Australian Government
Department of Industry, Science and Resources

Draft National RNA Sector Development Plan

September 2023

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Executive Summary

RNA technologies present Australia with an opportunity to grow our medical research industry and the health outcomes of all Australians.

The approval and use of multiple highly effective messenger Ribonucleic Acid (mRNA) vaccines against COVID-19 has elevated RNA as a class of therapeutics onto the world stage and accelerated appreciation of their benefits by the public. While the technology has been under development for decades, the development timeline of the vaccines was unprecedented. It was reported that it took merely two days after the SARS-CoV-2 genome was sequenced to select the appropriate sequence for the Moderna vaccine candidate, 25 days to manufacture the first clinical batch of mRNA-1273, and another 35 days to dose the first participant.

Australia has a long history of making key discoveries in fundamental RNA science including the seminal work of Shine and Dalgarno who discovered and characterised the specific sequence in mRNA that serves as the binding site for the cellular machinery that translates mRNA into protein. This is just one example of the significant contributions that have translated from RNA research into practice and been led by Australians.

While mRNA vaccines are a leading example of benefits, RNA technology has much greater potential due to:

- Its relative safety (mRNA and RNA therapies are non-infectious, non-integrating platforms with superior safety profile)[1]
- High potency (mRNA can be made more stable and highly translatable, and can be administered repeatedly)
- Capacity and scalability for rapid development and potential for low-cost manufacture (applicable to mRNA vaccines, RNA therapies and diagnostics).[2]

These benefits have resulted in a global 'arms race' to ensure that the right processes and infrastructure are in place to capitalise on the economic potential. RNA technology will change the way that not only human healthcare is delivered but how we control pests and disease in animals and the yield of crops in agriculture.

Australia lacked significant infrastructure for large-scale RNA production prior to the COVID-19 pandemic, but substantial investments have been made to swiftly establish the framework for a thriving RNA ecosystem. This is highlighted by the attraction of Moderna, BioNTech, Sanofi as global biotechnology companies capable of supporting the local industry. These pillars will help extend our eminence as leaders in RNA research but also support the introduction a new industry and provide a significant amount of economic benefit for Australia.

[1] Lee MJ, Lee I, Wang K. Recent Advances in RNA Therapy and Its Carriers to Treat the Single-Gene Neurological Disorders. Biomedicines. 2022 Jan 12;10(1):158. doi: 10.3390/biomedicines10010158. PMID: 35052837; PMCID: PMC8773368.
[2] Satapathy M.K., Yen T.L., Jan J.S., Tang R.D., Wang J.Y., Taliyan R., Yang C.H. Solid Lipid Nanoparticles (SLNs): An Advanced Drug Delivery System Targeting Brain through BBB. Pharmaceutics. 2021;13:1183. doi: 10.3390/pharmaceutics13081183

While the Australian RNA sector holds potential to become a significant contributor to the global RNA market, it faces several challenges that must be addressed to unlock scaling-up capabilities and ensure success. These include:

- The absence of national coordination, oversight and funding approach
- Fragmented commercial pipelines that limit translation of Australian born research to commercial products
- Complex RNA intellectual property (IP) landscape
- Other jurisdictions assumed market leadership of mRNA vaccines requires Australia to look at alternative options
- Limited onshore manufacturing capabilities hinder ability to complete end-to-end development at scale.

To harness this investment, it is imperative to initiate a national plan immediately, driving coordination, optimising sector investments, and capitalising on our distinctive strengths.

National RNA Sector Development Plan

This National RNA Sector Development Plan is based on extensive consultation by the Department of Industry, Science and Resources with industry, academia, government and the broader community to inform its vision of growing a sustainable and globally leading RNA ecosystem. Seven workshops were held across major cities, including one conducted virtually. A series of themes emerged from these consultations (see Appendix A) which informed the development of a set of opportunities to build on Australia's existing foundation to achieve growth in the RNA ecosystem.

Key to realising these opportunities will be ensuring that Australia overcomes its known barriers by investing in national coordination, streamlining the commercialisation pathway and developing a scalable and highly skilled workforce. Australia must also invest in areas where we already hold a competitive advantage when compared to our global neighbours. This will include maximising our discovery research potential, acting as an attractive destination for clinical trials, investing in agriculture delivery platforms and leveraging our location within the Asia Pacific region to conduct unique epidemiological studies that access the wide variety of environmental conditions, disease prevalence and lifestyles present in society.

The National RNA Sector Development Plan has identified seven central opportunities supported by key actions that will help Australia create a world-leading RNA ecosystem at the forefront of the global stage. These are focused on:

- Establishing a coordinating function or office within government to drive action and ongoing monitoring of success
- Developing and retaining a workforce that acts as the foundational enabler for the ecosystem
- Creating clear commercialisation pathways that support product ownership to remain in Australia
- Extending our leadership position in RNA therapeutics in agriculture
- Building our diagnostics capability to support the shift to precision medicine
- Leading the uptake of RNA technologies in the Asia Pacific region
- Advancing research into RNA delivery mechanisms.

The National RNA Sector Development Plan outlines how the Commonwealth in collaboration with Federal, State and Territorial jurisdictions will deliver on its vision to become a global player in RNA technologies. It also signals areas the government will consider for investment in the future.

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Australia's ambition within the RNA sector will not be realised by working in Government alone. Every part of the RNA sector needs to work in harmony, towards the same goal through investments of not only funding but shared resources. This will be driven by Government, but individual actions will be owned by our partners across the sector that include the RNA industry, academia and discovery researchers, the Australian Defence Force and peak bodies.

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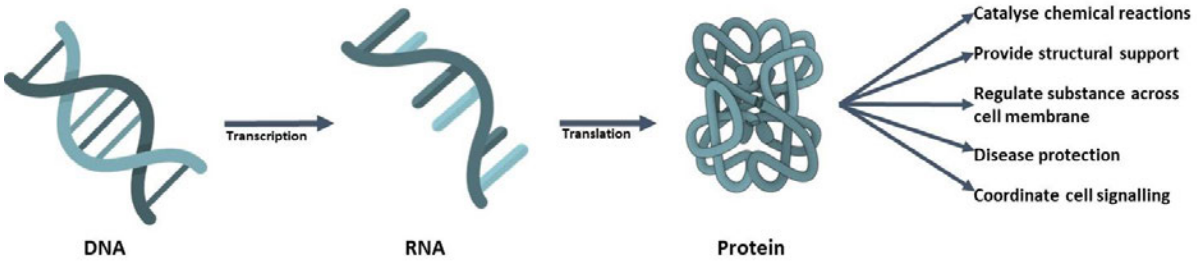
What is RNA?

Ribonucleic Acid (RNA) is a chemical molecule that holds biological code and is central to many processes within cells. RNA plays essential roles in gene expression, serving as a messenger between DNA and protein synthesis, as well as participating in a range of cell regulatory mechanisms (see Figure 1).

Figure 1: Overview of Protein Synthesis



The COVID-19 pandemic showcased the flexibility of RNA technology in the development of the first two COVID-19 vaccines by BioNTech in collaboration with Pfizer and Moderna. The development timeline of both vaccines was unprecedented. It was reported that it took merely two days after the SARS-CoV-2 genome was sequenced to select the appropriate sequence for the Moderna vaccine candidate, 25 days to manufacture the first clinical batch of mRNA-1273 and another 35 days to dose the first participant.

The success of the COVID-19 vaccines proved the scalability of RNA technology and that the relative simplicity of the development process and flexibility of the manufacturing platform can markedly accelerate clinical development in a cost-effective way. It has also highlighted to the world its potential as a completely new class of vaccines and therapeutics for a range of applications.

The scalability and cost-effectiveness of RNA extend beyond mRNA vaccines and apply to RNA therapeutics targeting previously undruggable targets. This approach enables rapid and cost-effective developments, in comparison to existing processes involving small molecules and recombinant proteins.[3]

RNA technology has broad potential that includes:

Its safety, high potency, capacity for rapid development, potential low-cost manufacture and safe administration, has ensured that RNA technology is at the forefront of a therapeutic revolution, which hasn't been seen since the advent of recombinant protein technology almost 50 years ago.

Australia is well placed to capitalise on this growing sector which could deliver advanced manufacturing, highly skilled jobs, and improve our sovereign resilience to manufacture future therapeutics and vaccines onshore. We are home to world leading scientists and healthcare

[3] Damase, Tulsi Ram, et al. "The limitless future of RNA therapeutics." Frontiers in bioengineering and biotechnology (2021): 161.

professionals, a stable socioeconomic environment, and strong IP regime. Our existing medical manufacturing is world class and we have already made significant investments in the RNA sector through partnerships with organisations that include Moderna, Sanofi, BioNTech, and Pfizer.

However, Australia's relatively small population means that it cannot specialise in everything, and we must invest in areas that leverage our unique strengths and that support increased international collaboration to fully unlock the benefits of RNA technology. Additionally, there are significant challenges to overcome – including improving commercialisation pathways and focus, national coordination, ensuring we have a highly skilled workforce, and making the most of enabling infrastructure.

Purpose of the National RNA Sector Development Plan

The global therapeutic market is growing and RNA vaccines and therapeutics, cell therapies and monoclonal antibodies are expected to contribute towards a significant proportion of the trillion dollar pharmaceutical industry.[4] The estimated size of the RNA vaccine and therapeutics market (see

Table 1~~Table 1~~) highlights the potential value in continuing to invest in Australia's emerging market position.

Australia's ambition is to be world leading. To capitalise on the existing capability and investments made by both the Australian Government and the states and territories we need to drive coordination and capitalise on the opportunity that our unique strengths provide.

The National RNA Sector Development Plan developed by the Australian Government describes Australia's path to this position. Its enactment, across the next 10 years aims to:

- Develop Australia's capabilities in this emerging technology
- Contribute to competitive industry opportunities with well-paid jobs
- Capitalise on Australia's world-class R&D
- Support strong commercialisation prospects
- Establish a critical sovereign capability.[5]

The National RNA Sector Development Plan outlines takes a whole-of-sector approach and outlines the potential options that Australia may explore to develop a thriving RNA ecosystem.

[4] Global pharmaceutical industry - statistics & facts (2022) Statista. Retrieved from https://www.statista.com/topics/1764/global-pharmaceutical-industry/#topicOverview.
[5] Department of Industry, Science and Resources "Discussion Paper – Shaping our RNA Future".

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Table 1: Size of the therapeutic segments in the pharmaceutical industry[6,7,8,9,10,11,12]

Select therapeutic segments	Estimated market size (2021; US$)	Future estimated market size (2030; US$)
RNA Vaccines and Therapeutics	Ranges from: $39.9 billion to $50 billion	Ranges from: $48 billion to $128.1 billion
Cellular therapies	Ranges from: $7.8 billion to $10.35 billion	Ranges from: $30.2 billion to $60.7 billion
Monoclonal Antibodies	Ranges from: $181 billion to $186.0 billion	Ranges from: $542.2 billion to $602.3 billion

[6] Cell Therapy Market Size (2022) GlobalNewswire. Retrieved from https://www.globenewswire.com/en/news-release/2022/05/12/2442322/0/en/Cell-Therapy-Market-Size-to-Surpass-US-60-67-Billion-by-2030.html.
[7] Report Overview (2020) Grand View Research. Retrieved from https://www.grandviewresearch.com/industry-analysis/monoclonal-antibodies-market.
[8] The Limitless Future of RNA Therapeutics (2021) Damase, T., et al,. Retrieved from https://www.frontiersin.org/articles/10.3389/fbioe.2021.628137/full.
[9] Facts about cellular therapies (Unknown) AABB. Retrieved from https://www.aabb.org/news-resources/resources/cellular-therapies/facts-about-cellular-therapies.
[10] mRNA therapeutics market Size, Share, Trends Analysis Report. Retrieved from https://www.grandviewresearch.com/industry-analysis/mrna-therapeutics-market-report.
[11] mRNA Therapeutics Market Report 2022-2030. Retrieved from https://www.precedenceresearch.com/mrna-therapeutics-market.
[12] Monoclonal Antibodies Market Size. Retrieved from https://www.gminsights.com/industry-analysis/monoclonal-antibodies-market.

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Overview of types of RNA

While mRNA has received the most attention and prominence recently due to the COVID-19 vaccine, there are multiple classes of RNA that play different roles in the body and can therefore also play different roles as therapeutics or targets for therapeutics.

Much of the RNA research is focused on ways to modify, interrupt or adapt natural RNA processes for specific therapeutic purposes. While not exhaustive, the list below highlights several RNA classes that have been applied as, or are being explored for, therapeutics or vaccines:

mRNA. Ordinarily carries instructions from DNA in the cell's nucleus to other parts of the cell machinery, telling them how to make proteins that are pivotal to our body's functions. mRNA can also be made synthetically and introduced directly into cells (e.g., not transcribed from DNA) to make specific proteins. mRNA vaccines (such as those developed by Moderna and Pfizer-BioNTech) tell cells to produce proteins usually found on the infectious agent (such as a virus) to help the immune system recognise the virus and prevent severe disease when a person is infected.

- **RNA interference (RNAi).** A type of RNA that acts as part of a naturally occurring cellular process where a sub-group of short interfering RNA molecules (siRNA), interfere with the mRNA translation process by targeting mRNA for degradation in a highly specific way. This process can be used as a therapeutic to 'silence' specific genes and is best exemplified by Alnylam's RNAi product suite that includes Patisiran to treat polyneuropathy and Givosiran to treat acute hepatic porphyria.
- **microRNA (miRNA).** Works in two main ways via two different mechanisms:
  1. Blocks mRNA translation by binding to it and preventing translation machinery from reading it to produce proteins, rather than degrading the mRNA
  2. Blocks mRNA transcription at the source by binding to the specific parts of genes in DNA that signals the start of mRNA transcription (i.e., the promoter sequence).
- **Antisense RNA (asRNA).** Disrupts mRNA function by binding to it, preventing the cell from utilising its instructions and can be employed as a therapeutic to inhibit the synthesis of the corresponding protein.
- **RNA aptamers.** RNA oligonucleotide that bind to specific targets and can be used in drug delivery to modulate specific biological process, block protein-protein interactions, diagnostic applications and gene expression.
- **Long non-coding RNA (lncRNA).** Includes several functions including interacting with and altering gene expression, regulating genetic output and facilitating different types of interactions with cellular machines.
- **CRISPR/Cas9.** An RNA-based gene editing technology that uses a designed guide RNA (gRNA) to make precise changes to specifically targeted DNA or RNA.

RNA therapeutics are typically delivered to the body in several ways:

- **Naked.** RNA without any coating but in a special liquid (buffer) to keep it stable. RNA is inherently unstable and there have been significant challenges with delivering naked RNA into cells.
- **Lipid nanoparticles (LNPs).** A small vesicle made of fats that encases and carries RNA into cells in the body. Although LNPs are not RNA molecules themselves, they are a delivery

platform that can be used in drug delivery, gene therapy and mRNA vaccine development. As such, they were a key component of the COVID-19 mRNA vaccine[13]

- **Exosomes.** Like LNPs, they form a protective membrane around the RNA, creating a vesicle that carries it into the cell.

The ongoing development and optimisation of mechanisms to delivery RNA therapeutics and vaccines into cells (irrespective of species) will be critical to realising the potential of RNA across a range of applications.

Applications of RNA Technology

As a burgeoning field, the full potential and application of RNA is yet to be fully realise. Continued discovery of RNA's involvement in normal cell functioning holds the key to unlocking its vast possibilities and broadening its application across diverse areas of science across numerous sectors. To highlight the size of the problem that RNA therapeutics may solve, healthcare costs directly attributable to cancer within Australia were estimated to be $11.7 billion in 2019.[14] These costs may benefit from future specific RNA anticancer therapies, or alternate delivery methods that impeded current cancer treatments.[15]

In the short-to-medium term (1-10 years), the application of RNA can be considered under two broad categories: human therapeutics and vaccines and non-human applications. These applications are discussed in Table 2.

Table 2: Potential applications of RNA technology

Application	Sub-application	Example applications
Therapeutics and vaccines	Human health	• Respiratory illness such as COVID-19 and respiratory syncytial virus (RSV) • Cancer treatments and vaccines for several cancers including both solid and blood cancers • Protein replacement therapies for diseases such as cystic fibrosis • Treatment for heart disease and rare diseases such as muscular dystrophy • Therapeutics for rare diseases, including neurodegenerative disorders like dementia and those affecting metabolic regulation • Sensing and diagnostics for a range of illnesses, including the rapid detection of infectious diseases.
Non-human applications	Animal health	• Improve health through changes in immune response to diseases (i.e., resistance to fatal diseases) • Enhance livestock production traits such as meat, milk and fibre production • Protect animals from biosecurity threats • Used in aquaculture to protect fish stocks against disease.
	Agriculture	• Transition to sustainable agricultural practices using non-chemical RNA pesticides

[13] Hou, X., Zaks, T., Langer, R., & Dong, Y. (2021). Lipid nanoparticles for mRNA delivery. Nature Reviews Materials, 6(12), 1078-1094.
[14] Australian Institute of Health and Welfare (2022), Cancer, <https://www.aihw.gov.au/reports/australias-health/cancer>, accessed August 2 2023
[15] RNA-based therapies: A cog in the wheel of lung cancer defense (2021), https://molecular-cancer.biomedcentral.com/articles/10.1186/s12943-021-01338-2, accessed August 5 2023

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Application	Sub-application	Example applications
		• Modification of gene expression in plants and crops to manage changing climates, regulate the timing of fruiting and characteristics of produce • Modification of gene expression to confer disease resistance.
	Environment	• Monitor ecosystems or particular species through the detection of RNA present in an ecosystem.
	Manufacturing	• Improve chemical techniques which would increase the yield in biotechnology processes or improve chemical waste treatment • RNA based biosensors can contribute to data driven manufacturing processes allowing for optimised process and reduced variability • RNA can be used to regulate metabolic pathways used in industrial fermentation, which can optimise manufacturing of biofuels, chemicals, and other valuable products in bioreactors.

Global trends in RNA science and technology

The global market for RNA technologies in 2021 was estimated to be US$50 billion, driven solely by the revenue of mRNA-COVID-19 vaccines.[16] There is now a focus on the emerging applications of RNA beyond COVID-19, and global efforts dedicated to understanding and discovering the use of RNA-based technologies to control gene expression for therapeutic purposes and develop targeted delivery and packaging systems.

Table 3 provides an overview of the international investment and focus areas into RNA.

Table 3: Investment and focus areas on mRNA/RNA in selected countries

Region	Country	Investments and focus areas
Western Pacific Region	South Korea	• Development of protein-based COVID-19 vaccines and mRNA vaccines by several South Korean biotechnology companies • Signed a Memorandum of Understanding with the Victorian Government where the two countries will exchange information and RNA research.
	China	• Abogen and StemiRNA, two Chinese biotechnology companies, are developing mRNA COVID-19 vaccines, funded through private investments • BioNTech is collaborating with Fosun Pharma to build a mRNA vaccine manufacturing facility in China.
	Singapore	• Partnership with Sanofi to build a vaccine manufacturing facility, which will be able to produce mRNA and other vaccines • Partnership with BioNTech to build an mRNA manufacturing facility • Singaporean researchers from the Genome Institute of Singapore, the Institute of Bioengineering and Bioimaging and the National University of Singapore Yong Loo Lin School of Medicine were awarded contracts from the Welcome Leap R3 (RNA, readiness and response) Program to develop second-generation mRNA vaccines.

[16] Xie et al, 'Evolution of the market for mRNA technology', (2021) *Nat Rev Drug Discov* 20(10) 735-736.

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Region	Country	Investments and focus areas
North America	Canada	• Research and capacity building for mRNA and COVID-19 vaccines • Partnership with Moderna for an mRNA vaccine production facility • Investment in Resilience Biotechnologies Inc. to increase manufacturing and fill and finish capacities for vaccines and therapeutics • Investment with Precision NanoSystems to improve Canada's capabilities in RNA therapeutics development.
	United States (US)	• Significant Government investment through Operation Warp Speed for the development of COVID-19 vaccines that included funding for Moderna and Pfizer.
European Region	France	• Investment from Sanofi to develop mRNA vaccines in France which includes the entire value chain from research and development (R&D) to manufacturing.
	United Kingdom (UK)	• Government investment into the development and manufacturing of mRNA vaccines and expand and upgrade the UK's onshore manufacturing lipid facility • Partnership with Moderna to build an mRNA manufacturing facility • Moderna will also invest in research and clinical trials in the UK.
	Germany	• Government funding to develop mRNA-COVID-19 vaccines • Signed contracts with several biotechnology companies including BioNTech, CureVac and GSK, to reserve mRNA vaccine manufacturing capacity.
	Israel	• Research on mRNA technologies, including research on the safety and efficacy of mRNA vaccines • Establishment of the Israel Innovation Authority, a synthetic biology applied R&D infrastructure which will include research into RNA.

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Australia's opportunity

Australia can capitalise on the opportunity to establish an innovative research and development ecosystem to position itself as a prominent global market player in the field of RNA. Ranked 10th in the world for RNA research output, Australia's researchers contribute approximately 3% of global RNA research publications each year, across human and non-human applications.[17] We have high quality research, medical and healthcare infrastructure, a stable socioeconomic environment, and a strong IP regime.[17~~17~~]

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Australia has made significant contributions in both fundamental and translational research leading to RNA technologies and demonstrates Australia's strong research capabilities. This includes:

- **The discovery of the Shine-Dalgarno sequence**, which ensures that genetic code is read correctly, and the correct protein is produced within a cell. This discovery is foundational to the design of effective mRNA therapeutics and vaccines.[18]
- **The discovery of the mRNA cap structure** found at the start of all mRNA molecules in animals, plants and fungi, allowing the conception of certain mRNA therapeutics.[19]
- **RNAi and gene silencing in plants** has led to the development of gene silencing technologies which are used in plant biotechnology application.[20]
- **Understanding of the regulatory function of non-coding RNA in complex organisms,** which has highlighted the important role of non-coding RNA in influencing the evolution of complex organisms.[21]
- **Contributions to the development of RNA therapeutics**, including an antisense therapy for Duchenne muscular dystrophy[22] and a therapeutic for the treatment of certain ovarian and breast cancers.[23]

Our existing Australian medical manufacturing sector is world-class and includes CSL, BioCina and AcuraBio. Given the therapeutic potential of RNA, and to build domestic resilience for production and supply, several Australian states and territories and the Commonwealth Government have invested significantly in attracting key market players and establishing the foundational and other enabling infrastructure that is essential for an RNA ecosystem. This includes Moderna, BioNTech and Sanofi which will provide sovereign capability to produce RNA therapeutics on a commercial and clinical manufacturing scale; addressing a key gap experienced during the COVID-19 pandemic. By capitalising on these opportunities, RNA technologies will deliver benefits to Australians, including:

- Accelerating economic growth
- Creating jobs and opportunities across industry
- Strengthening our international role
- Supporting our long-term prosperity.

[17] Australian Academy of Science (2022) RNA Science Report.
[18] Dalgarno, L., Shine, J. Conserved Terminal Sequence in 18S rRNA May Represent Terminator Anticodons. Nature New Biology 245, 261–262 (1973). https://doi.org/10.1038/newbio245261a0
[19] Adams, J. M. & Cory, S. Modified nucleosides and bizarre 5'-termini in mouse myeloma mRNA. Nature 255, 28–33 (1975).
[20] Waterhouse, P. M., Graham, M. W. & Wang, M. B. Virus resistance and gene silencing in plants can be induced by simultaneous expression of sense and antisense RNA. Proc Natl Acad Sci USA 95, 13959–13964 (1998).
[21] Mattick, J. S. Non-coding RNAs: the architects of eukaryotic complexity. EMBO Reports 2, 986–991 (2001).
[22] Wilton, S. D. et al. Specific removal of the nonsense mutation from the mdx dystrophin mRNA using antisense oligonucleotides. Neuromuscular Disorders 9, 330–338 (1999).
[23] Bywater M.J. et al (2012) Inhibition of RNA polymerase I as a therapeutic strategy to promote cancer-specific activation of p53. Cancer Cell 22: 51-65.

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Despite Australia's history of contribution, we are a small island nation that must focus our investments on where they will have the most impact and leverage our unique assets and capabilities. While not exhaustive, Error! Reference source not found.~~Table 4~~ outlines Australia's core areas of competitive advantage in the global RNA ecosystem. These will be used to focus our efforts, distribution of funding and provide guidance for the concentrated effort of our research sector.

Table 4: Australia's competitive advantage

Core area	Description
Deep expertise in research	• Australia is a global leader in scientific discovery in the life sciences sector. It has a reputation for high quality and internationally regarded RNA research. • Australia is perceived to have RNA research/intellectual property strengths in tropical disease, indigenous health, non-coding RNA, rare disease treatments, personalised medicine (LNPs), agriculture, and defence applications.[24,25,26] • We are home to leading academic networks of RNA research. • Australia is therefore well positioned to translate its research into a strong pipeline for innovative RNA products and platforms
Strong clinical trials capabilities	• Australia is an attractive destination for the conduct of clinical trials when compared to other international jurisdictions due our strong R&D tax incentives that attract pharmaceuticals. • We offer fast, pragmatic, and robust regulatory pathway with a quick ethical and scientific review process, adhering to international standards accepted by the US Food and Drug Administration and European Medicines Agency.
Existing RNA ecosystem investment	• Australia has invested significantly in establishing the foundational components of a thriving RNA ecosystem (e.g., clinical and commercial scale RNA manufacturing, workforce training programs, specific grant programs, collaborative networks between industry, academia and government). These investments can be leveraged to build upon and expand the country's capabilities, leadership, and influence in the global RNA ecosystem. • Australia has also invested in enabling / supporting infrastructure that can support the RNA ecosystem, especially in research. For instance, the establishment of the National Collaborative Research Infrastructure Strategy (NCRIS) and the Australian Institute for Machine Learning in South Australia.
Agricultural RNA research	• Australia currently possesses one of the few platforms suitable for efficient and widespread implementation of RNA-based solutions across agricultural settings.[27]

[24] Doherty Institute (2023), Scientific breakthrough harnesses mRNA technology to develop powerful malaria vaccine, < https://www.doherty.edu.au/news-events/news/mrna-technology-to-develop-powerful-malaria-vaccine>, Accessed: July 11 2023

[25] Mitter N, Worrall EA, Robinson KE, Li P, Jain RG, Taochy C, Fletcher SJ, Carroll BJ, Lu GQ, Xu ZP. Clay nanosheets for topical delivery of RNAi for sustained protection against plant viruses. Nat Plants. 2017 Jan 9;3:16207. doi: 10.1038/nplants.2016.207. PMID: 28067898.

[26] University of Melbourne (2023), New Centre for Advanced Defence Research and Enterprise established, < https://www.unimelb.edu.au/newsroom/news/2023/may/new-centre-for-advanced-defence-research-and-enterprise-established> , acessed July 11 2023

[27] Mitter, Neena (2022). "RNA-based biopesticides for sustainable agriculture: BioClayTM technology."

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Core area	Description
	• We are early adopters of RNA agricultural technologies. • Australia's current position in RNA applications of agriculture will assist in biodiversity management, crop protection, weed management, and climate resilience.
Unique environmental demand	• Australia has a unique environmental and biosecurity position that can provide an array of biological samples not found in other jurisdictions that may be used to study RNA processes in different species. • Our position also highlights the challenges we have from climate change and invasive species that RNA technology could mitigate and provide global benefit; for example, through gene editing using CRIPSR-Cas9 or other methods to target and control invasive species.
RNA diagnostics	• Australia has a leading role in RNA diagnostics,[28] our clinicians are using RNA sequencing to offer a precise genetic diagnosis for rare diseases and inherited cancer predisposition and aptamer-based biosensors and targeted therapy in animals. • A continued leadership position will allow effective disease identification and monitoring but also support the push towards precision medicine.
Geopolitical stability	• Australia's geopolitical stability makes it attractive for international investment in long term capabilities and assets
Geographic Location	• Our proximity to the Asia Pacific region and diverse population provides access to a larger addressable market for commercial products and a larger population base for clinical trials. • Our research strength in tropical medicine has high applicability to the Asia Pacific region that has a high burden of tropical disease.Error! Bookmark not defined.[22] Further, the increasing risk of tropical diseases/zoonoses in Asia Pacific in combination with climate change leading to geographical change in vectors.
Population level demand for RNA based solutions	• Asia's ageing population, along with a growing middle class expected to reach 3.5 billion by 2030, is driving higher cancer rates and increased susceptibility to diseases. RNA-based technologies offer potential solutions.[29] • Cancer is a major cause of illness in Australia and is responsible for 18% of burden of ill health by Australia and 9% of health system expenditure. As Australia's population ages, cancer incidence is projected to increase by 22% by 2031,[30] and 51% increase in the number of new cases by 2044.[31]

[28] Bournazos, Adam M., et al. "Standardized practices for RNA diagnostics using clinically accessible specimens reclassifies 75% of putative splicing variants." Genetics in Medicine 24.1 (2022): 130-145.
[29] Business council of Australia (2023), Seize the moment – A plan to secure Australia's economy, <https://www.bca.com.au/seize_the_moment>, accessed September 4 2023
[30] Australian Institute of Health and Welfare (2021), Cancer in Australia, < https://www.aihw.gov.au/reports/cancer/cancer-in-australia-2021/summary> accessed September 4 2023
[31] Luo, Q., O'Connell, D. L., Yu, X. Q., Kahn, C., Caruana, M., Pesola, F., ... & Canfell, K. (2022). Cancer incidence and mortality in Australia from 2020 to 2044 and an exploratory analysis of the potential effect of treatment delays during the COVID-19 pandemic: a statistical modelling study. The Lancet Public Health, 7(6), e537-e548.

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Size of the opportunity

A computable general equilibrium (CGE) model was used to compare a series of policy scenarios, against the base case (status quo) scenario. For more information on the CGE model see Appendix B: Economic analysis. Here, headline economic impacts — Gross Domestic Product (GDP) and employment — are discussed as well as the impact on specific sectors.

In each policy scenario, a change to the baseline occurs and are introduced to the model as shocks based on the demand modelling. The shock data is guided by the growth path of the Australian market share of the global RNA sector under three scenarios through to 2033.

It is assumed that the growth in Australia's share of the RNA market is driven by foreign demand. It is appropriate to simulate the impacts from commercialising RNA based goods, rather than hypothesising impacts from benefits that are inherently uncertain. Although these factors are present and are essential for the advancement of the RNA sector, their impact on health outcomes and productivity gains remains uncertain. Therefore, in this economic analysis, a conservative approach has been adopted.

Impact to economic activity of future RNA pathways in Australia

The continual development of Australia's RNA sector is estimated to have a substantial impact on the domestic economy over the next 10 years to 2033. The economic pathways are illustrative of the potential impacts to the Australian economy under different scenarios.

Under **Targeted Investment** and the **Therapy of the Future** scenarios compared to the base case scenario, the development of the RNA sector has a gain in value add, whereas the **Industry Exit** sees a loss of $448 million, net-present value (Net Present Value (NPV); 7%) to 2033. In the **Targeted Investment**, GDP is projected to be around $3.4 billion NPV higher by 2033. Whereas, In the **Therapy of the Future** scenario, GDP is projected to be around $8.4 billion NPV higher by 2033, reflecting the potential that the Australian RNA sector could capture compared with the base case scenario. These outputs are shown in Figure 1~~Figure 2~~ and Table 5.

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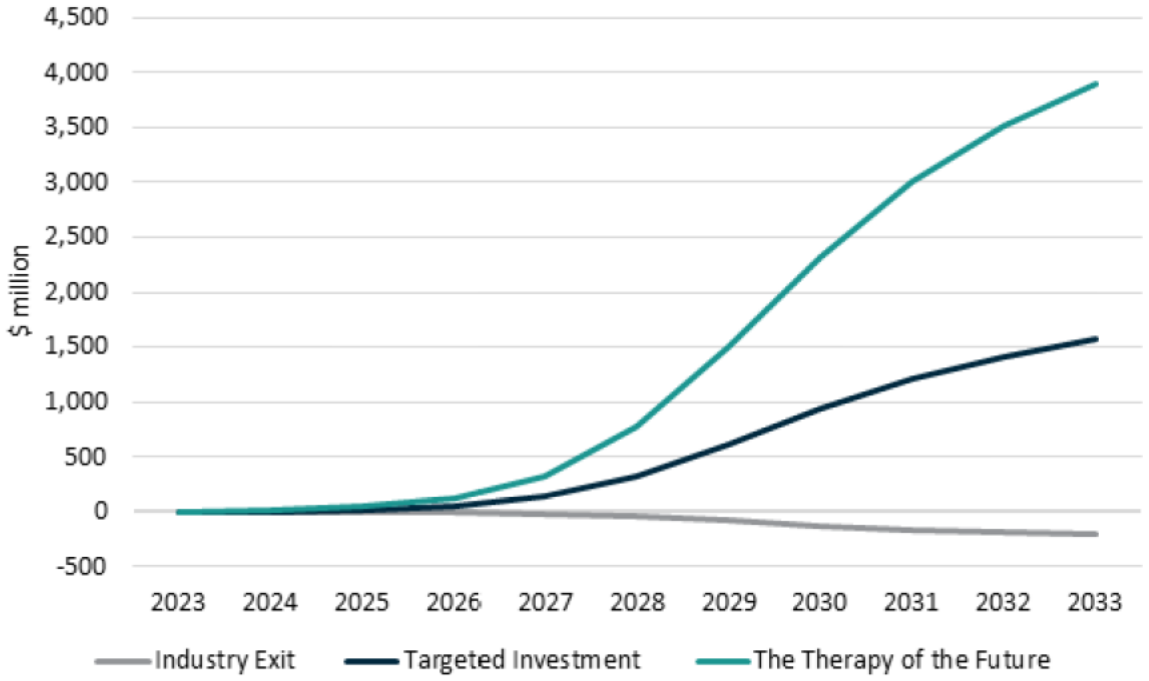
Figure 12: Projected deviation in Australian GDP from base case scenario, selected policy scenarios



Source: CGE Model

Table 5: Value add of policy cases

Scenario	Value Add to 2033 (NPV 7%)
The Therapy of the Future	$8.4 billion
Targeted Investment	$3.4 billion
Industry Exit	- $448 million

Source: Deloitte.

While the development of the RNA sector drives a meaningful dollar increase in Australia's GDP, in relative terms, the increase is modest. In the Therapy of the Future scenario, Australian GDP is projected to be just 0.15% higher compared to the base case in 2033, and just 0.06% higher under the Targeted Investment scenario. The Industry Exit scenario will result in GDP being 0.01% lower in 2033.

Headline impact to employment

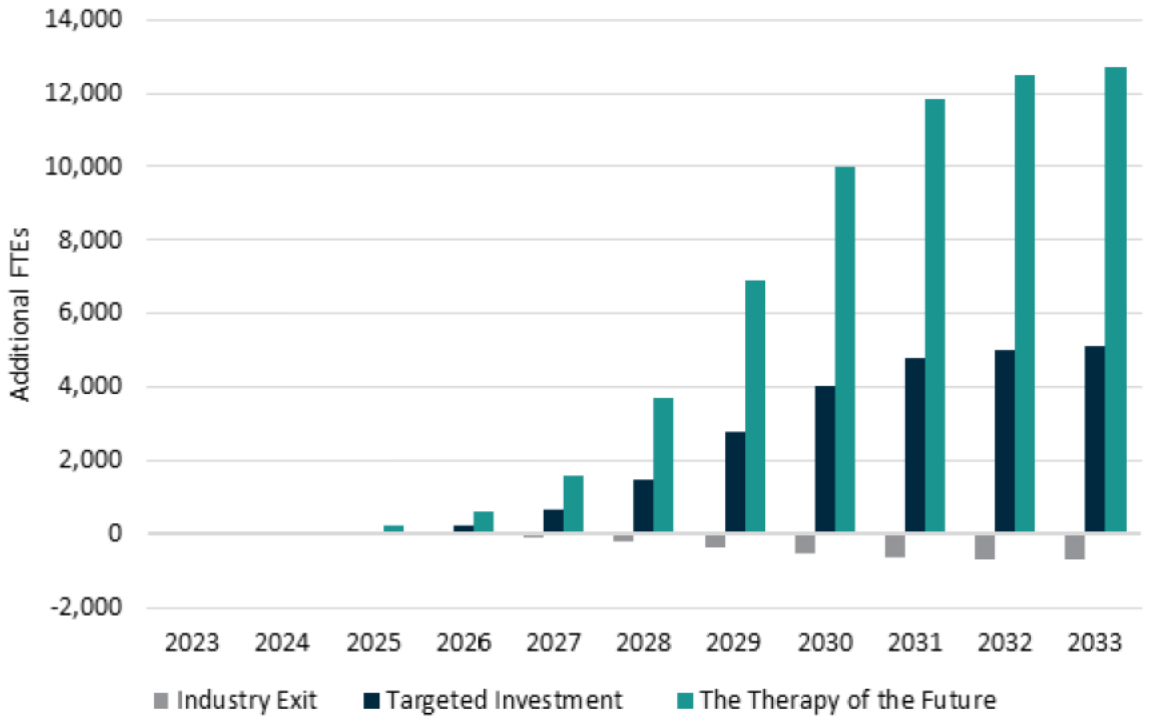
The modelled impact in the RNA sector results in a reallocation of labour from other industries offset by labour inflows and outflows from other regions. It is expected that majority of reallocation of labour will come from skilled jobs in adjacent industries including the pharmaceutical, biotechnology and engineering sector.

The Targeted Investment and Therapy of the Future scenarios will produce positive employment impacts to the Australian economy (see Figure 2~~Figure 3~~). However, the Therapy of the Future impact, in which Australia captures 3% of the global RNA market, are more than double that of the targeted investment scenario. This represents an attractive upside potential for commercialising the RNA sector.

Under the Therapy of the Future scenario, the Australian economy will have 12,724 additional Full Time Equivalent workers (FTEs) in 2033 and on average 5,467 additional FTEs over the modelling

time horizon. Whereas, under the Targeted Investment scenario 2,205 additional FTEs will exist on average and around 5,127 additional FTEs in 2033. Under the Industry Exit scenario Australia will have 694 fewer FTEs in 2033 and 299 less FTEs on average.

Figure 2~~3~~: Projected deviation in Australian Employment from base case scenario, selected policy scenarios



Source: CGE Model

The Australian RNA sector will drive this employment gain as the cumulative sum of all other sectors coming out to a loss in FTEs. The projected deviation in RNA employment at 2033 above the base case ranges from a contraction of 739 FTEs (Industry Exit scenario) to an addition of 13,918 additional jobs (Therapy of the Future scenario).

Sectoral impacts

The increase in Australia's GDP is projected to be driven by the RNA sector. In the Therapy of the Future and under the Targeted Investment scenario (see Error! Reference source not found.Figure 3~~Figure 4~~), $9.3 billion and $3.7 billion respectively are added in value by the sector. Due to the crowding out of other sectors amounting to $8.2 billion and $3.3 billion in The Therapy of the Future and Targeted Investment scenarios respectively, there is a reduced overall impact on the Australian GDP. As a result, industries including heavy manufacturing, mining and agriculture see lower value added and employment in the Targeted Investment and Therapy of the Future scenarios relative to the base case. This is due to expanding demand from the RNA sector which creates competition for inputs such as labour and investment resulting in 'crowding out' of other industries.

The growth in the RNA sector pushes up demand for goods and services from other sectors that are inputs of production for the sector. This creates spill overs to other sectors that drive economic activity and draw resources from industries that are not demanded resulting in crowding out. These three modelled impacts result in the total economic impact to the Australian economy.

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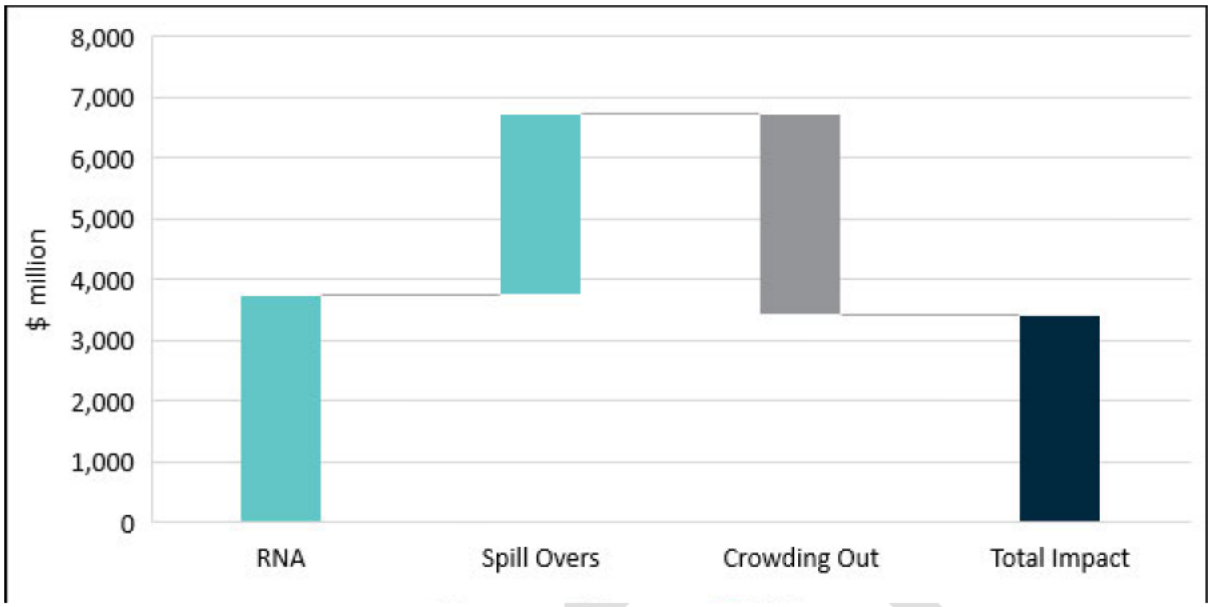
Figure 34: Change in value add from base case scenario in 2033, Targeted Investment, NPV 7%



Source: CGE Model.

Conversely, the Industry Exit scenario is projected to result in an RNA sector with $519 million lower value add than in the base case. As demand for the Australian RNA sector diminishes over the time horizon, some resources that would have been allocated to the RNA sector in the baseline shift to other industries. This results in crowding in of sectors such as heavy manufacturing, mining and agriculture that gain additional resources relative to the base case.

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Taking Action

Australia's RNA sector has been clear that they share ambitions, urgency and commitment to building a world leading ecosystem.

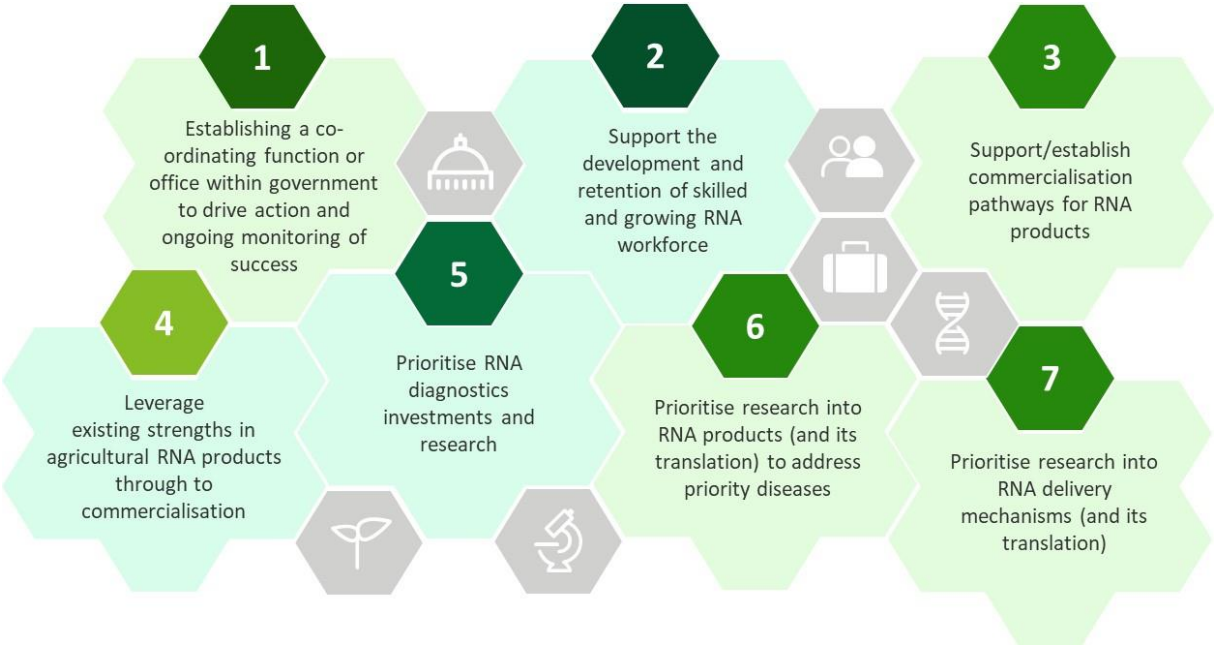
To fully realise the potential of Australia's RNA sector and establish a globally competitive ecosystem that generates economic advantages, a comprehensive cross-disciplinary approach and dedicated commitment to action are required. This necessitates the involvement of industry, academia and various government jurisdiction partners to collectively drive a nationwide initiative.

Opportunities

The National RNA Sector Development Plan sets outs the vision for Australia. It outlines a series of broad opportunities to strengthen the RNA sector (see Figure 5)**Error! Reference source not found.** supported by specific actions.

Appendix A provides additional detail on all opportunities, including risks and considerations for implementation.

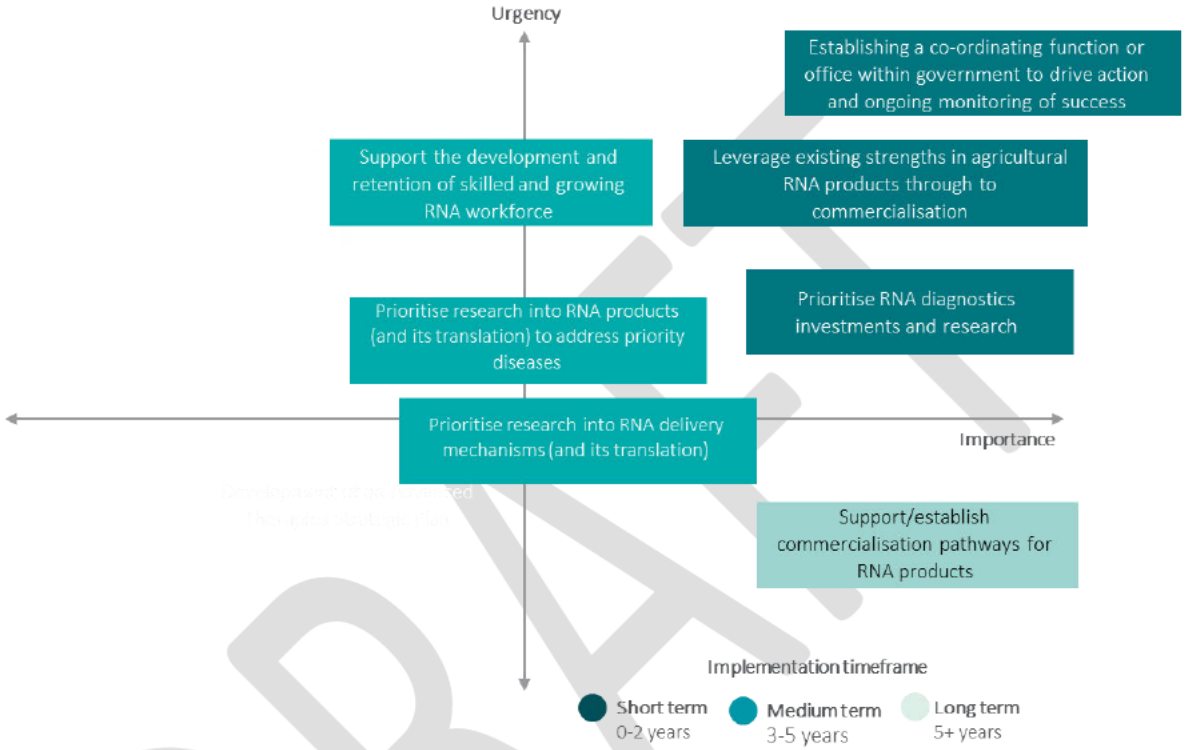
Figure 15: Opportunities areas for action



Implementation

To ensure Australia develops into a global leader of RNA therapeutics, time is critical to ensure opportunities are implemented and Australia's momentum is maintained within the RNA sector. Error! Reference source not found.~~Figure 6~~Error! Reference source not found. provides a depiction of the urgency and importance of each opportunity.

Figure 1~~6~~: Comparison of the urgency and importance of opportunities



Source: Deloitte

The realisation of each opportunity is contingent on a series of key actions. To that end, the following sections provide a detailed description of each opportunity and the key associated actions.

Aligned to the matrix in Figure 2~~Figure 7~~ each action has been:

- Assigned a level of importance
- Mapped against the key owner that should be responsible for the implementation across key stakeholder groups that include Government, Industry, Academia and the proposed coordinating function or office.

Figure 2~~7~~: Key of importance scale and stakeholder icons

Source: Deloitte

Opportunity 1: Establishing a co-ordinating function or office within government to drive action and ongoing monitoring of success

Urgency
Importance

Timeframe:
Next 12 months

To ensure Australia capitalises on the investments made across jurisdictions, both nationally and at states and territories we must coordinate action and investments. The establishment of a new co-ordinating function (or expansion of an existing entity) will provide leadership across the sector and signal the importance of the RNA sector. This function should:

- Establish and maintain processes to measure and report on progress against the National RNA Sector Development Plan
- Support coordination of investments across jurisdictions (including the Commonwealth Government) within the RNA ecosystem to ensure they are aligned to national health and economic interests.
- Influence national policies to foster and promote an integrated and efficient RNA value chain.
- Create and maintain mechanisms that promote collaboration and the development of partnerships across industry, academia and government.
- Advocate the value of an RNA ecosystem to drive research translation, build commercialisation competencies and support clear and streamlined regulatory processes for RNA technologies.
- Work with government and industry to understand, monitor and plan for supply chain resilience.

Implementation considerations and risks

- Fragmented stakeholder interests: Aligning the RNA sector may pose challenges due to differing interests and priorities among various entities.
- Financial sustainability: Securing long-term funding may be challenging in a competitive funding landscape.

Key actions:

Action 1.1

Design and coordinate approaches to funding to fundamental RNA science and applied science, that provide ongoing security to RNA researchers and reflects the Australian Government's commitment to the RNA ecosystem. This should include consideration of:

- Non-traditional funding sources
- Use of milestones /proof of concepts to 'unlock' additional funding
- Incentives for cross border partnerships on common challenges
- Targeted quality research towards existing research strengths in RNA, diagnostics, LNP and disease/regional advantages that align with RNA technologies.

Action 1.2

Develop a Strategic RNA Research Plan to ensure that funded research fills known knowledge gaps or further supports the development of RNA platforms (i.e., those that have value agnostic of therapeutic target). The Research Plan should also focus in on Australia's areas of comparative advantage such as agricultural uses to ensure a leading position globally.

Action 1.3

Develop a Monitoring and Evaluation Framework to ensure the Independent Entity can track its performance, identify areas of improvement, and make necessary adjustments to keep the RNA ecosystem on track toward becoming/maintaining a world leader in RNA research and applications.

Action 1.4

Develop or expand an existing mechanism for sector advocacy to the Commonwealth and state and territory governments that creates a unified voice to act in the best interests of the sector. This will help drive policy direction, coordination and attract public and private investments.

Action 1.5

Launch a public awareness campaign to educate the public about the potential of RNA technologies and their impact on healthcare, agriculture, and other industries to garner support for RNA research and development.

Action 1.6

Conduct periodic audits of Australia's RNA sector to map assets, supporting infrastructure and Australia's research pipeline to manage investments, duplication and capability. The audits should also involve market sounding to ensure that areas of investment remain relevant and aligned to Australia's areas of advantage.

Opportunity 2: Support the development and retention of skilled and growing RNA workforce

Urgency
Importance

Timeframe:
Now and ongoing

Workforce is the foundation from which the RNA ecosystem will be built. To remain contemporary and maximise technological advancements our approach to workforce needs to be broader than discovery researchers. We need to expand our capability to include the whole value chain and provide opportunities for our sector experts that fosters and establishes Australia as an attractive destination for international RNA specialists.

To develop the workforce the Australian Government should collaborate with industry and academia to:

- Promote Australia's world leading RNA ecosystem as a highly sought-after destination for companies establishing RNA technology advancements.
- Invest in specific skills across the supply chain, commercialisation and regulatory path, fill and finish, manufacturing and other ancillary service skills.

Implementation considerations and risks

- Unaddressed RNA workforce shortages may undermine investments made within the RNA sector.
- Current workforce may be attracted offshore through incentives or cross sector opportunities if an insufficient base is not maintained locally.
- Attractive opportunities need to exist across the RNA value chain to attract and retain a skilled workforce.

Key actions:

Action 2.1

Model the future workforce demand across the value chain including manufacturing, and supply chain requirements to ensure that an appropriately sized workforce is available.

Action 2.2

Foster collaboration between industry and academia through collaborative partnerships that facilitate the translation of RNA research in viable commercial products and services. This may be developed through:

- Encouragement of collaborative research and development efforts through funding models
- Internships technology transfer / knowledge exchange

Action 2.3

Promoting RNA Champions through established RNA researchers to highlight the viability of the industry within the tertiary education sector.

Action 2.4

Explore measures to attract international talent and position Australia as a top destination to build a promising career. This may be through updated visa requirements, financial incentives, and skilled migration programs.

Action 2.5

Develop programs and resources that support discovery researchers to understand the RNA commercialisation pathway to ensure Australian IP is protected early in the research phase.

Opportunity 3: Support/establish commercialisation pathways for RNA products

Urgency
Importance

Timeframe:
1 – 10 years

The existing path to market for advanced therapeutics, including RNA therapeutics, can be challenging to navigate for discovery researchers. This known challenge has seen investment from all levels of government however significant barriers remain. These impact Australia's ability to attract late-stage clinical trials through the Health Technology Assessment (HTA) pathway and IP/Patent navigation. Solving some of these challenges would support retention of product ownership throughout all clinical trial phases and facilitate a more robust commercialisation process where therapeutics discovered here are launched here.

It will be important for this nascent sector to allow fluidity and speed to ensure Australia doesn't get left behind and consider:

- Strategies to simplify and expedite IP protection processes, particularly across academia.
- Regular monitoring and evaluation of the impact of reduced IP barriers to track progress and ensure sustainability.

Implementation considerations and risks

- If IP processes are not simplified and expedited, Australia will risk remaining at a competitive disadvantage with new developments.
- Reducing barriers to IP protection and promotion of innovation may hinder collaboration and knowledge sharing without appropriate safeguards in place.
- Insufficient focus or adaptation of the HTA processes will not support efficient market access pathways for RNA technologies.
- Ensuring that research and early-stage development has a commercialisation partner.
- Addressing clinical need and assessing the market before applied research.

Key actions:

Action 3.1

Explore how the Commonwealth Government might support increased access to patents through a national approach to accessing specific IP related to key focus areas. This might involve establishing patent pools for specific technologies that allow multiple entities to access, and license patented technologies collectively that are considered key for Australian RNA research focus areas.

Action 3.2

Streamline the current Australian regulatory pathway to ensure expedited approval for Australian RNA therapeutics. This might involve equipping regulatory agencies with the skills necessary to understand and assess the unique characteristics of these therapies to facilitate their entry into the market. It should also build in a series of review cycles for the changes made in recognition of the pace with which the sector is moving.

Action 3.3

Develop a suite of tools and resources that supports RNA researchers to fast-track RNA products into clinical trials.

Opportunity 4: Leverage existing strengths in agricultural RNA products through to commercialisation

Timeframe:
6-12 months

Australia has a diverse agricultural, fisheries and forestry sector, producing a range of crop and livestock products for local and global consumption. RNA technologies can play a role in supporting these sectors through conferring pest and climate resistance, improving crop and livestock yield, improving livestock feeds and fertilisers, and introducing or combining novel traits to create novel products.

Australia has led the way in RNA-based research in the agriculture sector globally. Our researchers at CSIRO led the discovery of the naturally occurring pathway of RNA interference (RNAi) in plants and have since maintained a leadership position in RNAi research and its translation in plants, animals and humans.

Now is the time to leverage this expertise, and the growing acceptance of RNA-based products, to increase focus on commercialising our unique products in this space. This opportunity should be implemented and contingent of evidence of progress in Opportunity 3 to address commercialisation as a barrier.

Implementation considerations and risks

- Less regulatory stringency on production requirements (i.e., non- Good Manufacturing Practice [GMP]) and easier and more developed delivery pathways compared to human uses for RNA products make plant and animal applications more attractive and potentially a greater near-term target for commercialisation.
- Varied public perception and acceptance of RNA based technologies, particularly where fears of modified organisms may risk broader adoption and food production – particularly uncertainty around long-term effects.
- Changes in regulatory environment may limit sector growth.
- It is also necessary to factor in the economic challenges associated with treating individual animals versus addressing entire herds.

Key actions:

Action 4.1

Develop communication and education plan to address potential market concerns with RNA applications across agriculture sector. This should also highlight the use cases to the sector and promote the products as a solution to known challenges.

Action 4.2

Map priority areas and key stakeholders within agricultural RNA in Australia.

Action 4.3

Identify and prioritise key opportunity areas that can be targeted by RNA technology, with specific focus on domestic biosecurity risks, that may include lumpy skin disease, foot and mouth disease and other relevant conditions that are incursion threats in Australia.

Action 4.4

Explore opportunities to invest in specific RNA types that have potential within agricultural settings; this might include the use of double stranded RNA (DsRNA) and RNAi. Aligned to Opportunity 3, these investments should be supported with a streamlined regulatory pathway that assists with a quick path to market.

Action 4.5

Ensure that there is a dedicated focus on agriculture within the coordinating function (see Opportunity 1) to ensure that communication is prioritised across the sector, linking specialists, industry and funders more closely.

Action 4.6

Develop initiatives that drive opportunities for researchers within the agricultural sector and enhance links to domestic/international partners. This should potentially promote the transition of human focused researchers into agricultural research using similar platforms to support the RNA ecosystem.

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Opportunity 5: Prioritise RNA diagnostics investments and research

Timeframe:
6-12 months

RNA diagnostics have the potential to change the way medicine is delivered. The precision of RNA-based diagnostics makes them attractive across diverse areas of human health, including disease diagnosis, prognosis and therapeutic/treatment course selection. Current clinical applications include infectious diseases, cancer, rare-disease detection, transplant medicine and fetal monitoring.

The unique Australian environment and biosecurity risks coupled with RNA diagnostics research strengths (particularly in non-human applications) provides us with a great opportunity to continue leading the world in this niche.

As the push toward precision medicine continues the Commonwealth Government will:

- Leverage existing strengths in RNA diagnostics to develop end-to-end capabilities and establish market leadership position in key non-human applications.
- Incentivise the development of RNA diagnostic to help address specific national challenges.
- Catalyse private and public investment in RNA diagnostics for human and non-human applications.

Implementation considerations and risks

- Slow or delayed regulatory processes may hinder adoption of technology.
- Market size (for rare disease diagnostic trials) may be too small to be commercially attractive or viable.

Key actions:

Action 5.1
Develop collaborations between government and the established coordinating function with existing RNA diagnostic coordinator organisations such as SpliceACORD, aiming to promote greater communication and collaboration with strategic partners in industry, ultimately linking specialists, industry, and funders more closely.

Action 5.2
Support consolidation of expertise into appropriate clinical standards / guidelines to increase uptake of RNA-based diagnostic tests.

Action 5.3
Update funding guidelines and reimbursement approach across the public sector to improve access for RNA diagnostics to guide therapeutic options.

Action 5.4
Create a national framework/guideline to incorporate RNA diagnostics into an accredited pipeline of testing in standard clinical practice and pathology clinics.

Action 5.5
Promote the use of RNA diagnostics within the agriculture sector to allow the rapid detection and diagnosis of disease within crops

Opportunity 6: Prioritise research into RNA products (and its translation) to address priority diseases

Timeframe:
18-36 months

The Asia Pacific region has a growing population that has some consistent challenges where RNA products may have a role to play, including tropical diseases, infectious diseases and other rare diseases.

Australia has specific strengths in certain infectious disease areas such as malaria, dengue fever, influenza and other emerging diseases. This includes both regarding the causative infectious agents (e.g., viruses and parasites) and the vectors that carry and transmit them (e.g., often mosquitoes).

RNA products may have potential to disrupt multiple points across transmission chains of such infectious diseases from directly blocking virus replication, to forming RNA vaccines against the infectious agent or disrupting the reproduction/life cycle of vector hosts.

Australia has the opportunity to:

- Position itself as a regional leader to develop and commercial RNA products that can be of benefit to our population, but also those of neighbouring countries that may not have the capacity or capability to develop their own assets - assisting in addressing global inequities related to access.
- Improve protection for our population through addressing potential risks of incursions of existing and emerging infectious disease and biosafety threats.
- Leverage the growing and adjacent population for use in clinical trials to ensure population diversity and improve relevance of clinical trials.

Implementation Considerations and Risks

- Alternative therapies or poor efficacy of application of RNA in target diseases may lead to loss of market demand.
- Political instability and poor government relations in the region may threaten future partnerships.

Key actions:

Action 6.1

Incentivise R&D that focuses on RNA applications to treat infectious/tropical diseases. Specifically, this should target diseases with the highest cost to population and work towards treating vector-borne illness that have animal reservoirs and are associated with complex life cycles.

Action 6.2

Develop international partnerships between government, industry and research in the Asia Pacific region and other affected regions that supports the RNA sector to collaborate across borders and share IP/patents in a way that supports equity of access to developed products for communities.

Action 6.3

Identify and implement approaches that harmonize the regulatory standards for RNA therapeutics within the Asia Pacific region to streamline clinical trials, approvals, and commercialisation efforts. This might also include advocating across the region for a regulatory framework that ensures safety while promoting innovation and speed in therapeutic development.

Action 6.4

Establish a supportive environment for conducting multi-country clinical trials by streamlining ethics approval processes and providing resources for conducting rigorous trials.

Opportunity 7: Prioritise research into RNA delivery mechanisms (and its translation)

Urgency
Importance

Timeframe:
18-36 months

A key bottleneck to large-scale application of RNA products in clinical practice has been the development of effective delivery modalities. Naked (unpackaged) RNA is inherently unstable and without co-formulation with a packaging agent or other delivery mechanism it degrades readily and is poorly taken up by human cells.

This means that very high amounts of naked RNA are required to be introduced to have an effect which can lead to toxic or off-target effects.[32]

While several different modalities have been tested for RNA delivery into human cells, LNPs, as adopted in the Pfizer/BioNTech and Moderna COVID-19 vaccines, have come to the fore as highly effective in clinical use.

Australian researchers have successfully formulated LNPs for the manufacture of Australia's first homegrown COVID-19 vaccine candidate, that entered clinical trials in 2021.[33] Future developments and research could improve the targeting of LNPs, and their specific RNA cargo, to particular tissues or organs in the body or even specific cells.

Australia has the opportunity to:

- Support the research and commercialisation of novel LNPs and other mechanisms and modalities that support RNA delivery and targeting (such as exosomes, RNA modification, novel RNA coatings and vectors).

Implementation Considerations and Risks

- IP landscape is complex so clarity on freedom to operate is essential.
- Co-ordination required around investment in LNP and other foundational equipment.

Key actions:

Action 7.1
Incentivise R&D that focuses on novel RNA delivery applications and strengthens sovereign capability to manufacture RNA products for a range of applications.

Action 7.2
Undertake an assessment of IP landscape for LNP formulations and other RNA delivery modalities to provide a starting resource for Australian researchers to investigate and confirm freedom to operate.

Action 7.3
Ensure that there is a dedicated focus on RNA delivery mechanisms within the coordinating function or office (see Opportunity 1) to ensure that communication is prioritised across the sector between industry, government and academia.

[32] Singh, S., Narang, A. S., & Mahato, R. I. (2011). Subcellular fate and off-target effects of siRNA, shRNA, and miRNA. Pharmaceutical research, 28, 2996-3015.

[33] Pilkington, E. H., Suys, E. J., Trevaskis, N. L., Wheatley, A. K., Zukancic, D., Algarni, A., ... & Truong, N. P. (2021). From influenza to COVID-19: Lipid nanoparticle mRNA vaccines at the frontiers of infectious diseases. Acta biomaterialia, 131, 16-40.

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Appendix A: Stakeholder consultation summary

This Appendix summaries the key findings from the seven Stakeholder Consultations Workshops that were held across Australia with representatives from academia, industry, and government (see Appendix D for a breakdown of attendees). The Appendix is organised into three key sections:

- Australia's capability and ongoing challenges
- Australia's comparative advantage
- Opportunities for Australia to develop its RNA sector into a world leading ecosystem.

Australia's capability and ongoing challenges

Whilst the Australian RNA sector has the potential to become a key player in the global RNA market, several challenges were reported by stakeholders that may limit its success. These are discussed in detail below.

Lack of national coordination

Stakeholders reported that the small nature of the Australian market required strong national coordination to drive the Australian ecosystem, and ensure we are harnessing the most up to date innovation and investments. The absence of a national governance body or coordinating organisation in the Australian RNA ecosystem that provided oversight or coordination between jurisdictions and sectors (i.e., industry, academia, government) was reported to contribute to contribute to:

- A fragmented and inefficient approach to investment in RNA growth
- A high risk of duplication
- Competition rather than collaboration between stakeholders
- High levels of siloed state investment in RNA
- Lack of government communication with industry on the future priorities.

Additionally, industry and university research groups found that collaboration was hindered by their limited knowledge of who was doing what within the ecosystem. This was impacting their ability to pool resources and to commercialise discoveries. This meant that biopharmaceutical companies often coordinated the commercialisation of R&D, resulting in products being released overseas.

Fragmented commercialisation pathway

"It is difficult to get from research to market, we need an ecosystem to support that."

"Biggest failure in Australia is the translation of R&D to commercialisation."

Stakeholders reported that effectively translating RNA technology into commercial products poses a significant challenge in building a robust RNA ecosystem in Australia; this was acknowledged as a broader problem within the medical research sector impacting positive returns on investment. While Australia boasts strong capabilities and expertise in RNA R&D, the successful translation of scientific discoveries into practical applications remains limited to a handful of therapies. This failure hinders the progression of RNA-based therapies and technologies from the laboratory to the market, limiting their impact on healthcare and other sectors. The complexities involved in navigating the regulatory landscape, securing funding for clinical trials, and establishing strategic partnerships for commercialisation

contribute to the difficulty in translating RNA science. Overcoming these challenges requires a concerted effort to bridge the gap between scientific advancements and real-world implementation, fostering collaborations among academia, industry, government and regulatory bodies.

Manufacturing and scalability

Less established onshore manufacturing capability historically hindered Australia's ability to complete end-to-end development of RNA therapeutics at scale. The cost of raw materials required infrastructure and the establishment of RNA manufacturing capabilities was reported to have limited the RNA ecosystems development in Australia, particularly given Australia's small market size.

To facilitate further onshore production, there is a need for Contract Development and Manufacturing Organisation (CDMO) facilities that can eliminate some of the barriers to entry for small and medium-sized biopharmaceutical companies and start-ups. Australia currently heavily relies on international manufacturers for many intermediate and raw materials, such as RNA primers. However, efforts are being made to address these challenges through gradual investments in GMP-grade facilities and CDMOs with the capacity to manufacture RNA therapeutics and intermediates. Two such CDMO facilities are under construction, including the NSW GMP pilot manufacturing plant and Southern RNA in Ipswich, Queensland.[34,35] Stakeholders noted that for these CDMO organisations to be successful, the Australian RNA sector may need to be incentivised to support/purchase their products.

Nevertheless, despite this substantial financial commitment, the absence of a continuous and sustainable strategic research agenda aligned with Australia's medical research priorities has impeded the development of the ecosystem.

Funding

Australia has invested heavily in R&D across the medical research sector, including in RNA technology. However, despite the large financial investment, the lack of a continuous and sustainable strategic research agenda that is aligned with Australia's medical research priorities has impeded the development of the RNA ecosystem. This was reportedly true of RNA but also more broadly to the medical research sector. A scattered approach to funding affects not only research but also clinical trials commercialisation, and talent development/attraction. Without sufficient funding, researchers and institutions face obstacles in pursuing innovative projects, securing necessary equipment and resources, and attracting and retaining world-leading scientists and experts. It was reported, that at an industry level, there are gaps in capital investments which impact the ability to commercialise small-medium sized biopharmaceuticals, limiting their potential to reach the market and provide crucial medical solutions to patients. Greater and more focused investments are required instead of numerous smaller investments spread across different areas.

Workforce

Australia faces a significant challenge in its RNA workforce, characterised by a small number of highly skilled and specialised professionals. The current workforce exhibits a one-dimensional focus, with deep expertise in RNA and basic science research but lacking breadth across the value chain of the RNA ecosystem. Researchers often lack the necessary skills in areas such as commercialisation, IP, and broader industry aspects, highlighting the need for better coordination and collaboration. This presents an opportunity for the development of a strategic RNA research plan that guides

[34] NSW Government, RNA Pilot Manufacturing Facility, <https://www.chiefscientist.nsw.gov.au/funding/research-and-development/nsw-rna-r-and-d-and-manufacture/rna-pilot-manufacturing-facility>, accessed on 27 June 2023.
[35] SouthernRNA, Stage 2 – Good Manufacturing Practice mRNA Production, < https://southernrna.com.au/australian-manufacturing/stage-2-gmp-mrna-production/>, accessed 27 June 2023.

research efforts in this space, allowing for agreed-upon priorities and the establishment of foundational infrastructure.

Australia's comparative advantage

The Australian RNA sector possesses unique advantages that can be leveraged to build a robust ecosystem, enabling it to establish a prominent position in the global RNA market. Through stakeholder consultations and a literature scan, seven key comparative advantages were identified and categorised based on their relative importance and the emphasis placed on them during the consultations.

Deep expertise in research

Australia is widely perceived as a global leader in scientific discovery and academic research, particularly within the life sciences sector. It has the reputation for high quality and internationally regarded RNA research with approximately 3% of all scientific publications on RNA associated with Australian researchers.[36] Australia is perceived to have research/IP strengths and further opportunities in:

- Tropical disease
- Indigenous health
- Non-coding RNA specifically asRNA and siRNA
- Rare disease treatments
- Use of RNA in agricultural applications
- Personalised medicine (e.g., Nanoparticles and LNPs)
- Defence applications.

"We have a quality education and research system, built over many years."

"We are punching above our weight with research."

Stakeholders also highlighted the significant role played by leading networks of RNA research institutes (such as Monash RNA and the University of New South Wales RNA Institute) that have a history of collaboration, advancing the development of RNA therapeutic treatments within the country.[37,38] The interest of foreign biopharmaceutical investments and collaborations with Australian RNA researchers was also highlighted through partnerships with organisations such as Moderna and Sanofi.

Strong clinical trial capabilities

Stakeholders indicated that Australia is an attractive destination to conduct early-stage clinical trials when compared to other international jurisdictions. It boasts world-class infrastructure with state-of-the-art equipment for testing, treatment, and analysis across numerous domestic jurisdictions with patient recruitment supported by a highly multicultural society. Alongside the attractive R&D tax incentives for international pharmaceutical/biotechnology companies Australia also has a fast, pragmatic and robust regulatory pathway for clinical trials (e.g., ethical and scientific review process usually takes only four to eight weeks). This ensures the safety and efficacy of experimental treatments and provides confidence in the scientific conclusions reached by domestic clinical trials.

As all clinical trials involving unapproved medicines or medical devices conducted in Australia follow International Standards Organisation (ISO) good clinical practice (GCP) standards,[39] Australian clinical

[36] Australian Academy of Science (2022) RNA science report.
[37] Monash University (2023) Monash RNA, <https://www.monash.edu/mrna>, accessed 20 June 2023.
[38] Science & Technology Australia (2023) UNSW RNA Institute <https://scienceandtechnologyaustralia.org.au/profile/unsw-rna-institute/>, accessed 22 June 2023.
[39] Department of Health and Aged Care (2018) ICH Guideline for Good Clinical Practice, <https://www.tga.gov.au/resources/publication/publications/ich-guideline-good-clinical-practice>, accessed 22 June 2023.

data and results are accepted by international regulatory agencies including the US Food and Drug Administration and European Medicines Agency.

Global leader in agricultural RNA application

Australia currently possesses one of the few delivery mechanisms suitable for efficient and widespread implementation of RNA-based solutions across agricultural settings. This has translated to Australian researchers providing robust research outputs and valuable IP that will allow the Australian sector to become early adopters and a market leader of RNA technologies for agriculture. The current successes have used RNAi gene silencing to address domestic and international issues in biosecurity, crop protection, weed management and conservation.[40] As reduction targets for chemical usage are implemented, the use of RNA technology also offers a residue-free solution, which is highly sought after; this has the potential to tap into a vast market, providing cutting-edge advantages.

"There are huge opportunities in the agriculture space... in which Australia is a leader... there are only two companies globally doing it."

Agricultural RNA was also suggested by stakeholders to be more cost-effective and scalable compared to human RNA applications. This is partially due to lower factory footprints, less reliance on GMP quality materials and quicker pathways to market than human RNA. The easier access to market for non-human applications, coupled with Australia's expertise and scalable delivery platforms, solidifies its leadership position and competitive advantage in this area of RNA technology.

RNA diagnostics

Stakeholders emphasised Australia's strength in diagnostics as a significant asset. The technology will enable effective identification and monitoring of diseases at the molecular level. Clinicians are using RNA sequencing to offer a precise genetic diagnosis for rare diseases and inherited cancer predisposition. They are also using aptamer-based biosensors to provide targeted therapy in animals. Alongside its use in the sequencing of COVID-19 the diagnostic applications will support the push towards precision medicine and the adaptation of other diagnostics devices.[41]

Unique environmental demand for RNA technology

Australia has a unique environmental and biosecurity position, running one of the most comprehensive biosecurity systems in the world. However, the potential for outbreaks with potentially severe economic impacts and adverse effects on health, ecosystems, and food systems remains high.[42] RNA technologies have shown promise in responding to viral incursion and could be used to pre-emptively respond and assist in domestic biosecurity threats. This includes successful trials for RNA-based vaccines to prevent lumpy skin and foot and mouth disease.[43] RNA diagnostics also hold the potential to detect foreign pathogens, leading to the development of ~~a~~ robust and comprehensive biosecurity measures. Impending environmental and biosecurity demands combined with Australia's RNA research strengths presents lucrative investment opportunities to develop a further comparative advantage in this space.

[40] CSIRO (2023) Australian RNAi technology: silencing gene expression for plant, animal and human health science, <https://www.csiro.au/en/research/production/biotechnology/rnai>, accessed June 22 2023.
[41] CSIRO (2023), Biosensors and diagnostics, < https://www.csiro.au/en/research/health-medical/biomedical/biosensors_and_diagnostics>, accessed July 1 2023.
[42] CSIRO (2020), Australia's Biosecurity Future: unlocking the next decade of resilience (2020-2030), <https://www.csiro.au/en/research/natural-environment/biosecurity>, accessed July 19 2023
[43] Department of Agriculture, Fisheries and Forestry (2023) Lumpy skin disease, <https://www.agriculture.gov.au/biosecurity-trade/pests-diseases-weeds/animal/lumpy-skin-disease>, accessed on 26 June 2023.

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Geographic location

Australia's position in the Asia Pacific region gains greater significance as global dynamics evolve. Geographical shifts present an opportunity to develop Australia as the Asia Pacific leader in end-to-end RNA technology development. The geographical proximity to a region undergoing rapid population growth can serve to address market size and demand issues associated with commercialisation of RNA. Similarly, Australia can leverage the large population base in the region to pool populations for clinical trials, especially important in the context of developing rare and infectious diseases. Tropical climates in Australia and Asia Pacific can also provide a market that could be explored and justify investment in specific RNA therapeutics to address tropical and infectious diseases. With these factors in play, Australia's onshore demand for sovereign capability in RNA technology serves as a key driver of its competitive advantage in the region and beyond.

"We are within eight hours of two-thirds of the world's population."

Large pipeline of RNA therapies and advanced technologies

Australia is well positioned to harness existing medical research infrastructure, capabilities, and resources to build a strong pipeline of RNA innovations and technologies for commercialisation. The established advanced therapy and biotechnology sector including in gene therapies and regenerative medicine in Australia was identified as a key asset to support the development of pipeline RNA developments. Our expertise in these areas can complement RNA research capabilities with advancements in adjacent sectors generating benefits for RNA developments. The existing infrastructure in these adjacent sectors can be leveraged to develop shared manufacturing capabilities and provide opportunities for collaborations with other industry to leverage spill-over effects. In particular, this is expected across fill and finish, and CDMOs.

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Appendix B: Economic analysis

Economic analysis was undertaken to assess the potential commercial opportunity that the RNA sector presents for Australia over a 10-year horizon (through to 2033). This section summarises the economic modelling methodology and defines the parameters used to produce the estimates which have been presented in this National RNA Sector Development Plan.

CGE modelling

A shock to the economy in the form of a policy or program has reverberating impacts throughout the economy. These effects are often defined as 'second round impacts' where agents (households, firms and the government) respond to changes in prices that result from the shock. Ultimately these responses cause crowding out or spill overs into other regions and sectors as the economy adjusts to a new policy path. Estimating these impacts, through economic impact analysis, is critical to understating how a project or policy might affect the broader economy.

The CGE modelling is multi-region model with Australia, Asia Pacific region, and the rest of the world incorporated. The size of these regions and sectors are derived from the Global Trade Analysis Project (GTAP) database and are informed by data from the Australian Bureau of Statistics (ABS) and IBIS World. The model projects change in macroeconomic aggregates such as GDP and employment. Baseline economic growth includes forecasted GDP growth trajectory, labour supply and population based off macroeconomic forecasts. At the sectoral level, detailed results such as output, exports, imports by commodity and employment by industry are also produced. Scenarios are incorporated into the model by export driven and foreign demand shocks.

Why CGE?

CGE modelling estimates how a policy or program would impact the allocation and flows of scarce resources (natural resources, land, capital and labour) to industries, relying on accepted microeconomic theory. It differs from other tools of economic analysis such as Cost Benefit Analysis (CBA) or Input Output (IO) modelling. For instance, CBA evaluates the overall advantages of a project or policy to society by considering all the relevant costs and benefits. This method is suitable for analysing individual projects rather than industry and economy-wide impacts. While IO modelling quantifies the economic contribution of policy or program in a historical sense at a specific point in time.

CGE Methodology

Database aggregation

To conduct CGE model analysis, it is necessary to have a database that allows the sector of interest be 'shocked'. The data for this analysis is typically sourced from a GTAP database. However, the GTAP database does not explicitly include an RNA sector. As a result, estimations of the RNA industry must be compiled by aggregating data from related sectors within the database.

Based on desktop research and publicly available data, the pharmaceutical sector and the RNA sector were assumed to have the same user structure and similar cost structure. The pharmaceutical and RNA sectors are assumed to be in direct competition within the same market. These industries are organised in a manner where they act as substitutes for each other rather than complementary products. Using desktop research and available market data, the Australian RNA sector was approximated as 0.93% of the pharmaceutical industry and was split out from its parent sector.

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The estimations of the RNA industry were classified by typical ABS industry classifications and were used to link the RNA sector to the database.[44]

The relevant industries for consideration are as follows

- Class 1841: Human pharmaceutical and medicinal product manufacturing
- Class 1842: Veterinary pharmaceutical and medicinal product manufacturing.

Scientific research services (Class 6910) were excluded from the database for this analysis. The CGE model assumes that most of the future sector growth as determined by export demand will be on the commercialisation side.

Table 6: Linking GTAP sectors to Australian and New Zealand Standard Industrial Classification (ANSZIC) sectors

CGE Sector	GTAP Code	ANZSIC 4	ANZSIC 4 Description	ISIC Code	Description
Pharmaceutical manufacturing	bph	1841	Human Pharmaceutical and Medicinal Product Manufacturing	21	Manufacture of pharmaceuticals, medicinal chemical and botanical products
Pharmaceutical manufacturing	bph	1842	Veterinary Pharmaceutical and Medicinal Product Manufacturing	21	Manufacture of pharmaceuticals, medicinal chemical and botanical products

Source: GTAP and ANZSIC.

Scenarios

CGE models are the best-practice method available for examining the impacts of a change in one part of the economy on the broader economy. The economic impacts of the RNA sector are assessed by comparing one base case scenario and three distinct policy case scenarios.

Base case scenario

The base case is a scenario that describes the current *status quo* and is used as the basis for comparing various potential policy case scenarios. The base case involves simulating the future market growth trajectory and assumes no further investments will be made in the Australian RNA sector beyond those already committed as of June 2023. It also assumes that announced investments are fully operational by 2033 and capable of producing the COVID-19 mRNA vaccine alongside other RNA based vaccines. The base case has been informed by a bottom-up approximation of the RNA market in Australia, and includes,[45] but is not limited to a range of investments listed below:

- Australian and Victorian Government partnership with Moderna
- R&D Grant Programs across the Australian, Victorian and NSW Governments
- Monash University and Moderna Workforce Training Centre
- Establishment of a mRNA vaccine research hub by Queensland Government and Sanofi
- mRNA Victoria partnership with BioNTech to establish a mRNA clinical R&D centre in Victoria
- NSW Government RNA Research and Pilot Manufacturing Facility (NSW pilot facility)

[44] Australian Bureau of Statistics (2013), Australian and New Zealand Standard Industrial Classification (ANZSIC) <https://www.abs.gov.au/statistics/classifications/australian-and-new-zealand-standard-industrial-classification-anzsic/latest-release<, accessed June 27 2023

[45] The list of investments included in the Base case has been informed via publicly published data and is not assumed to be exhaustive.

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- NSW Government funded University of Technology Sydney (UTS) to establish a vaccine and RNA design centre
- BioCina and Cytiva are developing technologies for precision mRNA vaccines
- Syngenis's development of raw materials for Polymerase Chain Reaction (PCR)
- Southern RNA vaccine manufacturing and processing facility
- Australian Academy of Technology and Engineering's 'Global Science and Technology Diplomacy Fund'
- Cummings Global Centre for Pandemic Therapeutics (Doherty Institute).

The base case scenario is quantified by summing the total operating expenditure of RNA-related manufacturing facilities and any funding towards RNA-specific R&D. Capital expenditure is excluded from the CGE analysis and therefore not considered in the base case. Where it was not possible to disaggregate operating and capital costs from publicly available expenditure data, an approximate operating to capital cost ratio was derived from estimations in Kis et al (2022).[46]

Policy case scenarios

The economic analysis assesses future potential growth of the RNA sector over a 10-year horizon (to 2033). While relatively short, there is significant uncertainty around the possible pathways Australia's RNA industry may take in the near future. Key determining factors of RNA sector growth include the possibility of commercialising and translating RNA research and the efficacy and success of wide-ranging applications of therapies across health, agriculture, animal and diagnostic applications.

Reflecting the uncertainty with which Australia's RNA ecosystem might evolve, a range of policy scenarios have been developed. Three future pathways have been stylised ranging from a pessimistic to a more optimistic scenario and are described in Figure 1: Comparison of urgency and importance of opportunitiesFigure 1~~Figure 8~~. These scenarios cover a wide range of possibilities, and it is feasible to make inferences between any of these scenarios. Each illustrative pathway has been informed by publicly available market reports – global RNA market growth and an assumed Australian share of the global RNA market.

[46] Kis, Z., Tak, K., Ibrahim, D. et al. Pandemic-response adenoviral vector and RNA vaccine manufacturing. *npj Vaccines* 7, 29 (2022). https://doi.org/10.1038/s41541-022-00447-3

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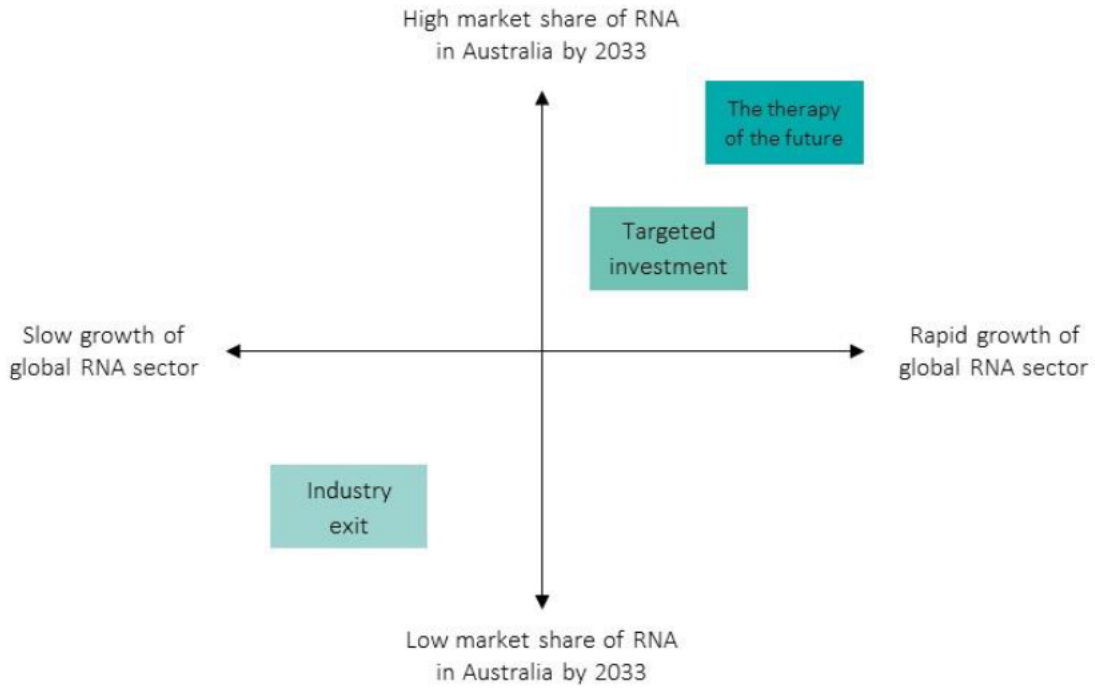
Figure 18: Comparison of urgency and importance of opportunities



Source: Deloitte

The therapy of the future (high case scenario)

The therapy of the future represents the high case scenario and the most optimistic growth in the RNA sector with substantial global and domestic demand potential. This scenario sees RNA science and technology emerging as a disruptive global industry, which experiences a high growth trajectory similar to the potential of monoclonal antibodies.[47] In the high scenario, Australia is a global leader in the development of RNA COVID-19 and non-COVID-19 vaccines throughout the Asia Pacific region. The potential of RNA is realised beyond vaccines to therapeutics (and includes all stages of the RNA pipeline from discovery science to patient access) and across sectors to include human health, animal health, agriculture and biosecurity.

Targeted investment (medium case scenario)

The targeted investment represents the medium case scenario and illustrates a growing potential of RNA vaccines and therapeutics globally paired with significant government investment in the development of the RNA product pipeline. In this scenario, RNA therapeutics may replace some alternate conventional therapies and be adopted across sectors including agriculture, biosecurity and animal health.

Industry exit (lower than base case scenario)

The industry exit represents a lower than base case scenario, which illustrates a situation where global RNA technology does not grow as predicted and there is minimal future government investment into growing Australia's RNA ecosystem. Australia's capabilities would be limited to what already exists currently such as the production of small-scale vaccines with continued significant reliance on offshore capabilities.

[47] Market Data Forecast (2021), Global monoclonal antibodies market, <https://www.marketdataforecast.com/market-reports/global-monoclonal-antibodies-market> acessed 12 June 2023.

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Policy scenario inputs

The main assumptions used to inform the policy scenarios are global RNA market growth and estimated market share of Australia in the RNA sector by 2033.

Current estimate and forecasted annual growth of the global RNA market

The global RNA vaccines and therapeutics market was estimated from a variety of publicly available market analysis papers. The estimated global RNA market is predicted to grow at rates that range between 1.7% to 13.0% per annum over the next 10 years. Although not explicitly called out in the papers, it is assumed that the market estimates include the adoption and potential of RNA technology outside of human health.[48]

Table 7 presents the scenarios of annual RNA global market value in 2033 used in defining the policy cases. At present, the sector is dominated by the developments and sales of the mRNA COVID-19 vaccine. Over the next 10 years, it is expected that non COVID-19 RNA vaccines which may include RSV and influenza will drive the RNA market growth.[49]

Table 7: Scenarios of annual RNA global market value

Policy case	Global Market Value by 2033 (Billion $AUD)	CAGR	Source
Lower than base case	$71	1.7%	Grandview Research (2023)[50]
Medium case	$169	7.4%	Midpoint of low and high case
High case	$267	13.0%	Precedence Research (2021)[51]

Sources: As indicated in the table.

Australian market share of global RNA sector

Alongside global market growth, the stylised policy scenarios consider the potential for Australia to capture various market shares. Point estimates of future Australian market share range from between 0.46% to 3.0% (at 2033) and were informed from a range of sources including the proportion of investments in Australia to global sector estimates from publicly available market data sources and similar industry proxy estimates (see Table 8).

Table 8: Scenarios of Australia's proportion of global RNA market captured by 2033

Policy case	Australia market share by 2033	Source
Lower than base case	0.5%	• Applying the proportion of current investments in Australia to global sector estimate from Grandview research (2023)[50~~35~~] • This estimate is also proxied from Australian share of monoclonal antibodies industry in Australia (from Grandview Research)[52] and globally (from Market Data Review)[53]

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[48] Based off stakeholder consultations

[49] Xie W, Chen B, Wong J. Evolution of the market for mRNA technology. Nat Rev Drug Discov. 2021 Oct;20(10):735-736. doi: 10.1038/d41573-021-00147-y. Erratum in: Nat Rev Drug Discov. 2021 Nov;20(11):880. PMID: 34475543.

[50] Grand View Research (2020), mRNA Therapeutics Market Size, <https://www.grandviewresearch.com/industry-analysis/mrna-therapeutics-market-report> accessed June 12 2023

[51] Precedence research (2023), mRNA Therapeutics Market Size, <https://www.precedenceresearch.com/mrna-therapeutics-market> accessed June 12 2023

[52] Grand View Research (2023), Australia and New Zealand research antibodies market <https://www.grandviewresearch.com/industry-analysis/australia-new-zealand-research-antibodies-market> accessed June 12 2023

[53] Market Data Forecast (2021), Global monoclonal antibodies market, <https://www.marketdataforecast.com/market-reports/global-monoclonal-antibodies-market> acessed June 12 2023

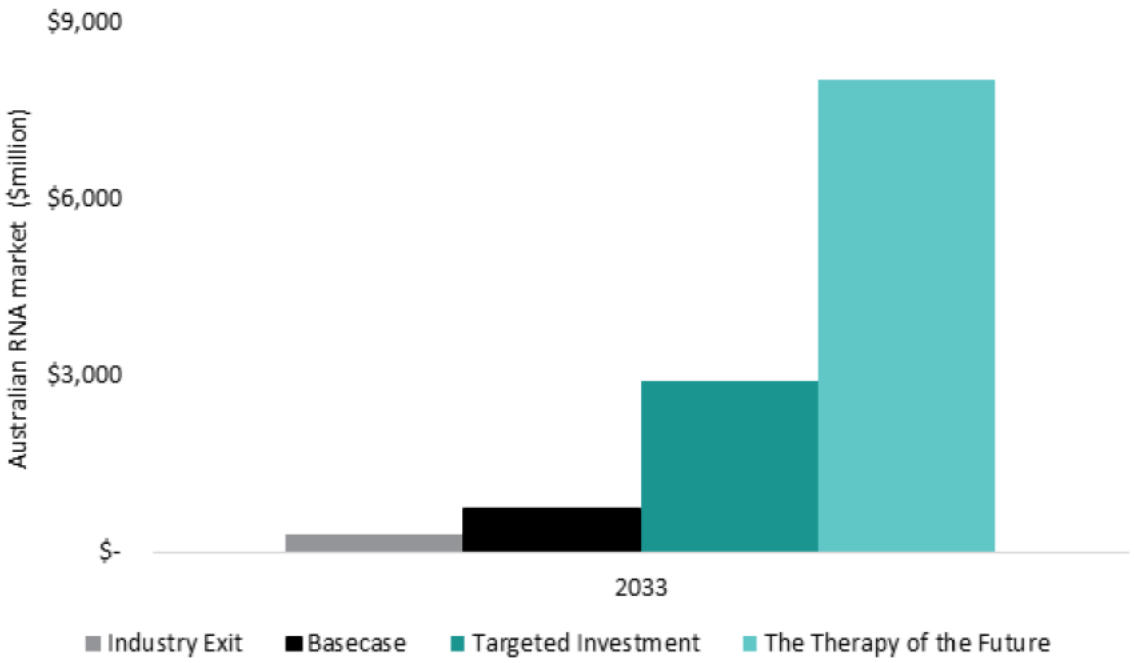
Policy case	Australia market share by 2033	Source
Medium case	1.7%	• This estimate is the midpoint of the low and high estimate.
High case	3%	• CSIRO (Australian share of pharmaceutical web science publications)[54]

Source: As indicated in the table.

Combined inputs for policy scenarios

Three scenarios based off combination of different market growth values and market share in Australia. A graphical representation of the forecasted Australian RNA market is presented in Figure 2~~Figure 9~~.

Figure 2~~9~~: Stylised RNA market size projections in 2033, Base case and illustrative policy scenarios



Source: Deloitte.

In addition to the uncertainty of the Australian industry at 2033, it is uncertain the speed and timing with which the market might expand (or contract). To illustrate this uncertainty the stylised policy scenarios are illustrated as following an S-curve. This pathway is regularly used to depict the natural evolution of a range of economic and non-economic pathways and have three general phases. First a startup or initial phase, which is characterised by significant learning and adaption but little apparent growth. The second phase is one of more rapid growth which is then followed by the final third phase where growth peaks and plateaus as maturity is achieved.

Limitations of the analysis

The following limitations should be considered in the interpretation of the economic analysis outputs:

[54] CSIRO Futures (2021) A National Synthetic Biology Roadmap: Identifying commercial and economic opportunities for Australia. CSIRO, Canberra

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- **Manufacturing shocks.** The analysis utilised manufacturing shocks, operating under the assumption that the RNA sector would lead to the development of commercialised technology and that there would be overseas export demand to drive its growth. It is assumed that the Moderna and NSW pilot facility will commence manufacturing in 2027.
- **Researcher shocks.** Due to the lack of data, no research shocks were included in the analysis. However, it is likely that a growth in the RNA sector will come with an influx of scientific researcher from other disciplines such as AI, biotechnology and biological sciences.
- **Healthcare productivity shocks.** Given the uncertainty and lack of data for future pathways and the health landscape, health productivity shocks are not modelled into the RNA landscape in CGE modelling. There is some evidence of health benefits of some RNA therapeutics over conventional therapies. This includes increased therapeutic potential in druggable targets, improved therapeutic efficacy of drugs, longer half-life and lower safety profile and side effects.[55,56] In turn, there is some potential health productivity gains from RNA therapeutics which could realise a number of benefits including returning to work sooner. Similar effects are expected to occur in non-human sectors, such as animal and agriculture, to the extent that RNA technology is adopted in these industries.

[55] Zogg H, Singh R, Ro S. Current Advances in RNA Therapeutics for Human Diseases. Int J Mol Sci. 2022 Mar 1;23(5):2736. doi: 10.3390/ijms23052736. PMID: 35269876; PMCID: PMC8911101.
[56] Pardi, N., Hogan, M., Porter, F. et al. mRNA vaccines — a new era in vaccinology. Nat Rev Drug Discov 17, 261–279 (2018). https://doi.org/10.1038/nrd.2017.243

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Appendix C: Stakeholder engagement

Table 9 provides a list of stakeholders who participated in the seven stakeholder workshops held across Australia.

Table 9: Stakeholder list

Stakeholder name	Organisation
s22	University of Queensland
	Virbac
	mRNA Victoria
	MTP Connect
	University of NSW
	CSIRO
	MTP Connect
	Acura Bio
	Pfizer
	University of WA
	Australian Academy of Technological Sciences and Engineering
	CSL
	New South Wales Health
	University of Sydney
	New South Wales Health
	Virbac
	National Biologics Facility
	Telethon Kids
	Dulux Group
	University of Adelaide
	Novacina
	St Vincent's Institute
	Acura Bio
	Animal Medicines Australia
	Monash University
	University of Queensland
	Virbac
	University of Adelaide
	Monash University
	SABRE
	University of Melbourne
	MTP Connect
	Woolcock Institute of Medical Research
	Investment NSW
	Investment NSW
	University of Technology Sydney
	Garvan

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Stakeholder name	Organisation
s22	MTP Connect
	Investment NSW
	CSIRO
	DMTC
	PYC Therapeutics
	University of Technology Sydney
	Department of Jobs, Tourism, Science and Innovation (WA)
	Noxopharm
	University of SA
	CSIRO Manufacturing
	Acura Bio
	University of Technology Sydney
	University of Adelaide
	Biocina
	Cell Therapies
	Monash University
	University of Melbourne
	NSW Department of Primary Industries
	Westmead Institute of Medical Research
	Monash University
	University of WA
	New South Wales Health
	Aus Biotech
	Peter Macallum Cancer Centre
	CSIRO
	New South Wales Health
	Research Australia
	University of Adelaide
	Pathology Technology
	Griffith University
	Virbac
	Australian Research Council Centre of Excellence for Nanoscale BioPhotonics
	SA Government
	University of Adelaide
	Hudson Institute
	mRNA Victoria
	Flinders Centre for Innovation in Cancer
	Investment NSW
	University of Melbourne
	Syngenis
	Engeneic
	NSW Health
	Australian Academy of Technological Sciences and Engineering

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Stakeholder name	Organisation
s22	Newcastle
	University of Queensland
	Office of the Chief Scientist
	Noxopharm
	CSIRO
	CSIRO Manufacturing
	University of Adelaide
	Australian Academy of Technological Sciences and Engineering
	Tiba Bio
	Critical Technologies
	CSIRO
	Zoetis
	mRNA Victoria
	mRNA Victoria
	Southern RNA
	Thermofisher
	CSIRO
	Moderna
	SA Government
	Children's Medical Research Institute
	Monash
	Cytiva
	Seqirus
	Murdoch University
	Therapeutic Innovation Australia
	MTP Connect
	Monash University
	Murdoch Children's Research Institute
	Australian National University
	University of Queensland
	MTP Connect
	University of Technology Sydney
	Monash
	University of Queensland
	University of WA
	CSIRO
	Griffith University