic technologies, but not as an advocacy group.

Developing infrastructure

Data infrastructure is crucial to Aotearoa New Zealand's future. The development of a data commons would benefit Aotearoa New Zealand by providing integrated data across sectors that can support system-wide queries. A data commons would be a key piece of infrastructure, particularly as AI becomes an effective tool for decision-making. Genomics Aotearoa, and its partners, can advocate for a data commons, but we will also focus our activities on developing and maintaining our own data repository, the AGDR. That said, we certainly do not rule out the possibility of it becoming a key part of a national data commons. We aim for this piece of infrastructure to be an exemplar for allowing access but with clear and appropriate kaitiaki control and governance.

We will expand the repository to include environmental DNA datasets and develop new functionality to ensure it remains of international quality. We will promote the AGDR across the sector as a safe and controlled place to keep genomic data, with the aim that it becomes the long-term solution for genomic data in Aotearoa New Zealand. As an exemplar and key database for our future, the AGDR will contribute to nation-building.

We will also support, alongside agencies such as Tāpui Aotearoa, national discussions about biobanking and archiving, recognising a broad need for tissue banking. This will further recognise the opportunity to support kaitiaki and cultural activities such as germplasm collections and wānanga aligned to whakapapa, tikanga, mātauranga, and other cultural elements which support genomic science.

Communication and outreach

To effectively implement genomics, we need to tell people about the power and value of genomic solutions, and how these can impact their lives in a positive way. We will engage in a strong external communication programme, indicating our successes, promoting the tools and technology we have developed, and positively lifting the profile of genomics across Aotearoa New Zealand. This programme will also have a targeted Māori strategy which will support Te Tiriti principles and empowerment, in particular tino rangatiratanga and partnership.

We will also undertake an Aotearoa New Zealand-wide map of community perspectives on genomic and genetic technologies, gathering the range of views and opinions to better target our communication and outreach. We will expand our current outreach programme, in partnership with experts in this area, to develop ways to discuss the benefits of genomics, provide information, and build trust in these technologies. We will deliberately form partnerships to deliver these programmes, building on relationships with national and international bodies that can extend this engagement.

“...we need new ways of monitoring the environment, new tools to protect Papatūānuku from biological threats, and a better understanding of the impact of climate and resilience.”

International leadership

Genomics is an international science, and we must continue to strongly engage internationally. Building on our relationships with international genomic agencies we will leverage ourselves into international leadership fora on genomics and genomic data. We will use the AGDR and the Indigenous Foundation (incorporating the Indigenous Genomics Platform) as examples of best practice for building relationships with Indigenous groups and maintaining Indigenous guardianship over data. Given the recent discussions on biological data at the UN Biodiversity Conference (COP15), there is a need for international solutions for data sovereignty over genomic data.

We will continue building relationships with Bioplatforms Australia, the Wellcome Sanger Institute, the Broad Institute, the Human Pangenome Reference Consortium, and Genome Canada, with a view to developing joint projects. Finally, we will examine opportunities for working with Horizon Europe to develop projects that are mutually beneficial to European partners and ourselves. Aligning with Māori needs and those of our South Pacific neighbours will provide a point of difference, showcasing how genomics can contribute to building international Indigenous capability.

The range and scale of these activities will require investment at a level significantly above the first tranche of Genomics Aotearoa funding.

5.1. Research missions

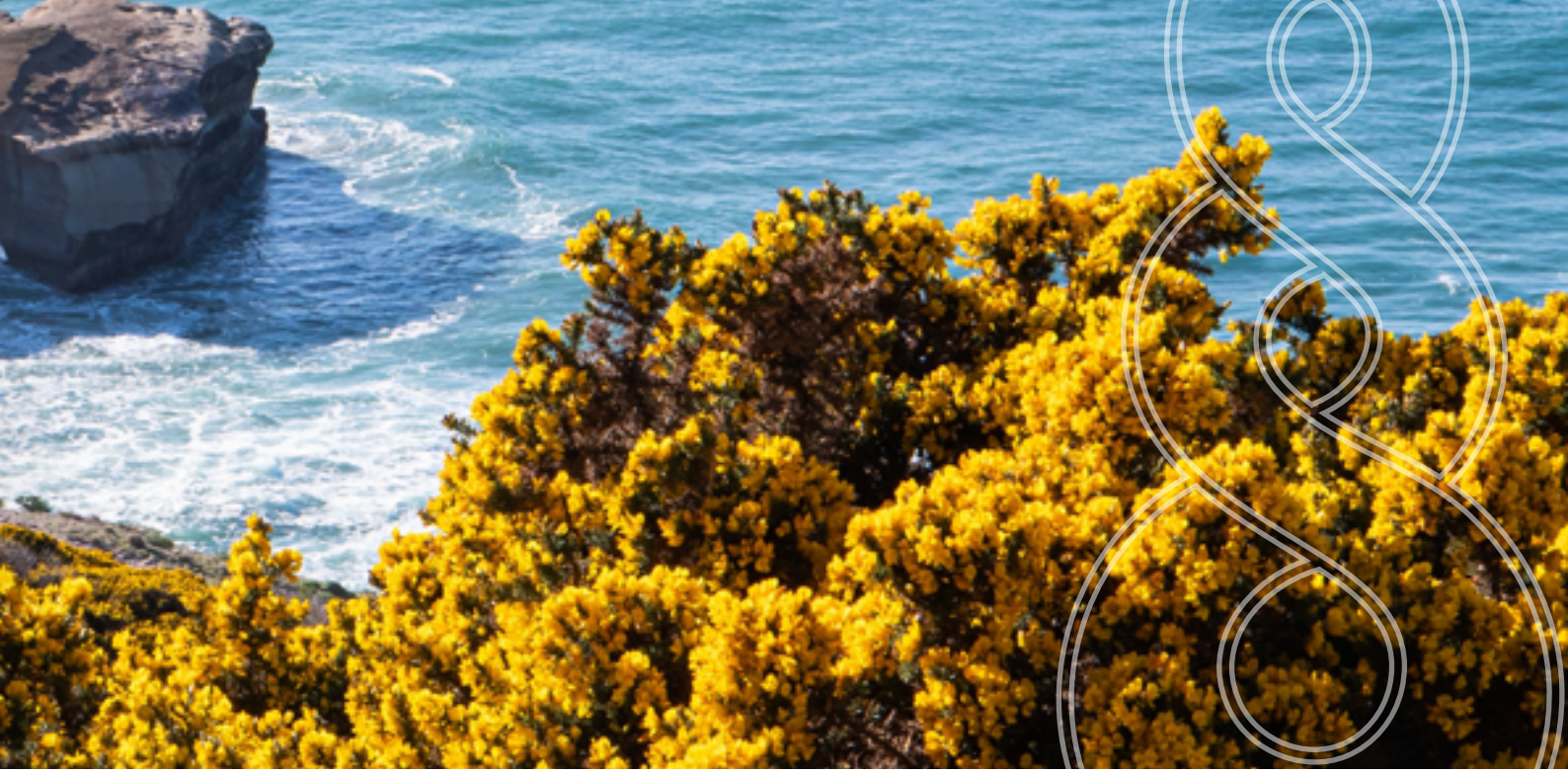
Developing infrastructure through research missions

We aim for Genomics Aotearoa’s research to produce world-class capability and capacity, and generate tools and approaches to solving those biological problems unique to us. This exemplar project approach has been instrumental in our past successes and is crucial to our approach in the future. As part of the process of developing research exemplars, we propose three broad missions that will underpin our research. These missions will be world-leading, future-focused science, but with a clear line of sight to implementation (see below).

Climate change, and the impacts it has on the environment, biosecurity, health, primary production, and migration, is a crucial challenge, but globalisation and food security will also have impacts on the future of Aotearoa New Zealand and our South Pacific region. We aim to develop the genomic tools and train the people who will underpin our response to these challenges.

In each mission we will target specific activities, examples of which are provided here.

Our research missions take on the most crucial biological challenges of our time. Investing in them will generate implementable tools and technologies, as well as capability and capacity, that will materially aid in our responses to



these challenges. The technologies used in them, including AI, bioinformatic analyses, data science, gene-editing, and genetic technologies, will provide connectivity across missions. The final projects may address more than one mission and we will prioritise research that connects research missions and delivers on our Te Tiriti obligations.

Mitigating for and adapting to changing environments

Climate change is a crucial challenge for Aotearoa New Zealand. In response, we need new ways of monitoring the environment, new tools to protect Papatūānuku from biological threats, and a better understanding of the impact of climate and resilience. Carbon neutrality by 2050 is the national target but this mission will need to focus on biological science if it is to be achieved. Aotearoa New Zealand has committed to the goals of the United Nations Convention on Biological Diversity. To meet these obligations, we will need better data on biodiversity, including taonga species, along with improved reference genomes, data from population genomics, and environmental monitoring tools. Generating these data, recognising mātauranga, establishing baseline measures, and implementing rapid cost-effective monitoring will allow us to develop an understanding of the market value of ecosystem services and its maintenance and will provide tools to stabilise and restore our natural environment.

Key research areas will include:

- Biodiversity discovery and monitoring (eDNA) to measure impacts and responses to change.
- Invasion and biosecurity genomic and genetic technologies to protect our primary production and conservation estates.
- Identifying genetic vulnerabilities in conservation populations responding to climate change and other stressors.
- Using genomic data to understand and predict future states (e.g., ecosystem function, tipping points, range expansion, and contraction) to support climate resilience and restoration.
- Genetic technologies to assist with mitigation and adaptation.
- Development of baseline mātauranga including whakapapa and tikanga, and genomic data on our taonga and threatened species and ecosystems.
- Conservation of genetic diversity which enhances our natural environment.
- Support for Māori and Pacific Peoples uptake of genomic technologies and outputs.

Advancing equitable health and wellbeing

We need to bring genomic data and technologies to bear on our health system in order to reduce cost and increase benefit. This must be done in equitable ways that take account of Te Tiriti and our diverse population. We need to understand the diversity within our population and ensure that new treatments take account of this. We aim to develop and implement genetic technologies to improve responses to infectious and non-infectious diseases, and to develop the infrastructure through which equitable precision medicine can be implemented. We will also develop new ways to measure environmental exposure via epigenetics.

Key research areas may include:

- Mātauranga alignment to genetic technologies.
- Variation assessment and pangenome construction for our diverse population base.
- Clinical implementation of genomic diagnosis and monitoring.
- Precision monitoring and prediction of infectious disease.
- Predictive modelling of non-communicable disease.
- Rapid diagnosis and treatment of acute infections.
- Precision wellbeing.
- Environmental interactions, epigenetics, gene expression, and understanding environmental exposure.
- Rapid response to human health challenges (including zoonoses).
- Supporting policy development for genomics research and application in Aotearoa New Zealand.

Growing sustainable food production in changing ecosystems

We need to produce more food that requires less input and ecosystem disruption. This will help us meet our climate change goals, but will also contribute to our health, well-being, and economic imperatives. Rather than focus on developing technologies for already successful industries, we will target new sources of food, their production and value chain support, and ways in which we might protect our systems from pests, diseases, and climate change impacts.

Key research areas may include:

- Taonga and future foods.
- Supporting the Māori economy.
- Managing populations undergoing wild harvesting and other contemporary pressures.
- Climate adaptation genomics of our production plants and animals.
- Describing, modelling, and predicting (productive) ecosystem dynamics.
- Sustainable food production; enhancing attributes of food, increasing our economic competitiveness, and reducing the environmental impact of current food systems.

6. What does success look like?

Capability and capacity are key measures of success for Genomics Aotearoa. We need skilled people in science, industry, government, and our Māori communities to guide us through our transition to a genomics-informed future.

The delivery of an Indigenous Foundation in genomics, ensuring engagement with Māori communities, co-development of technologies and projects, and delivery of tangible benefits to Māori is a key output of Genomics Aotearoa.

The development of bespoke Aotearoa New Zealand tools – meeting our problems with our unique solutions – is a key outcome of Genomics Aotearoa's work. Development and adaptation of genomic tools and technologies that are fit for purpose for Aotearoa New Zealand will be a key measure of our success.

Genomics Aotearoa's baseline genomic data on our treasured ecosystems and species will be used to enable the monitoring of biological change, support our South Pacific neighbours, meet our international obligations, and value natural ecosystem restoration.

Genomics Aotearoa's objective commentary on gene-editing and genetic technologies will generate collaborative research and implementation of novel biological products supporting Aotearoa New Zealand's climate change and environmental aspirations.

Genomics Aotearoa will ensure that we keep up with our international partners in this fast-moving area. This will occur by ensuring we are linked into leading international thought in genomics, and have the capability to rapidly implement emerging genomic technologies developed overseas.

Genomics Aotearoa's work will generate clear paths to the integration and implementation of technologies in industry, health improvement, and the environment, ensuring the benefit of genomics is spread widely.

Genomics Aotearoa will be measured against its ability to produce and disseminate world-leading research in genomics and bioinformatics, ensuring we have the international reputation to earn a place at key international fora.

The AGDR will be a vibrant and much-used fixture of genomics research in Aotearoa New Zealand, and will be part of an integrated network of databases used in research and beyond.

Genomics Aotearoa will enable a joined-up genomics research sector that delivers for Aotearoa New Zealand, is responsive to this country's needs and doesn't duplicate or fragment research and translation efforts.

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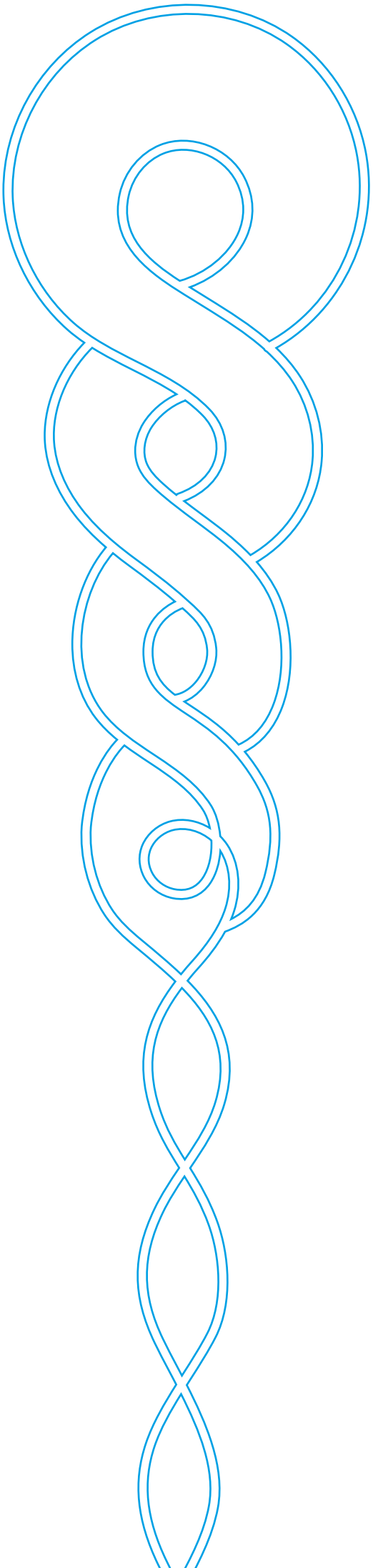

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The natural shape of the three-twist pikorua depicts the growth of two pikopiko fern fronds and is a traditional Māori symbol that represents the strength of bonds between groups and cultures. The shape is also reminiscent of the DNA helix that connects us all.

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