Australian Government

CTPCO
CRITICAL TECHNOLOGIES POLICY COORDINATION OFFICE

Synthetic Biology

Designing and constructing biological systems and devices that have useful functions not found in nature. Applications for synthetic biology include creating microorganisms that can clean-up environmental pollutants and recycle plastics, manufacturing animal-free meat and dairy products and biological computers.

Key Sectors

- Health
- Agriculture
- Construction
- Manufacturing
- Energy & Environment
- Defence & Defence Industry
- Mining & Resources
- Space
- Transport & Logistics

Estimated impact on national interest	Low	Med	High
Economic Prosperity			X
National Security		X	

Key Australian Government Actions

Initiatives

- CSIRO Synthetic Biology Roadmap
- CSIRO Synthetic Biology Future Science Platform
- National Collaborative Research Infrastructure Strategy
- ARC Centre of Excellence in Synthetic Biology
- Modern Manufacturing Strategy
- Low Emissions Technology Statement

Regulations

- Food Standards Australia New Zealand Act 1991
- Gene Technology Act 2000
- Convention on Biological Diversity 1992
- Sanitary and Phytosanitary Agreement 1995
- Cartagena Protocol on Biosafety 2000
- Biological and Toxin Weapons Convention 1975
- Defence and Strategic Goods List 2021

Example Outcomes

- Production of novel biological components and systems with new or optimised functionality, e.g. mRNA vaccines, and nitrogen fixing bacteria
- Improved healthcare outcomes from novel drugs, vaccine development and cell-based therapeutics
- Increased manufacturing of food ingredients and materials, including alternative protein and dairy products
- Reduced carbon emissions through new low emissions production processes
- Improved waste management and natural environment restoration
- Reduced biodiversity loss through the introduction of genetic diversity and genetic improvements to environmental hazards
- Access to growing regional market demand for food products, sustainable textiles, and increased capacity for aid provision
- Improved supply chain resilience to key electronic components, e.g. semiconductors

Opportunities and Risks

Synthetic biology offers a unique opportunity to address many global challenges: meeting the increasing demand for energy and food; mitigating the effects of environmental degradation; and enhancing human and veterinary health and well-being. Synthetic biology could be worth an estimated $700 billion globally by 2040, with the potential for $27 billion annual revenue and 44,000 new jobs for Australia. Increased capability in this area will enable Australia to build new, globally-competitive industries, and enhance existing industries.

As a result of various economic and national security incentives, several major economies are making large investments in synthetic biology capabilities. This includes the United States, the United Kingdom, China, Singapore and South Korea. For example, synthetic biology forms one of 22 strategically important science and technology initiatives in China's 2016 Five-Year Plan. Without focused and coordinated efforts both domestically and internationally, Australia will be unable to leverage its existing research strengths to grow its synthetic biology capabilities. The CSIRO Synthetic Roadmap recognises these opportunities and highlights how we can realise the potential from synthetic biology for Australia.

While synthetic biology will generate economic, social and environmental benefits, it could also be misused – for example, to produce biological weapons, or to alter the germline of animals and humans, or forensic manipulation (criminal perversion). Synthetic biology is reducing the level of technical proficiency required to undertake malevolent acts and is accelerating the emergence of new national security threats, such as biohacking and genetic piracy. Synthetic biology also raises fundamental ethical questions around the relationship between humans and nature, distributive justice, and synthetic biology's benefit or harm to humanity.

Australia is well poised to manage these risks, as its gene technology regulatory system is considered to be among the most effective and progressive in the world. With a proactive approach and a regulatory system that stays up-to-date with new genetic technologies, industry trends and international developments, Australia can have a thriving synthetic biology industry.

Underpinning Science

ANZ Standard Research Classification Category

- Genetics
- Plant biology
- Animal production
- Crop and pasture production
- Fisheries sciences
- Forestry sciences
- Horticultural production
- Agricultural biotechnology
- Environmental biotechnology
- Industrial biotechnology
- Bioinformatics and computational biology
- Medical biotechnology
- Veterinary sciences
- Statistics
- Data management and data science
- Machine learning
- Software engineering
- Applied computing
- Artificial intelligence
- Sociology
- Applied ethics
- Food sciences
- Chemical engineering
- Environmental engineering

Australia's place in the world

The United States has the highest research impact for synthetic biology, and six research institutes in the international top 10. Australia ranks 9th globally for research impact, led by the University of Queensland.

Venture capital (VC) investment globally has been increasing at around 31% p.a. since 2016, with a significant increase in 2020. The United States dominates VC investment, well ahead of the United Kingdom and France. Australia is unranked for VC investment.

While patent activity has been steady since 2016, China and the United States, with similar numbers, have nearly 10 times the number of patents as the remaining top 5 countries (Japan, United Kingdom and Germany). Australia ranks 13th internationally for patent numbers.

The value of synthetic biology to the Australian economy is highlighted in the CSIRO Synthetic Biology Roadmap, with possible synthetic biology-enabled solutions for some of Australia's greatest challenges in the health, biosecurity, environment and agriculture sectors. Return on investment in this area is being realised with numerous spin-out companies producing synthetic dairy products, alternative eggs, and sustainable textiles, as examples.

Example Applications

Readiness Level – Now

- Vaccines, in particular mRNA vaccines
- Biosensor-based diagnostic tools
- Cell-based therapies
- High value food ingredients
- Livestock and aquaculture feed
- Agricultural chemicals
- Biosensors for food safety, quality control and surveillance of conditions or contaminants.
- Waste bioremediation
- Invasive species control
- Engineered cells or enzymes (bio-printing cells, tissue, cartilage)

Readiness Level – 2–5 years

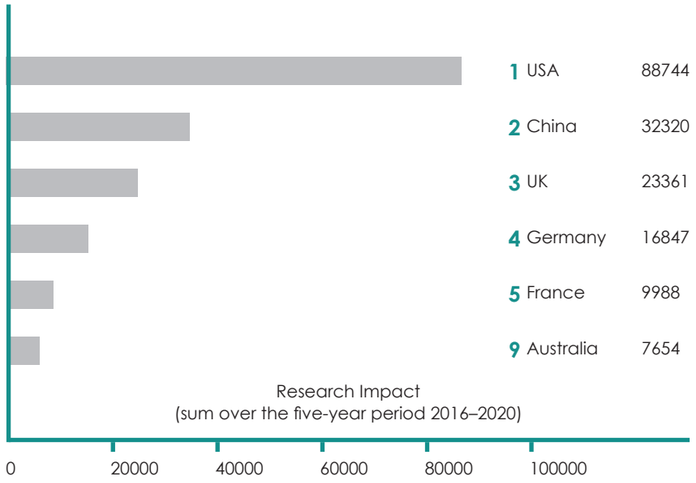
- Repairing of damaged or diseased organs
- Growing new of skin for burn victims
- Improved production methods for foods, animal feed stocks, textile production
- Synthetic probiotics for improved health
- Engineered bio products (coatings, fabrics, materials, sensors)

Readiness Level – Beyond 5 years

- Human augmentation via genetic modifications
- Countermeasures for chemical, biological, radiological and nuclear threats
- Fabrication of entire organs suitable for human transplant such as lung, heart or liver
- Food and medicine production in austere environments (space)
- Theranostic (i.e. combination diagnostic and therapeutic) cell lines for personalised therapies
- Smart materials
- Biological robots
- Longer-lasting and renewable batteries
- Lighter, stronger, tougher materials
- Stronger, more durable adhesives, anti-fouling, anti-corrosion coatings
- Novel dielectric materials for organic energy storage
- Microbial fuel cells for electrical power

Research Impact (RI)

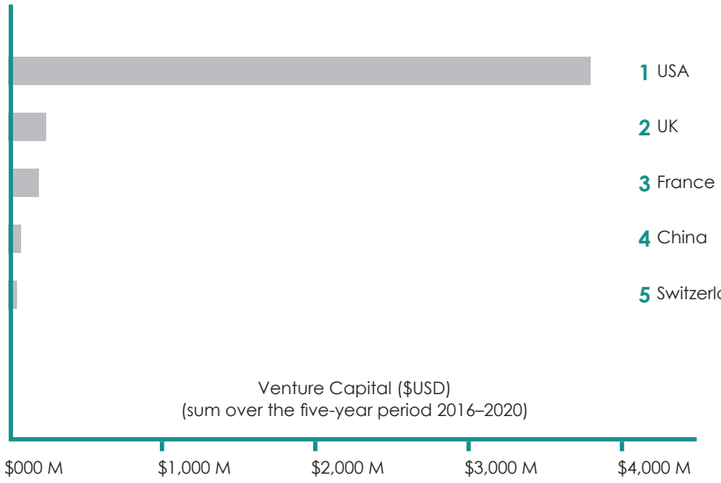
The United States has the highest research impact, with Australia ranked 9th. Total volume of published research has increased at around 3% p.a. over the 5 year period 2016–2020, with 21% of research involving international collaboration.



The research impact provides an indication of the productivity of a country or institution. Here, productivity was assumed to be represented by the volume of publications (i.e. scholarly output) as an indicator of the resources & facilities, and the level of interest in the publications as an indicator of quality.

VC Investment

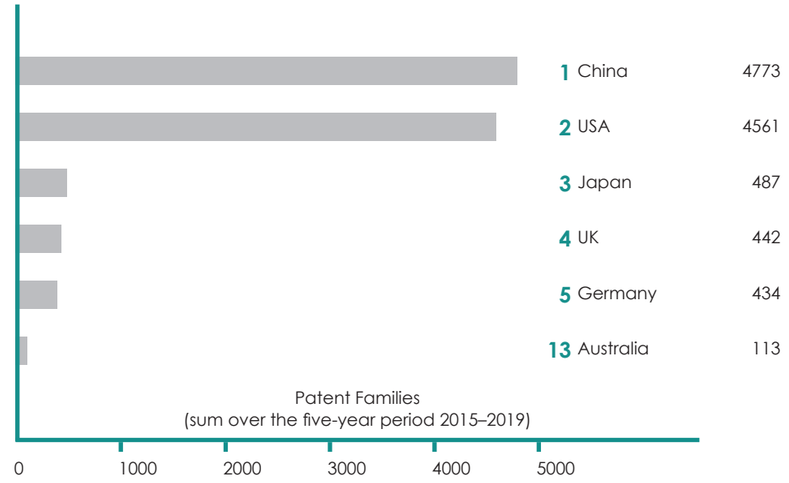
Venture capital (VC) investment is led by the United States, with significantly greater amounts of investment compared to the United Kingdom (2nd) and France (3rd). Australia is unranked for VC investment. Investment in synthetic biology has been growing at 31% p.a. since 2016.



Data from Crunchbase. The Crunchbase database provides a partial view of the global VC landscape. However the quantity, quality and richness of the data are considered to be statistically significant, and indicative of global trends.

Patents – International

The number of patents filed annually in this field has remained steady from 2015 to 2019. Most patents in this field were filed by applicants or inventors from China and the United States, with Australia ranked 13th.



Research Institutions – International

Consistent with their overall ranking for research impact, the United States has 6 institutes in the top 10 international institutes. China, France, the United Kingdom and Denmark make up the remaining institutes.

Rank	Top International Institution	Research Impact
1	Harvard University | United States	9363
2	Massachusetts Institute of Technology | United States	8837
3	Chinese Academy of Sciences | China	6132
4	CNRS | France	5645
5	Stanford University | United States	5591
6	United States Department of Energy | United States	4184
7	University of California at Berkeley | United States	3860
8	Howard Hughes Medical Institute | United States	3611
9	Imperial College London | United Kingdom	3480
10	Technical University of Denmark | Denmark	3166

Research Institutions – Australia

Within Australia, the University of Queensland has the highest research impact, followed by the University of Sydney and the University of Melbourne. No Australian university is ranked in the top 50 international institutes.

Rank	Top Australian Institution	Research Impact
1	University of Queensland	1219
2	University of Sydney	1038
3	University of Melbourne	940
4	University of New South Wales	850
5	Monash University	746
6	University of Western Australia	652
7	CSIRO	638
8	Australian National University	618
9	Macquarie University	585
10	University of Adelaide	541

Patents – Australia

Top 5 Australian Patent Applicants	Patent Families
Queensland Institute of Medical Research	7
Benitec Biopharma	5
Calimmune Australia	4
CSIRO	4
CSL Gene Therapy	4

Patents filed by Australian businesses, 2015–2019.