Biotechnology West:

Strengths, Weaknesses

and Opportunities

December 2000

About TIAC…

In 1987, the State Government determined that it required an independent advisory body to assist it in formulating policy directions for the State's economic development.

This decision was put in to effect by way of a specific Act of Parliament in that year.

Since then, TIAC has played an important role in stimulating thought and action toward a strong economy in Western Australia. TIAC has been a key agent of change, providing Government with robust research and reports which have led to tangible outcomes. Council's "Awareness Raising Activities" such as its 2020 Breakfast Seminar program and Science and Technology Regional Forums program have sought to ensure that the community is kept informed and given opportunities to participate in the formulation of its advice to Government.

For TIAC, the imperative is not only to map these changes, but also to anticipate what lies ahead and provide informed advice to Government, to ensure that Western Australia is ready to be competitive in today's business and technological environment. Over the last five years, TIAC's advice was provided in reports entitled:

Export of Western Australian Education & Training: Constraints & Opportunities	*10/00*
Drivers and Shapers of Economic Development in Western Australia in the 21st Century	*09/00*
Technology, Skills and the Changing Nature of Work	*04/00*
Western Australia's Minerals and Energy Expertise: How can it be optimised? – Growing the R&D Sector	*06/99*
From Mines to Minds: Western Australia in the Global Information Economy	*02/99*
Research & Development: Role of the State Government in Attracting External Funding	*05/98*
Western Australia's Minerals and Energy Expertise: How can it be optimised? – Defining the Issues – A Background Paper	*09/97*
Telecommunications Deregulation – Is Western Australia Prepared?	*12/96*
Financing Options for Regional Infrastructure in Western Australia	*11/96*
Towards an Information Infrastructure Policy for Western Australia – the Business Aspect	*02/96*
Medical Research Infrastructure Funding in Western Australia	*04/95*

The range and diversity of TIAC's advice reflects a broad base of expertise resident within TIAC's membership. Appointed by Cabinet, Council is representative of the State's economic sectors of science, engineering, resources, education and training, management, economics, academia, business and marketing.

(Further details on TIAC are available in Appendix H or at www.wa.gov.au/tiac.)

WESTERN AUSTRALIAN
TECHNOLOGY & INDUSTRY ADVISORY COUNCIL

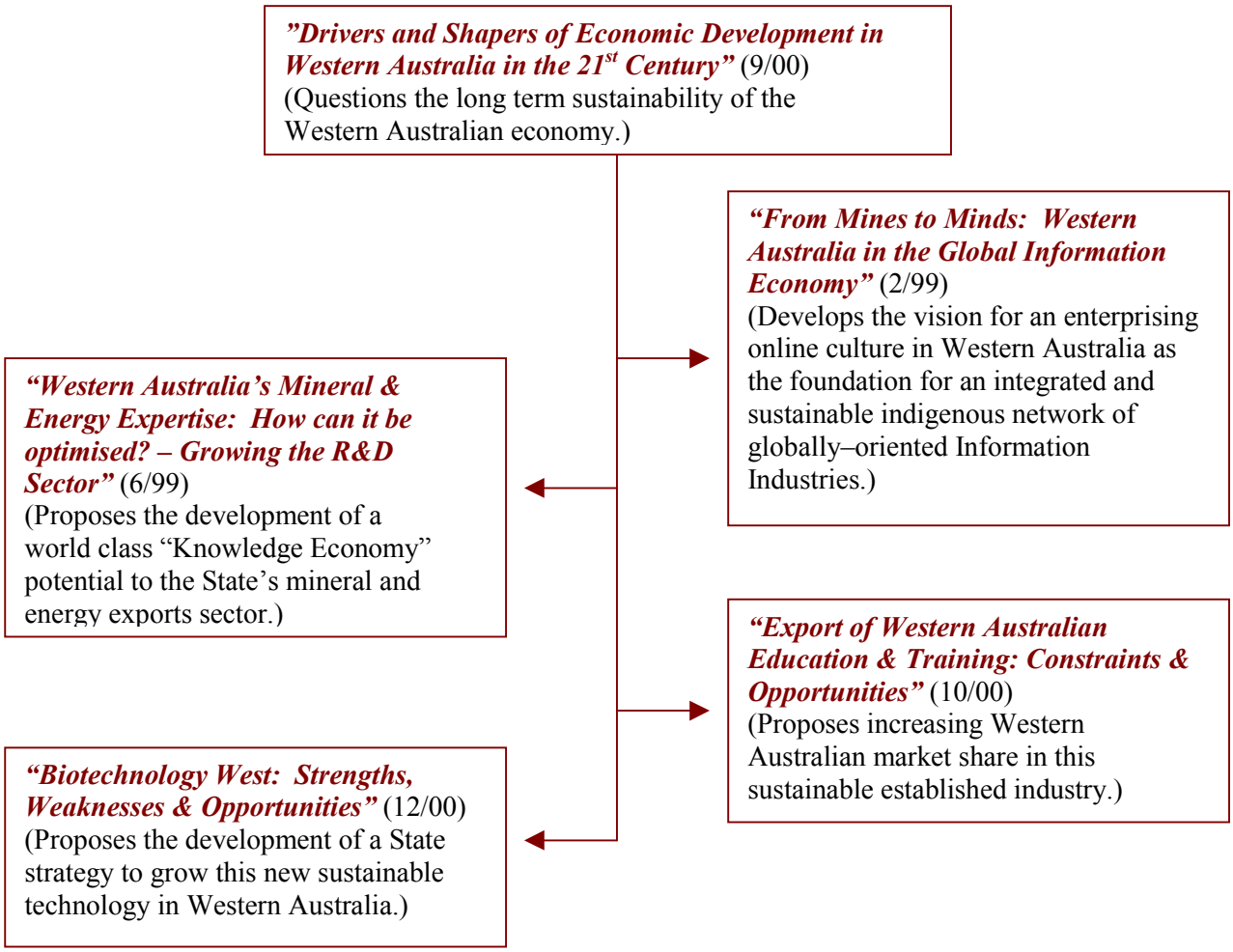
Biotechnology West:
Strengths, Weaknesses and Opportunities

December 2000

Additional copies of this report can be obtained from our website – www.wa.gov.au/tiac

Towards a Western Australian Knowledge Economy

TIAC's report, "Biotechnology West: Strength, Weaknesses and Opportunities", completes Council's 1999-2000 reporting program under the theme, "Towards a Western Australian Knowledge Economy". The relationships between these reports are shown below:



Copies of these reports can be obtained from our website – www.wa.gov.au/tiac.

Foreword

Over the past century, Western Australia's industries of mining and agriculture have achieved world class efficiency and revenues, through investment, innovation and the wise utilisation of the resources of this State.

In the 21st Century, these and other industries are being transformed by the two new enabling technologies, biotechnology and information technology. Biotechnology is transforming agriculture, with better nutritional quality of crops, and reduced use of pesticide and fertiliser; mining, with extraction processes which are reducing damage to the environment; medicine, with new drugs and treatments, and it is showing potential for solving the environmental problems we face in the 21st Century such as salinity, the degradation of land and greenhouse gas emission.

Other states in Australia, and countries such as Singapore, USA, and Ireland have pro-actively embraced biotechnology both as a major transformer of their "old economy" industries and a creator of new industries and products.

Western Australia is now at the point of choosing whether to commit itself to reaping the economic benefits of biotechnology by adding maximum value to its established industries and establishing new industries based on world class biotechnology research, **or** taking no initiatives and as a result, continuing to be an "old economy" supplier of raw materials to the world.

It is "decision time" for our State's future and TIAC has produced this report, for the community's consideration, which:

- Provides an inventory of resources available in this State, for biotechnology researchers and companies;
- Puts Western Australia's biotechnology activity in the context of that of other states and internationally;
- Considers existing and potential applications of biotechnology to build this State's economy;
- Identifies factors which have led to successes in biotechnology companies and research institutions around the world;
- Identifies constraints which are holding back success in biotechnology in Western Australia;
- From these findings, recommends ways of building a world class, biotechnology based industry in Western Australia.

I would like to thank the small but enthusiastic community of biotechnology researchers and companies in Western Australia, whose vision of the future benefits to the State has inspired us.

I would like to thank the members of the TIAC Steering Committee, consultants Dr Lyndal Thorburn and Dr Kelvin Hopper and their staff for the research, and Professors Ian Constable, Fiona Stanley and Val Alder for their helpful comments.

Dr Lesley Borowitzka
Chair, Steering Committee

Executive Summary

Biotechnology and Information Technology are the two major new enabling technologies of the new century. They are adding new value to established economy industries, and are creating businesses and whole industries which could not have been imagined 20 years ago.

Biotechnology is defined as the use of living organisms or parts of organisms to create products and processes. It has created insulin and human growth hormone for the medical and health industry, insect resistant cotton and slow ripening tomatoes, improved rennet and food additives in the agriculture and food sector, provided bacteria tailored to breakdown specific environmental pollutants and to reduce sulphide ores to their oxides in the mining industry.

It is the type of technology that, in TIAC's opinion, can be utilised to assist in addressing some of the issues raised in Council's previous report, "Drivers and Shapers of Economic Development in Western Australian in the 21st Century".

In the past year, public awareness and commercial interest in biotechnology has accelerated. The completion of the project to sequence the human genome was announced jointly by USA President Clinton and British Prime Minister, Tony Blair. The USA announced an unprecedented investment in biotechnology research, and Queensland and Victoria announced biotechnology initiatives of A$270 million and A$400 million respectively. In October 2000, CSIRO plant biotechnologists, Dr Jim Peacock and Dr Liz Dennis, won the inaugural Prime Minister's Science Prize.

This report identifies the present state of biotechnology-related research and industry in Western Australia, and recommends specific and cost effective ways to assist building it to a world class industry. To achieve this we must focus on what Western Australia is good at, and add further key infrastructure as needed, to develop significant new industry in the State.

Western Australia led Australia in establishing a State Science and Technology Policy, but it has no stated whole of government policy or strategy for biotechnology. For our aspirations to succeed, we urgently need support from across Government, in the form of a strong strategy and political leadership to lead and inspire our companies, researchers, and financiers.

This study confirmed that Western Australia has excellent foundations in quality research and infrastructure to support the structure of a world class biotechnology industry, and that it has a relatively high number of very independent, but generally isolated entrepreneurial small biotechnology companies who are "doing it tough".

Western Australia has world class research in agricultural biotechnology at the State Agricultural Biotechnology Centre. It also has world class research in biomedical biotechnology at the Lions Eye Institute, the Institute for Child Health Research, the Western Australian Institute for Medical Research and the Western Australian Biomedical Research Institute. However, compared with the Australian average, it has a relatively low rate of patenting discoveries, commercialising research from universities and institutes and in forming spin-off companies. Clustering of new companies in incubators around research institutions, a process which has succeeded in supporting and nurturing spin-offs in the USA, Europe and Queensland and Victoria, has not happened in Western Australia.

Unlike Queensland, NSW, Victoria and South Australia, Western Australia has no large biotechnology based companies, to provide employment, training, and experience for our otherwise well trained and educated students, or support for local suppliers and contractors. The attraction of the headquarters, production facility or an R&D centre of a major biotechnology company would add significant infrastructure to the sector.

The number of researchers, facilities and infrastructure are not limiting our present low level of biotechnology activity, but will become a major limitation as we start to grow the industry. Case studies show that the most cost-effective way of building strong research teams is to attract a world-leading researcher, with a chair, probably endowed for 5 years.

Excellent researchers, supported with the necessary infrastructure, attract good students, further excellent researchers and research grants which produce Intellectual Property, spin-off companies and revenues to the State.

Recently, the previously poor availability of seed and venture capital in Western Australia has been improving, but must be monitored carefully, to make sure that it does not impede the growth in new biotechnology companies.

Western Australia's biotechnology based industry is small but entrepreneurial, with some world class researchers and excellent teaching. In interviews and discussion groups it was made clear to us that these people are very keen to grow the industry fast, want to be part of a major success story in Western Australia, but are frustrated by their perception that we are being left behind by other states in Australia, as well as by the USA, Singapore, Ireland, India, Israel and others.

Starting with commitment and leadership from the State Government to in turn activate the support and enthusiasm of our businesses, researchers and financiers, the State can quickly build new businesses in biomedical products and treatments, add significant value to the existing agricultural and mining industries and in waste treatment. Furthermore, we can also creatively address the burden of greenhouse gas emissions.

Western Australia can position itself to add increasing value to its strong established industries of Mining and Agriculture as well as be able to use the tool of biotechnology in new enterprises and industries which have not as yet been defined.

Recommendations

Recommendation 1

In recognition of the enabling aspect of biotechnology when applied across all industry sectors, it is recommended that a Biotechnology Strategy be developed through the Department of Commerce and Trade and the Co-ordinating Committee of Science and Technology and incorporated into the State's Science and Technology Policy.

This strategy should contain programs which:

(a) Actively promote biotechnology enabled industry in Western Australia;

(b) Build a strong R&D base for biotechnology in Western Australia;

(c) Support properly controlled trials of biotechnology based processes and products in Western Australia;

(d) Support the development of business plans for the application of biotechnology across all sectors of industry including:

(i) health and medicine,
(ii) agriculture,
(iii) mining and mineral processing,
(iv) environment and waste management, and
(v) marine industry.

Recommendation 2

The Strategy should establish separate biotechnology funding to be used to implement the programs and business plans contained in the State's Biotechnology Strategy.

Recommendation 3

It is recommended that the Biotechnology Strategy contains programs which:

(a) Strengthen and encourage the commercialisation of biotechnology based research in universities, government agencies and other institutions – this includes clarifying institutional policies on sharing royalties between researchers, research entities and students;

(b) Facilitate seminars through ABA, AIM and AICD to raise the awareness of researchers in:

(i) funding start-ups,
(ii) duties and responsibilities of directors,
(iii) the availability and source of grants and other government assistance available for industrial research;

(c) Facilitate the clustering of newly formed companies either through an incubator program or through facilities around research institutions such as SABC at Murdoch University or Sir Charles Gairdner/UWA for a biomedical facility.

Recommendation 4

The successful application of biotechnology as both an enabler and problem solver across industry and as a development tool for new industries, is assisted by the fostering of linkages and networks. It is recommended that the proposed State Biotechnology Strategy contain programs which will:

(a) Support the Western Australian branch of the ABA so as to facilitate inter and intra State events which raise awareness of issues relating to biotechnology based industries;

(b) Support through the overseas offices of the Department of Commerce and Trade and Austrade, international linkages with biotechnology based institutions in the USA, Singapore, Ireland, India and Israel;

(c) Use the State's very successful Centres of Excellence program;

(d) Leverage and add value to Commonwealth funding that eventuates through Biotechnology Australia and discussions on the Biotechnology Innovation Fund.

Recommendation 5

It is recommended that the proposed State Biotechnology Strategy contain a program which funds key international researchers in biotechnology by providing:

(a) Endowed chairs for five years;

(b) Funding for post-doctoral researchers;

(c) Attractive support and facilities, and scholarships for students to build the research groups.

The main criterion for choice of key researcher should be excellence, then, defining a particular field of expertise. The business plans in the proposed Biotechnology Strategy for each sector will help define areas of expertise that will contribute most to the State. Case studies indicate that these key researchers will in turn attract funding, equipment, facilities and other good researchers and students.

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Common Acronyms

AgWA	Agriculture Western Australia
AIMS	Australian Institute of Marine Science
ANGIS	Australian National Genome Information Service
CALM	Conservation and Land Management
CBCD	Centre for Biomolecular Control of Disease
CCST	Co-ordination Committee on Science and Technology
CLIMA	Centre for Legumes in Mediterranean Agriculture
DCT	Department of Commerce and Trade
DEP	Department of Environmental Protection
GMO	Genetically Modified Organism
ICHR	TVW Telethon Institute for Child Health Research
IIF	Innovation Investment Fund
LEI	Lions Eye Institute
MHRIF	Medical and Health Research Infrastructure Fund
NH&MRC	National Health and Medical Research Council
SABC	State Agricultural Biotechnology Centre
UWA	University of Western Australia
WABC	Western Australian Bioinformatics Consortium
WABRI	Western Australian Biomedical Research Institute
WAIMR	Western Australian Institute for Medical Research
WAISS	Western Australian Innovation Support Scheme
WACM	Western Australian Centre for Microscopy
WAHRI	Western Australian Herbicide Resistance Institute

1 Introduction

This study was commissioned by the Technology and Industry Advisory Council (TIAC). TIAC's role is to advise the Minister of Commerce and Trade; Regional Development; and Small Business on the encouragement, and promotion, development and growth of technology, industry, science, research and trade in Western Australia.

Biotechnology is expanding rapidly and has been the focus of specific Government policy attention in several states of Australia and at the national level. TIAC believes that biotechnology can enhance efficiency, improve competitive advantage and create new jobs in Western Australia. The report was commissioned to assess the opportunities for biotechnology to add value to Western Australia's economy.

1.1 Terms of Reference

The study aimed to:

- Provide an inventory of the resources available in biotechnology-based companies and the institutional biotechnology research capacities in Western Australia;
- Place the Western Australian activity in biotechnology in a national perspective with specific reference to the implications and opportunities to Western Australia of:

  (i) the Queensland biotechnology funding initiative;
  (ii) the Federal Government's establishment of Biotechnology Australia; and
  (iii) the establishment of the (Interim) Office of The Gene Technology Regulator.

- Identify existing and potential applications of biotechnology, which build on the already strong industries of Western Australia, in order to use them as a basis for developing appropriate and strong biotechnology-enabled industry;
- Place the Western Australian and Australian activity broadly in an international context;
- Determine success factors in research institutions, biotechnology companies and of public policy for developing greater biotechnology capacity in Western Australia;
- Identify constraints on the industry in Western Australia such as the need and access to critical infrastructure; access to venture capital; access to process IP held by multinationals; difficulties in finding suitable partners and alliances; overall economic outlook for Western Australian-based biotechnology; availability of markets; and international regulatory frameworks;
- Provide recommendations for public policy and public and private investment that would increase the level of biotechnology-based industry in Western Australia.

This report is structured along the same lines as the Terms of Reference. The next chapter introduces biotechnology as a technique, while Chapters 3, 4 and 5 provide the inventory of research resources, commercial biotechnology and Government programs in a national context. Chapter 6 outlines success factors internationally and Chapter 7 identifies opportunities and constraints in Western Australia. Our recommendations for a way forward are given in Chapter 8.

1.2 Methodology and Timing

The study commenced in January 2000. Data were collected in six stages in order to maximise input from the R&D and industry community.

Stage 1: Identification of relevant industry and research organisations. Sources used, included company databases held by the consultants, the Biotechnology Industry CD produced jointly by the Department of Industry Science and Resources and the Australian Biotechnology Association in 1999, and input from the TIAC Steering Committee. Major biotechnology firms are listed in Appendix B.

Stage 2: Desk research on biotechnology in Western Australia. The consultants obtained written reports, journal articles, brochures and web-based information in order to research the role and growth of biotechnology-based activities internationally, nationally and at the State level. Data sources included, for example:

- Australian Bureau of Statistics surveys;
- Data on successful grants, and reports available from the relevant Federal departments;
- State and Federal Government statements and reports;
- TIAC reports;
- Department of Commerce and Trade and Department of Resource Development web pages and contact with staff (e.g. for data on WAISS grants);
- Western Australian-based industry associations and their national offices.

Stage 3: Written survey which was emailed or faxed in late January 2000 to approximately 150 individuals nominated from Stage 1 and who were known to be involved in biotechnology-related research, industry and service provision. In all, 39 responses were received to the survey instrument (a response rate of 26%). Of the total 39 responses to the questionnaire, 16 were from industry, 17 from research, 4 from representatives of Government agencies and two from other (consumer representatives and a non-government MP).

Stage 4: Face-to-face interviews with key individuals in Perth in February 2000. These interviews covered the material in the survey but also sought input on other issues including the relationships between major groups in Western Australia. Twenty four individuals were interviewed face-to-face and the results of the interview were used to supplement the written responses to the survey.

Stage 5: Focus groups, held in the second week in March 2000 over three days with a total of 18 people. The first focus group was on Agriculture and Food Biotechnology, the second on Environmental and Waste Biotechnology and the third on Therapeutics and Diagnostics Biotechnology. The fourth focus group discussed the outcomes of the other three meetings and was designed to discuss the broader issue of biotechnology in the Western Australia economy.

Stage 6: Industry and research information, gathered directly from firms and research institutions in Western Australia. Advance Consulting & Evaluation's proprietary database of Australian biotechnology firms was also used at this stage to analyse Western Australia's biotechnology firms in the wider Australian context.

A total of 117 people and organisations (78 research/Government, 39 industry) were consulted for the study. A full list of those consulted is given in Appendix G.

2 Biotechnology-Based Industries and Their Importance

2.1 What is Biotechnology?

Biotechnology is a method of using living organisms or parts of organisms to create products and processes. Living organisms can be manipulated, in some cases by genetic engineering, to make them useful in industrial, agricultural or clinical applications. The definition of biotechnology-related applications used in this report embraces these techniques but excludes traditional farming, fisheries and aquaculture. Clearly, biotechnology is rapidly expanding and sophisticated biological research techniques and the outcomes of this use are applied to traditional sectors of the economy. In order to be inclusive we will take a broad definition but will define those limits where necessary.

2.2 Role of Biotechnology in Key Sectors

Biotechnology methods are applicable to a wide and increasing range of industries and are used to improve productivity and create new products in agriculture, medicine, mining, manufacturing and the environment. Because of the advances being made in biological research it is expected that biotechnology will have far reaching consequences to the economy, to our society and the environment stretching well into the future.

For example, DNA probes are used to identify whether patients have inherited genetic diseases such as cystic fibrosis, thalassaemia, muscular dystrophy and Huntington's chorea. DNA fingerprinting can also be used to determine whether a tissue sample (e.g. blood, hair) from a crime scene has come from a particular individual.

Genetic engineering has been used to transfer useful genes from plants and animals to bacteria where they can be grown in large quantities. It is particularly important in production of biotechnology-based therapeutics for treatment of human and animal diseases, e.g. insulin, used for treating diabetes.

Genetically engineered bacteria may also manufacture enzymes used in the food industry for development of texture and appearance, and to create flavours and aromas. They are also used in industrial processing to alter the temperature at which reactions occur and to reduce waste products. Such bacteria may also help to treat industrial wastes (e.g. sewage, contaminated soil and waste chemicals). Some bacteria can oxidise mineral sulfides and are used in the mining industry to extract gold and copper from ores.

Genetic engineering also enables desirable genes from plants and animals to be inserted into other organisms so that they can be expressed as desirable attributes in the organism. The Australian Government, in line with other governments worldwide, is in the process of establishing a nationally consistent regulatory framework which controls how firms and scientists develop and release genetically modified organisms into the environment.

Genetic engineering can be applied in a number of ways to improve productivity in agriculture. INGARD® cotton, for example, has been genetically engineered to produce a pesticide in its leaves so that leaf-eating insects die when they attack the plant, thus leading to a reduction in the amount of chemical pesticide sprayed on the cotton during its growing season. Wild types of some plant species have similar insecticides but these traits have been bred out through centuries of breeding. New traits can also be introduced into animals to improve livestock, e.g. transgenic sheep may grow better wool without requiring dietary supplements, and animals may be used in the production of human therapeutic proteins. In

forestry and horticulture, tissue culture is used to produce large amounts of plants of the same genetic makeup. Cell lines of micro-algae can also be used to produce food ingredients such as polysaccharides for use in food processing and high value fine chemicals e.g. beta-carotene and docosahexanoic acid.

In medicine, biotechnology is a fundamental tool. For example, cultures of skin cells are also used to grow skin for grafting on to burns, and researchers are trying to develop techniques to use cell lines from bone marrow to grow bone that can be used to replace bone lost as a result of accident or disease. The complete sequencing of the human genome also provides a powerful tool for disease diagnosis and for the development of new drugs and treatments.

Table 2.1 summarises the present application of these techniques to various industry sectors.

Table 2.1 Examples of the Intersection of Biotechnology Techniques and Potential Market Applications

Industry Sector	Technique			
	DNA Probes	**Monoclonal Antibodies**	**Genetic Engineering or Selection of Naturally Occurring Organisms**	**Tissue Culture**
Plant Agriculture	Detection of genetically modified food, detection of pathogens.	Detection of diseases.	Development of functional foods with dietary or health benefits, biofertilisers involving nitrogen-fixing bacteria; biopesticides in crops.	Use of plants as factories to produce antibodies; development of breeding lines.
Livestock Production	Parentage of stud animals. Detection of viral strains in disease.	Detection of disease e.g. bovine Johne's disease.	Enzymes to improve digestibility of feeds or reduce methane emissions; use of bacteriocins to replace antibiotics to treat disease.	Xenotransplantation, production of specialised breeds.
Food/Beverages	Rapid diagnosis of micro-organisms.	Diagnosis and tracing of bacterial contamination.	Biopreservation, enhanced flavour/aroma, development of functional foods.	Production of food ingredients.
Chemical Manufacturing	Identification of mutations in micro organisms for production control.	Purification of product using affinity chromatography.	Production of pre-cursors and reagents from bacteria or plants.	In future for production of small molecules and pre-cursors.
Mining and Energy	Identification and monitoring of strains for bioleaching.	Identification of contaminant, process control.	Remove contaminants from petroleum and save energy; reduce solvent use; convert ores to metal; alter viscosity of fluids to aid processing.	Propagation of bacteria.
Forestry, Pulp and Paper	Identification of endemic vs. introduced stocks, assessment of biodiversity.	Diagnosis of disease and pests.	Pre-treatment of wood pulp to reduce processing and bleaching costs. Development of tree varieties with specific characteristics, selection of traits.	Propagation of tree stocks.
Pharmaceuticals	In vitro monitoring of growth of precursors, In vitro expression.	Development of diagnostics for disease; identification of allergens.	Production of pre-cursors, production of therapeutic compounds, gene based therapies now in clinical trials.	Plant cell suspensions for use in screening for active molecules.
Environment	Identification of populations.		Selection of bacteria to clean up oil spills and mining waste.	Culture of rare plants/animals for conservation.

Derived from Australian Food Council (1996), Gaston et al. (1995); Porter et al (1999); Stafford (1999); Jaworski (2000) Relationship Between Research and Industry.

The biotechnology-related industries have entered a new phase of growth due to several factors including development of the knowledge-base, increased role of patents and intellectual property protection, and trends in commercialisation of public sector research.

2.2.1 Knowledge-Base in Life Sciences

There has been a massive increase in knowledge in life sciences over the past 10 years with almost exponential growth in publications and patents. The recent completion of the Human Genome Project (well ahead of forecasted time), for example, will provide the basis for the design of drugs to treat human and animal disease. Proteomics, the identification and characterisation of proteins using high-throughput screening, will provide further systematic information to help characterise disease at the protein molecular level. Applications of these basic technologies to health and agriculture, in particular, have led to better, more specific products and, for the first time, the ability to attack biological problems at the molecular genomic and protein level.

2.2.2 Intellectual Property Protection

There is now increased proprietary protection for biotechnology inventions through patents, trademarks and plant breeder's rights**.** Nucleic acids, proteins, cell lines and whole organisms can all be patented in Australia, as can processes including fermentation, treatments and diagnosis. Over 9,400 applications for patents for genes or gene sequences had been lodged in Australia up to the end of 1999.

2.2.3 Regulatory and Market Development

Knowledge of regulatory affairs, preclinical and clinical studies, packaging and formulation, and global market needs and values are all important in designing products which will be readily accepted in world markets. There has been a revolution in the manufacturing and marketing of new technology products and this is often overlooked in assessments of trends in biotechnology which focus on the innovation. Many biotechnology processes, for example, production of recombinant insulin (in medicine) and rennet (in food), are now accepted as mainstream manufacturing.

Research groups and firms are assisted in commercialisation of biotechnology research by the three factors listed above. The most successful geographical regions in the commercialisation of innovation are those where there is close proximity between research, small companies and sources of capital, which understand the nature of the industry sector.

3 Inventory of Public Sector Resources for Biotechnology in Western Australia

This chapter summarises the biotechnology training offered by research institutions, the equipment and other resources available for research and the research programs themselves. Appendices C and D provide further information on the major equipment and public sector research programs relating to biotechnology.

3.1 Inventory of Higher Education and Training

There are five universities in Western Australia (four public, one private). The four public universities are independent, Commonwealth-funded institutions created under State legislation and all offer biology or biotechnology courses. The University of Notre Dame is a private Catholic university established in 1990. It does not currently have courses or research in biological science directly relevant to biotechnology.

Table 3.1 Public University Campus Locations in Western Australia

University	Biology/Biotech. Students %	No. of Campuses	Biotechnology Training
Curtin	30.2%	5	Centre in human biology, undergraduate course in biological science.
Edith Cowan	25.0%	7	Centre for human genetics, undergraduate/postgraduate courses in human biology, School of Environmental Biology.
Murdoch	25.3%	2	Formal biotechnology course; chair in biotechnology.
Western Australia	36.9%	1	Medical research, undergraduate units within biotechnology.

Source: See Appendix F for details of statistics.

The **University of Western Australia** (UWA) is the oldest in Western Australia and has well established teaching and research departments in the sciences that feed the biotechnology-related industries. It also has the only medical school in Western Australia and has several associated teaching hospitals, together with highly regarded medical research institutions, notably the TVW Telethon Institute of Child Health Research, the recently formed Western Australian Institute for Medical Research (WAIMR), the Lions Institute of Eye Research and the Australian Neuromuscular Research Institute.

The **Curtin University of Technology** originated from the Western Australian Institute of Technology in 1986 and has the largest number of students in Western Australia. It emphasises technology and has a centre in human biology. It is also recognised as an Australian centre for mining and petroleum engineering with three Co-operative Research Centres and several specialist centres over several campuses including the Western Australia school of Mines. Curtin also is closely affiliated with the West Australian Technology Park adjacent to its Perth campus.

Murdoch University was established in 1973 and is strong in agricultural biotechnology. It has four academic divisions in Science and Engineering; Veterinary and Biomedical Science; Business, Information Technology and Law; and Social Sciences Humanities and Education plus a division in Research and Development. Murdoch hosts several biotechnology groups such as the State Agricultural Biotechnology Centre (SABC), the Centre for Bioinformatics and Biological Computation, the Centre for Rhizobium Studies, the AJ Parker Centre for Hydrometallurgy, the School of Biological Sciences and Biotechnology and the Centre for Biomolecular Control of Disease. A campus at Rockingham covers Engineering and has a close working arrangement with TAFE. Murdoch's biotechnology degree course, established with State Government support, was the first such course in Australia and has served as the model for development of similar courses elsewhere in Australia and overseas.

Edith Cowan University has several campuses and focuses on the service industries and professions. It was established from a College of Advanced Education and several teaching colleges and other institutions. It offers undergraduate and postgraduate courses in human biology in the School of Biomedical and Sports Science, the Centre for Human Genetics which is associated with the Human Genome Project, and Schools of Environmental Biology and Pharmacy.

3.1.1 Business, Technical and Other Training

Graduates in the biological sciences areas need to acquire practical business skills in biotechnology companies after their university education. All universities offer business training with opportunities to combine business and science courses, but because of insufficient opportunities for industry employment, these graduates cannot easily practice and hone commercial business skills. Although some will be employed in academic positions and research centres, we believe it is unfortunate that many extremely capable people are not finding employment in Western Australia.

There appear to be fewer opportunities for training for students at the operator technician level in biological science at TAFE or for on-the-job training, also because of the lack of sizable industry in Western Australia.

In Australia generally, the poor quality of business management staff has been raised as an issue by venture finance companies and biotechnology firms themselves. National surveys (such as the Australian biotechnology report by Ernst & Young) have forecast a sharp increase in the need for staff with R&D, business development, manufacturing or regulatory skills worldwide. Overall, although technical labour shortages are not an issue, management skills and experience are in short supply. A significant percentage of firms are turning to overseas sources (usually the USA) to recruit staff. Human resource managers, specialising in biotechnology recruitment, are also starting to emerge. Firms could also look to expatriate graduates or other nearby regions such as Asia, particularly Singapore, for highly educated executives with a range of business skills. It is likely that very attractive packages will have to be offered to attract quality staff.

3.1.2 Commercialisation of University Research

Universities are expected to commercialise their research, and there are many models of how this is done. Curtin and Murdoch appear to have well developed internal processes for doing so. There is a need for all participants in this process to have greater access to expertise and information.

Murdoch has recently put effective commercialisation processes in place, and has established infrastructure within the SABC for the development of start-ups through their incubator program. This model resembles other highly successful centres and focuses attention on the further development of intellectual property with involvement of the researcher in the product development.

The program at Curtin University allows considerable scope for negotiation of commercialisation agreements, supports early patent applications and can also provide some seed funding.

The Western Australian Biomedical Research Institute (WABRI), a joint venture of Murdoch and Curtin is proposing to handle biomedical-related intellectual property and commercialisation arising in the centre.

3.1.3 Discussion

Each Western Australian-based university can and does deliver strong biological science courses. The differences between universities reflect their strategies in serving particular sectors of the education markets. However, it is increasingly difficult to provide a course structure that satisfies the needs of biotechnology-related industries because of the diverse nature of the technologies involved and the range of industries. Many other universities outside Western Australia have changed their structures to integrate biotechnology-related courses into general biological sciences in recognition of the origins of biotechnology from main stream disciplines such as biochemistry and microbiology.

We have not compared the standing of graduates from the different universities in the workforce and obviously these are not all equivalent nor do they offer the same courses. However, in our research interviews, the courses and faculties in science, commerce, law, finance, medicine and business are very highly regarded and there is obviously a highly trained workforce available for an emerging biotechnology industry.

3.2 Major Equipment and Centres of Expertise

Resourcing major equipment costing more than $100,000 is restricted to a few mechanisms, two of them at Federal Government level and the remainder from within Western Australia.

The Australian Research Council has a budget of $21.7 million for equipment grants (in 2000) and subsidises 75% of the cost of equipment for medical biotechnology. Western Australia obtained 7.1% of the total available in 2000 to with a success rate of 45.45% (five grants). Of these grants, three grants were applicable to biotechnology.

The Commonwealth's Co-operative Research Centres scheme some provides funds for equipment as part of the funding for the CRC. Successful applications to the scheme must usually demonstrate extensive national and international collaborations and significant private sector investment.

Two Western Australian schemes which fund the provision of infrastructure, including equipment are the Centres of Excellence for Industry Focused R&D program and the Medical and Health Research Infrastructure Fund. The former program invests approximately $5 million per annum while the latter has provided $8 million over five years for medical and health research.

Major biotechnology related equipment is located at Western Australian Centre for Microscopy (WACM), Western Australian Biomedical Research Institute (WABRI), Western Australian Centre of Excellence in Mass Spectrometry (CEMS), Western Australian Institute for Medical Research (WAIMR), Western Australian State Agricultural Biotechnology Centre (SABC). All of these have been funded through the Centres of Excellence Program. An inventory of major equipment at all centres and their research is in Appendix C.

Table 3.2 Location of Major Pieces of Equipment

Centre	Participants	Facilities
Animal Research Centre	Western Australian statutory authority on Murdoch campus.	Facilities for producing laboratory animals and fertile chicken eggs, cryopreservation equipment.
Western Australian Centre for Microscopy (WACM)	UWA, Curtin, Murdoch and Edith Cowan.	Electron, laser and light microscopic techniques for materials characterisation, including seagrass.
Western Australian Biomedical Research Institute (WABRI)	Curtin (Centre for Molecular Technology and Therapeutics) and Murdoch (Centre for Biomolecular Control of Disease).	Molecular biology, transmission and scanning electron microscopy, confocal microscopy and other analytical procedures including cell sorting, musculo-skeletal analysis and elemental analysis.
Western Australian Centre of Excellence in Mass Spectrometry (CEMS)	Curtin (HQ), UWA and CSIRO; used by Edith Cowan, Murdoch and others.	Organic and inorganic mass spectrometry equipment, with the recent addition of a ICP-MS and a stable isotope facility for use in earth science, environmental agriculture, etc.
Western Australian Institute for Medical Research (WAIMR)	UWA, Curtin and Murdoch Universities, Royal Perth, Sir Charles Gairdner and Fremantle Hospitals.	Virtual centre. Gene targeting and transgenic facilities now at SGCH campus. DNA analysis equipment, cell sorting and imaging equipment will also be added to the facilities.
Western Australian State Agricultural Biotechnology Centre (SABC)	Murdoch. Collaborative research with local firms, all Western Australian universities, 3 CRCs, CSIRO, AgWA, GRDC, Institute Pasteur, University of Alaska and USDA National Animal Research Centre.	Secure glasshouse and other facilities for growth and manipulation of plant, viral, fungal and bacterial cultures; sequence detection system, DNA sequencers and PCR machines; capillary electrophoresis system with imaging densitometres, confocal scanning laser microscopic and micromanipulation equipment, MALDI-TOF mass spectrometer, robotic; houses the Western node of ANGIS.

Other groups which are important as resources for biotechnology include the four listed in Table 3.3.

Table 3.3: Other Centres Applicable to Biotechnology Research

Centre	Participants	Facilities
UWA, Dept of Chemistry	UWA, also services Murdoch, Curtin and Edith Cowan Universities and the Western Australian Maritime Museum.	NMR facility; 600 MHz high-field NMR spectrometer for use in solution studies and molecular dynamics including rational drug design, enzyme studies and immunophilins, and agriculture biotechnology.
UWA, Crystallography Centre	UWA.	Generation area-detector low temperature X-ray diffractometer facilities for small molecule structure determination activities.
Western Australian Bioinformatics Consortium	Co-ordinated by Murdoch University, Centre for Bioinformatics and Biological Computing.	SUN Enterprise E450 server (dual processor), G4 Macintosh, IBM-compatible PCs and SUN workstations as well as access to 14 SUN workstations within the Information Technology School.
State Chemistry Centre	Curtin University.	Chemical and associated analytical investigative and advisory services, tests in the areas of food science, natural resources, forensic science and racing chemistry.

Availability of suitable, state-of-the-art equipment in both core and enabling technologies is a dominant issue both for academic R&D in the field and for emerging industry, as the equipment is not only extremely expensive, but needs regular upgrading. To remain at the forefront of the technology, major infrastructure must be updated or replaced relatively frequently. This has an obvious flow-on effect on the ability of researchers to gain competitive grants and creates a circular argument between equipment and research funding. We have not found evidence that lack of equipment has limited Western Australia in gaining such funds.

The most effective way to maintain equipment of sufficient scale and leading edge is to locate it in centres which act as a resource for a range of groups. In addition, such centres stimulate collaborative activity and thus generate benefits arising from interaction between research groups.

Western Australia has already developed some exemplary institutes and centres which act as foci for a specific technology and serve numbers of research groups, and is continuing the drive towards constructive consolidation. It is important to emphasise that much high-technology equipment can be used across a broad range of research fields, and that in this context, biotechnology must not be considered in isolation. For example, the equipment at the Centre for Microscopy is mainly used for characterisation of inanimate materials but could be equally applied to drug design.

3.3 Inventory of Public Sector Research

3.3.1 Agricultural Research

Research in agricultural biotechnology in Western Australia is broadly-based, and was the area of research strength most frequently mentioned by those consulted for this report. Agriculture Western Australia, Curtin and UWA are involved in floriculture, and plant molecular markers are studied by CLIMA, SABC, WAHRI and UWA. The CSIRO Centre for

Mediterranean Agricultural Research conducts research in a range of areas including gene expression, molecular techniques for insect and plant interactions, biotechnology for animal breeding and microbial pathogens.

The leading agricultural laboratory with a major focus on biotechnology is the SABC, which was the only Western Australian-based national facility listed in the recent review of national facilities. SABC is a State Centre of Excellence. The SABC is involved in many areas of research in both plant and animals. SABC's success is reflected in several factors including its external funding of $3.3 million in 1999, extensive facilities and equipment and new extensions completed in 2000 costing $1.45 million. This facility supports researchers in the areas of crop biotechnology, agricultural bioinformatics, rumen biotechnology, *Rhizobium* studies and biomedical researchers. Murdoch also hosts the new National Centre for Necrotrophic Fungal Pathogens. Some achievements in agriculture include:

- A patent for a vector for use in vaccine strains for use as immunocontraceptives which was a result of work done at the UWA (Dr Geoff Shellam) through the CRC for Pest Animal Control;
- The establishment of Centre for High Throughput Agricultural Genetic Analysis, associated with SABC;
- New pasture crops and lentils developed by CLIMA for commercial use;
- The development of the world's first transgenic yellow lupin (SABC).

Researchers in agriculture appear to have greater numbers of external collaborations than other sectors, citing over 70 in Western Australia, Australia and overseas. All but four of these were with other research institutions.

AgWA has programs which could use biotechnology techniques but to date, have generally focused on traditional means to support the rural industry.

3.3.2 Medical Research

Biomedical research is undertaken at UWA, Murdoch and Curtin Universities and a number of centres and institutes. There are several specific areas of international standing and the recent establishment of two institutes, Western Australian Biomedical Research Institute (WABRI) and Western Australian Institute for Medical Research (WAIMR) is a positive development. WABRI, which includes the Centre for Molecular Technology and Therapeutics and Centre for the Biomolecular Control of Disease, was established as a Centre of Excellence in 1999. WAIMR is a State initiative, to facilitate collaboration in research based at UWA and aims to bring groups together to form a critical mass. It has the potential to become a leader in the areas of aging and mental health, which are studied by only a few groups elsewhere in Australia.

UWA is the leading university in medical research, and studies are usually carried out with collaborators in other institutes and hospitals (Royal Perth, Princess Margaret and Sir Charles Gairdner). Some key institutions are listed below.

- The TVW Telethon Institute of Child Health is a prestigious institution with an international reputation, focusing on childhood leukaemia and other cancers, asthma and allergic diseases, infectious diseases, birth defects, cerebral palsy, cystic fibrosis and other respiratory ailments;

- Lions Eye Institute has an international reputation and its invention of Eye:Q, a solid state laser, is a world leading technology which has received international recognition;

- The Lions Cancer Institute has an international reputation for its development of a hyperthermia technology for the treatment of liver cancer;

- Curtin University (School of Biomedical Science) has developed diagnostic technologies which are being commercialised (detection of drug-resistant *Staphylococcus aureus,* and *Candida);*

- The Centre for Human Genetics (Edith Cowan University) has international collaborations including the Human Genome Project program and WHO;

- The Australian Neuromuscular Research Institute conducts research in molecular genetics, neuromuscular and neurological disorders and brain mapping.

Researchers in medical biotechnology reported a greater proportion of overseas collaborations than those in other sectors. This relates to the international standing of the researchers and to the global interest and markets in biomedical products. The clinical trials for testing new therapeutics also require collaboration between firms and this group reported the only collaborations with overseas companies.

3.3.3 Mining

The AJ Parker Cooperative Research Centre for Hydrometallurgy (through CSIRO Division of Minerals and the Division of Science and Engineering at Murdoch University) focuses on bioleaching and hydrometallurgical processing of sulfide ores. Investment in biotechnology (both bioleaching and bioremediation) will establish the Parker Centre as a centre of excellence for this emerging technology. The Centre is optimising the selection of indigenous bacteria and control of bioprocessing conditions and enhancing biomineral processing reaction rates. The mineral chalcopyrite $CuFeS_2$ can be economically processed pyrometallurgically but not hydrometallurgically. Because of its economic importance, considerable efforts are being made to find a suitable hydrometallurgical processing route. Preliminary work at the Centre has shown that bioleaching of chalcopyrite is possible and this project is directed towards defining these conditions, both for conventional leaching and bioleaching.

The Minerals and Energy Research Institute of Western Australia funds research projects which include biological research and site remediation.

3.3.4 Environment

In the area of water management, the Centre for Biomolecular Control of Disease (CBCD) at Murdoch University, is developing a DNA-based diagnostic test for the simultaneous detection of three enteric pathogens – *Cryptosporidium, Giardia*, and *Cyclospora*, for use in environmental and clinical settings. The key researcher in this project, Dr Una Morgan, has recently been awarded the national Minister's Prize for Achievement in the Life Sciences.

The Dampier site of the Australian Institute of Marine Science (AIMS) provides a facility for the study of the biodiversity of the Indian Ocean. It is increasing the taxonomic and geographical diversity of its collection of marine organisms. The facility also studies algal toxins and the toxicity of pollutants to coral and fish. This research has considerable potential for biomedical applications.

A number of the activities undertaken in SABC have consequences for improving the environment, through the development of enriched lupin strains, which could reduce the land used for grazing, control of viral and fungal plant pathogens, and nematode research. In the area of vertebrate pest control, the Pest Animal CRC is developing new biological control methods, manipulating fertility to control birth rates of feral pests, targeting rabbits, foxes and mice.

The newly established State Centres of Excellence in Environmental Technology and Organic Waste Management at Murdoch University will focus on biotechnology applications for environmental management and waste disposal.

3.3.5 Bioinformatics

A Western Australia Bioinformatics Consortium (WABC) is being developed through Murdoch University, WAIMR and the IRF to bring together the groups currently working in the area of information technology applications in biology. The Australian National Genome Information Service (ANGIS) is setting up a regional node in Western Australia. Although still in its formative stage, the centre will provide services such as training, customisation of software and expert advice to the science community as a whole. It has collaborations with other centres in Australia and overseas.

3.3.6 Other Biological Science Research

Biotechnology is a relatively recent epithet and arises from the more traditional biochemistry, biology and molecular biology disciplines. With the exception of the Wet Tropics Research Centre of the Australian Institute of Marine Science (AIMS), most research in this area is carried out at the universities, with Murdoch University again the leading institution. The following are some important sectors that can be further developed:

- Commercial scale algal culture and new biochemicals such as astaxanthin from algae (Murdoch University);
- Industrial microbiology and micro-propagation of native plants (Murdoch University);
- DNA probes for the identification of plant pathogens and other species (Murdoch University);
- The Centre for Microscopy and Microanalysis (UWA) has comprehensive facilities and equipment, providing services to external institutions.

Details of the research undertaken at Western Australia's major universities are at Appendix D.

3.3.7 Discussion

Western Australia has three strong research disciplines in biotechnology: human health, agriculture and mining/environment. The three main universities carry out research in each of these areas but there is some specialisation. Several institutions are also involved in similar topics, for example, both CSIRO and CLIMA are involved in Mediterranean agriculture research, although there is collaboration between the two institutions. Of the universities, Murdoch University's strongest focus is in agriculture, primarily due to SABC. Edith Cowan, Murdoch, Curtin and UWA conduct biomedical research, the latter through collaborations and

affiliations with the Lions Cancer Institute, the Institute of Child Health Research and WAIMR. Curtin University's program is more wide-ranging and includes medical research and agriculture. There is little mining and environmental biotechnology research in the main institutions although there are companies with expertise in these areas and there is a significant local need.

In other States, the Governments have provided the substantial funding stimulus needed to create larger entities. In the two States of comparable size, the QIMR precinct is being developed in Queensland and the Waite Institute in South Australia is built around a strong agriculture focus. Considering the importance of novel, competitive research in sustaining a biotechnology industry, such infrastructure support, in magnitude and commitment, is vital. This is discussed further in Chapter 5.

3.4 Conclusions

Western Australia has comparable or better population-based enrolments at both undergraduate and postgraduate level in biology-related areas than Australia as a whole and the individual States of Queensland and South Australia (Appendix F). Education in biotechnology-based disciplines appears to be of high standard. In all parameters assessed, Western Australia ranks highly compared with other states in Australia.

For students expecting to enter employment in biotechnology as researchers and technicians, an excellent grounding of scientific training is available. However, because of the present lack of industry employment many extremely capable people must leave Western Australia in order to be employed at the level to match their training. This is also a problem in other states where there are too many graduates for local firms to employ. While this means that local firms can be assured of the best staff, many Australian biotechnologists eventually find work overseas.

Access to business management staff and attraction of world leading researchers is an issue of particular importance to Western Australia. In large part, this is an issue of retaining Western Australian graduates and providing better career opportunities to build up the depth of talent. However, it is clear that some of the current successes are due to the appointment to key positions of researchers and business managers from outside Western Australia. Thus, Western Australia will need to be an attractive location to both home-grown graduates and postgraduates as well as researchers from elsewhere in Australia and overseas. These leaders need to be supported with facilities, infrastructure, international collaborative opportunities to broaden their contacts and participation in collective decision-making. All committed researchers also need to be provided with good career opportunities and advancement and by rewarding excellence. See Chapter 7 for case studies of how other regions have attracted research leaders.

While the equipment at Western Australia's research institutions appears to be adequate for most current needs, it should be noted that only the SABC is big enough to warrant listing in the recent Commonwealth review of Major National Facilities, although two other centres (AgWA and State Chemistry Centre were identified as not quite meeting the definition). Thus it appears that the scale of facilities available in Western Australia for biotechnology is probably smaller than that available elsewhere in Australia. Having said this however, respondents did not identify any pressing equipment requirements beyond the need to know about and have access to equipment at other institutions and there was one call for expanded glasshouse facilities. It is apparent that the existing equipment and renewal programs are sufficient for the current scale of activity in Western Australia, but if the activity increases there will be a need for further facilities.

The relatively large number of research foci are sustainable provided there is collaboration, with emphasis on the growth of the Western Australian community as a whole, rather than competition and fragmentation. Recent collaboration between institutes such as WABRI and WAIMR and focus on complementary areas will help to reduce this. Good working relationships across institutions need to be maintained and improved in the long term to ensure that Western Australia as a State reaps the benefit of the research.

The important area of bioinformatics not being given sufficient emphasis previously is now beginning to be addressed. This can be applied in the areas of research strengths in Western Australia – plant genomics (the determination of the coding for genes), parasitology and medical research.

4 The Western Australian Industry and the Impact of Biotechnology

Biotechnology has the potential to affect many economic sectors. This chapter commences with an overview of the Western Australian economy and then describes the biotechnology industry in Western Australia and its interaction with other areas of the economy. The analysis concentrates on core biotechnology firms, which are those that derive the majority of their turnover from products or services produced using biotechnology techniques (Appendix C). Firms that use biotechnology techniques to obtain a minority of their revenues are considered to be minor users and as such were not surveyed specifically for this study. Where there is some data collected by this study, some references are made to their activities.

This chapter also compares Western Australia's biotechnology activity with the rest of Australia, particularly Queensland, which has a smaller number of biotechnology companies but a larger public profile, and South Australia, which has roughly the same population as Western Australia.

4.1 Economic Background

Western Australian has just over 1.8 million people (out of a total Australian population in 1998 of 18.75 million) and has the nation's fastest population growth rate (1.86%p.a.) ahead of that of the Northern Territory (1.65%) and Queensland (1.74%). The population is concentrated in Perth, which in 1998 had 1.34 million people, or 74.5% of the State population. Western Australia has 33% of the Australia's land area.

Gross State Product in 1998/1999 was $50.6 billion, giving Western Australia the second highest GSP per capita in Australia (after ACT). Annual economic growth has averaged 4.3%, which is above the national average of 3.3% over the last 10 years. This is due to the general rise in private consumption, dwelling investment and business investment. The State also benefits from high employment growth and net interstate immigration. Western Australia has 39,900 businesses, of which 90.5% have less than 20 employees. These firms have gross product of $25.82 billion.

Western Australia's large firms have a lower average gross product than the average large firms in the Australian economy. Finance, property and business services account for 20% of GSP in 1998/99, followed by mining (17%) and wholesale and retail trade and hospitality (16%), construction and utilities (11%), manufacturing (10%), transport (8%) and agriculture (4%). Employment is concentrated in wholesale and retail trade and hospitality (33% State total), followed by Government and Community Services (21%). Manufacturing employs about 9% of the population while mining and agriculture employ 3% and 4.5% respectively.

4.1.1 Exports

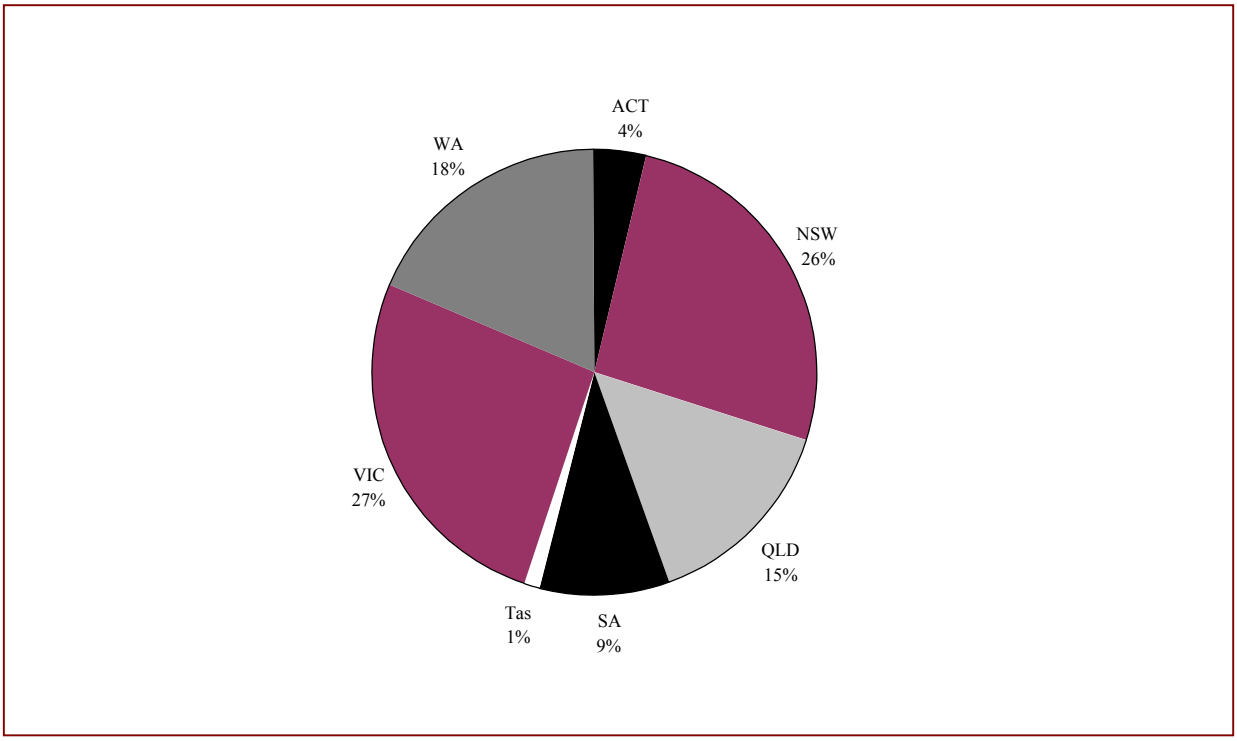
In 1998/99 Western Australia had exports of over $24.4 billion, or 23% of Australia's total. This is more than double what would be expected on a per capita basis. The largest sector of direct exports were from mining and energy at $12 billion, or 49% of Western Australia's total exports. The second largest sector of direct exports was agriculture with $3.74 billion or 15% of Western Australia's total. The top three export destinations are North East Asia, East and West Europe and South East Asia.

Agricultural exports from Western Australia comprise on average 20% of Australia's total agricultural exports. The leading crops are cereals (37% of Australia's total), wool (17%), fish and crustaceans (37%), and oil seeds (34%). The main markets are in South East Asia. Manufacturing comprises 10% of exports ($2.4 billion), with the main categories being paints and pigments, specialised industrial machinery, ships and boats, inorganic chemicals and pharmaceuticals.

4.2 Major Characteristics of Biotechnology Firms

Biotechnology firms were first established in Western Australia in the early 1980s, 10 years later than Australia's first biotechnology firm. However, when compared with other states of a similar population, Western Australia is well-endowed with core biotechnology firms, with 18% of the Australian total (Figure 4.1 – see also Appendix B). This is due to bursts of company formation in the mid 1990s in human therapeutics, food and beverages and diagnostic services.

Figure 4.1: State Distribution of Australian Biotechnology Firms by Number of Firms



Source: Advance Consulting & Evaluation company database.

Of the core biotechnology firms in Western Australia, just under 90% are located in Perth. Five firms are in West Perth, because of proximity to the CBD and sources of capital. The next largest groups are located near Murdoch University, Curtin University and the Technology Park and UWA. Over half the firms are scattered throughout Perth and surrounding areas.

This degree of scattering is unusual. In Melbourne, for example, the majority of firms (particularly those in medical biotechnology) are clustered around Parkville, which is the site of two major university campuses, around CSIRO's work in molecular science and several hospitals and medical research institutes. In Queensland, firms are clustered around the University of Queensland and CSIRO at St Lucia, and in the inner north near the major hospitals. Similar clusters are evident in Sydney (North Ryde, inner city) and Adelaide (Thebarton, west Adelaide).

Biotechnology clusters form because firms are dependent on research institutions as sources of equipment, library resources, intellectual property, staff and access to equipment, and many have arisen from research institutions as spin-offs.[1]

In Western Australia, only four of the 27 existing core biotechnology firms (15%) are known to be spin-offs of research institutions (Table 4.1). Over the last 20 years, the overall proportion is 18%. Nationally, the average spin-off rate over the last 20 years has been 46%, the highest being the ACT (75%) followed by South Australia (60%) and Queensland (53%). Actual numbers are highest in Queensland, where institutions such as Queensland University have implemented specific spin-off-support policies. The lack of spin-offs in Western Australia is likely to be due to absence of specific support policies at the institutional level, and absence/low levels of finance and expert advice for new firms.

Table 4.1: Research Spin-offs[2] in Western Australian Biotechnology

Firm	Year Est.	Source Institution	Sector Class
Institute of Molecular and Applied Microbiology WA Ltd*	1982	Curtin	Diagnostics
Biowest Pty Ltd*	1984	UWA	Supplier
In Vitro Technology/Embryotech	1985	Queen Elizabeth II Hospital	Therapeutics
Vaccine Technologies*	1992	UWA	Therapeutics
Insulin Mimetics Pty Ltd	1993	Curtin University	Therapeutics
Genetica Biotechnologies Pty Ltd	1995	Curtin University	Diagnostic Products
Ozgene Pty Ltd	2000	Western Australian Institute of Medical Research	Supplier

**No longer operating. Biowest Pty Ltd is different from the current company Biowest Australia Pty Ltd.*

4.2.1 Size

Western Australian core biotechnology firms are small. The total employment of Western Australia's core biotechnology firms is 250, or eight per firm. Chemical and environment firms had the highest average size (18 staff), followed by agricultural biotechnology (9.3 staff), and human therapeutics firms (9.9 staff).

[1] *Spin-offs are defined as new firms established to exploit intellectual property from research institutions and often a researcher will move into, or be associated with, the firm. Spin-off firms usually license the technology from the parent institution, which may also hold equity in the firm.*

[2] *DNA-ID Labs, Biowest Pty Ltd and Australian Spirulina Farms have been founded by researchers from Curtin University(1) and Murdoch University (2) respectively but are not classified as spin-offs as they are not commercialising university-intellectual property developed.*

Table 4.2: Comparison of Biotechnology Companies Across Industry Sectors

Sector	No. Core Firms	No. Staff	Average
Chemicals, Environment	5	90	18.0
Human Therapeutics	8	79	9.9
Agriculture	4	37	9.3
Suppliers	2	11	5.5
Food	3	10	3.3
Diagnostics	3	9	3.0
Mining	2	14	7.0
Total	**27**	**250**	**8.0**

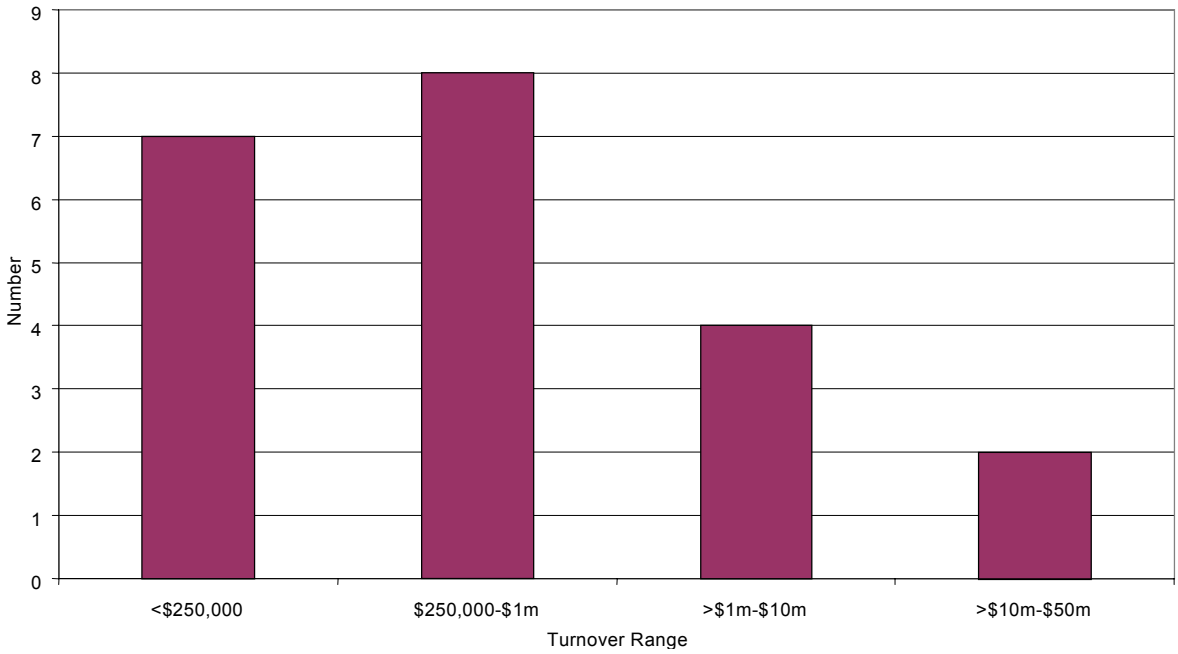
Source: Company responses; multiple sector firms have been allocated to their major sector of activity. Table excludes non-Western Australian-based employees of Provalis and Cognis which are included elsewhere. A complete list of core firms is provided in Appendix B.

At the national level the average per firm is 30-40 staff. This figure includes CSL, which has over 1300 staff. Excluding CSL brings the average firm employment down to around 15 staff. Thus the Western Australian firms, at an average of eight staff each, are about one half the size of the average Australian firm, so even with a larger number of firms there is a smaller total workforce in biotechnology companies.

4.2.2 Turnover

Turnover of Western Australian core biotechnology firms is also low compared to other states, with the majority of firms reporting turnover of less than $1 million in 1998/99 (Fig 4.2). However, data held by the consultants shows that this is comparable with other firms nationally, and it is certainly in the range of the average small Western Australian firms in other sectors.

Figure 4.2: Turnover Range of Core Biotechnology Firms in Western Australia



Source: Company responses (n=21).

The top 10 listed biotechnology firms in Australia have a market capitalisation of approximately $5 billion, of which 79% is due to CSL. Although one of these Provalis plc, is nominally located in Western Australia, nearly all its activities are in the UK. Several listed Australian firms also have listings on overseas exchanges. All the firms in the top 10 target human therapeutics (Table 4.3).

Table 4.3: Comparison of Listed Australian Biotechnology Companies

Name	State	Year	Sector	Market Cap. $M
CSL	VIC	2000	Human Therapeutics	4,030
Novogen	NSW	2000	Human Therapeutics	319
Biota	VIC	2000	Human Therapeutics	257
Circadian	VIC	2000	Human Therapeutics	121
Amrad	VIC	2000	Human Therapeutics	77
Provalis plc	WA	2000	Human Therapeutics	70
Progen Industries	QLD	2000	Human Therapeutics	52
Autogen	VIC	2000	Human Therapeutics	43
Biotech International*	QLD	2000	Human Therapeutics, Diagnostics, and Molecular Biologicals	38
Peptech	NSW	2000	Veterinary and Human Therapeutics	38
Bresagen	SA	2000	Veterinary and Human Therapeutics	28
Total				**5,073**

Source: Deloitte's Biotech Index, July 2000.
** ex-Western Australia.*

4.2.3 Intellectual Property

Fifteen of the core biotechnology firms in Western Australia have 59 patents registered, an average of 3.5 per firm. The remainder have licensed in technology from elsewhere. This patenting rate is very low compared to other biotechnology firms, where an average of 10 patents is considered normal.

Patent attorneys and lawyers consulted on this issue, however, believed that patents are particularly important in biotechnology. A recent study of Australian technology patents lodged in the USA found that firms with patents that were highly cited and highly science linked had a 25% higher market-to-book value for up to three years into the future, than companies with lower quality patents. Thus the low usage of patenting by Western Australian firms may be directly linked to their generally smaller size. Trade secrets are the best protection for processes which are not considered novel enough to be patented. However, firms which rely on trade secrets may find that another organisation has patented the process and that continued operation places them in breach of these patents.

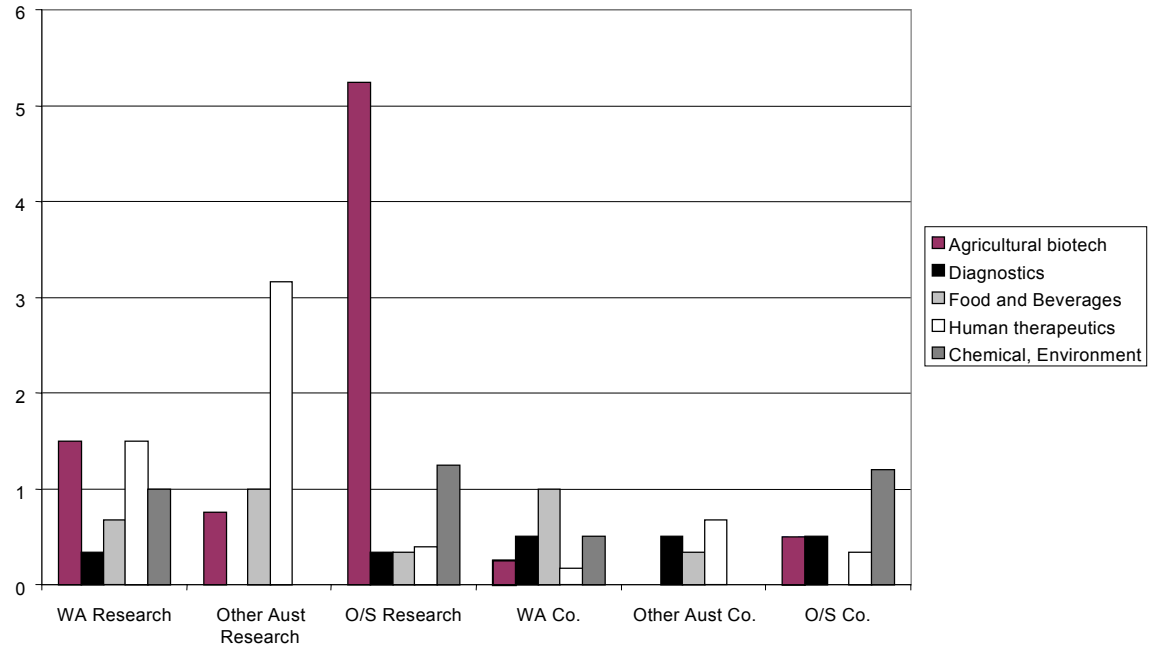
4.2.4 Networks

Local clusters around research institutions help firms form informal networks and to keep in touch with the research occurring in the major institutions nearby. Lack of clustering by Western Australia's biotechnology firms means that informal links are few and are not sufficiently encouraged by the activities of local industry associations and other groups.

Core biotechnology firms had an average of five formal research links with companies and research institutions per firm (Figure 4.3). Approximately half of these were with overseas groups, a rate that is half the national average. Alliances were frequently with research institutions in other parts of Australia and overseas, rather than with companies in Perth or elsewhere.

Respondents to the survey reported that alliances provided access to intellectual property, gave them credibility and helped them obtain grants or tax concessions. Firms with local links to public sector research institutions obtained access to students, while firms with links to distant research institutions obtained access to national or international leaders in a field. Firms with local links to other Perth-based companies obtained access to unique skills whereas firms with links to other firms elsewhere in Australia used these to access technology and markets.

Figure 4.3: Average Alliances per Firm by Sector and Location



Source: Company responses.

A 1996 study of the formal linkages of 70 Australian biotechnology firms found an average of 10 links per firm. These varied between sectors, from a low of 4.3 per firm in food and beverages, to a high of 12.1 per firm in human therapeutics. Assuming the relative number of links is unlikely to have changed in the intervening period, Western Australia's firms in agricultural biotechnology are about average in their numbers of links, those in chemicals, environment and other and food/beverages are a little below average, and those in human therapeutics and diagnostics are significantly below average.

Table 4.4: Comparison of Links of Western Australian Biotechnology Firms with National Biotechnology Firms

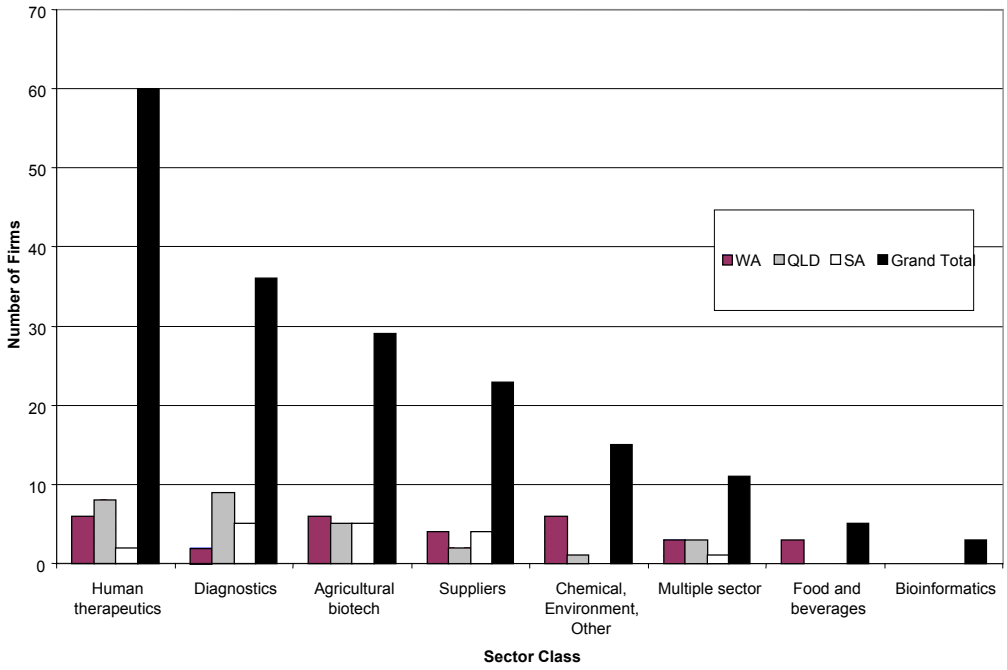
Sector	Average Links per Western Australian Respondent	Average Links in National Study
Human Therapeutics	6.25	12.1
Diagnostics	2.16	11.6
Agriculture	8.25	9.0
Chemicals, Environment, Other	3.95	4.8
Food & Beverages	3.30	4.3

Source: Survey respondents and Thorburn (1999).

4.3 Target Markets of Biotechnology Companies

At a national level, the main market targeted by Australian biotechnology firms is human therapeutics and diagnostics. Western Australia is strong in agricultural biotechnology, chemical, and environmental compared to South Australia and Queensland.

Figure 4.4 Target Markets of Biotechnology Companies



Source: Company responses and Advance Consulting & Evaluation company database.

4.3.1 Therapeutics and Diagnostics Manufacturing

Coal, petroleum and chemicals, a classification that includes pharmaceutical manufacture, has a turnover of $3.3 billion and employs 6,500 people, or 8% of the total. Ninety pharmaceutical wholesalers and manufacturers are listed in the Western Australian Yellow Pages. However, only a handful of these companies actually manufacture products locally. These include **Kabi Pharmacia** and **Pharmacia & Upjohn Pty Ltd**, the latter of which purchased local pharmaceutical company Delta West and now operates the manufacturing facility at Technology Park, Bentley. The lack of local large manufacturers was of concern to survey respondents.

> *"There are no major industrial companies based here doing R&D", Health researcher.*

> *"There is not enough industry in our sector in Western Australia", Health researcher.*

There are seven core biotechnology firms targeting therapeutics include **Bioprospect,** which screens naturally occurring compounds for active entities that may be useful in a range of markets; **Cognis Nutrition and Health** (formerly **Betatene**), which is based in Melbourne, but has operations in Western Australia since its acquisition of Western Australian-based firm Western Biotechnology. Cognis manufactures natural beta carotene which is used in human nutritional supplements and also as food and animal feed additives; **Enzymatics,** which has a portfolio of projects in antibiotic development, enhancing existing drugs to improve their performance and denaturation of environmental pollutants; **Insulin Mimetics**, a research company developing alternatives to insulin therapy for diabetics; **Meditech Research** (formerly Hyal Pharmaceutical Australia), which is developing a number of therapeutic treatments for cancer, blindness, asthma, melanoma and HIV; and **Provalis plc**, a UK-based biotechnology firm, formerly known as Cortecs International. The firm was founded in Perth but its existing operations in Australia are small; and **TRI-MED**, which manufactures therapeutics and diagnostics aimed at treating *Helicobacter pylori*, a bacterium which causes stomach ulcers.

Western Australia has also been the base for **Biotech International** until this year. Biotech International, which merged with Brisbane-based **Agen Biomedical** in 1999 is now headquartered in Brisbane, but maintains two non-pharmaceutical subsidiaries in Western Australia. Other pharmaceutical firms do not use biotechnology techniques in their production, or are primarily importers and distributors.

There are three companies devoted to diagnostic products and services: **DNA-ID Labs**, which performs parentage and zygosity (twin) testing; **Genetica Biotechnologies,** which was formed to commercialise research into development of a diagnostic test for the parasitic fungus, *Candida albicans*, which causes a wide range of medical conditions and has become an increasing cause of death amongst cancer patients; **Tissue Technologies**, which is undertaking research into prostate cancer in order to develop improved methods of diagnosis.

Western Australia's therapeutics and diagnostics firms, as the second largest group in employment terms, are also linked strongly into local and overseas research. Most of the spin-offs fall in to this category, and the firms themselves are commercialising unique technology arising out of Western Australia's research institutions. Several other firms are working in devices and related health fields that strengthen overall activity in Western Australia.[3] Many of these firms, however, are likely to need access to larger firms in order to commercialise their work (marketing alliances, access to complementary technologies or regulatory advice). Some have already formed such links but others are yet to do so and many are also yet to launch products on to the market. These will need substantial expert advice and high levels of funding to reach their global markets.

Of the firms identified here, only a handful are directly involved in manufacturing and distribution, and some of these have sub-contracted manufacture outside the State. In major areas such as therapeutics, there also appears to be little direct involvement in clinical trials. When clinical trials are conducted, they are often in cities other than Perth e.g. Meditech's trials at Monash University in Melbourne, where the researchers who developed the product are located. It can be argued that companies in Western Australia can exploit their technology through associated companies elsewhere or through favourable licensing agreements and there is little need to take a product to later stage of manufacture in the State. This limits the local returns, does not contribute to the local workforce and fails to build skills with which to develop further products.

[3] *There are several other firms in the medical devices area, including Genesis Biomedical, SIRTEX Medical (formerly Paragon Medical) which listed on the ASX in August and Q-VIS (formerly TELCO Medical technologies) also recently listed.*

4.3.2 Agricultural Biotechnology

Agricultural production in Western Australia totalled $4.3 billion in 1998/99, approximately 14% of the value of Australia's gross agricultural output (i.e. slightly higher than predicted on a per capita basis), which is in turn 3% of GDP. Western Australia has one-third of Australia's total cropping area (7.3 billion hectares out of a total of 21.6 billion hectares). The main crops in Western Australia in 1997/98 were wheat (38% of Australia's production); barley (23%); oats (25.4%); oilseed (27%) and lupins (84%). Western Australia has three agriculture firms listed in the BRW Top 500 companies, Geraldton Fishermen's Co-op, Heytesbury and Sanford Limited. The major multi-national corporations (MNCs) which dominate much of world production and key technologies are generally not represented in Western Australia.

Agricultural biotechnology was identified by respondents as a key area of industrial strength. Western Australia's four ag-biotech firms work predominantly in plant agriculture: **Biowest Australia** has interests in crop improvement, biological testing and agricultural biotechnology consulting; **Grain Biotechnology (Australia)** is a wheat breeding and biotechnology company; **ID+Plus** has developed products to obtain biometric information on livestock for identification and genetic evaluation; and **Microgene** is a microbiology and molecular genetics laboratory that conducts R&D on the natural microbiological interactions in soils in order to maximise crop production.

Western Australia's ag-biotech firms focus on areas of economic strength, wheat and lupins. They have close links into the local research system through associations with SABC and co-location at Murdoch University. These have been established by a small core of individuals who can see business opportunities arising, and who know how to exploit these. However, most smaller companies are likely to need alliances with multi-national corporations to license in key intellectual property. These alliances appear to be absent. Thus, Western Australia's ag-biotech firms are likely to require assistance in managing relationships with MNCs and skilled advice will be essential if they are to succeed.

4.3.3 Suppliers

Western Australia has range of suppliers of reagents and molecules for use in biotechnology-related activities: **Animal Resources Centre**, a government authority, reproduces and sells (including exports) strains of mice for use as laboratory animals;[4] **Fisher Biotec** manufactures and distributes DNA polymers, DNA markers, cloning vectors and buffers; and **Ozgene**, a firm associated with WAIMR and the Animal Resources Centre, produces knockout mice.

Other firms are partially involved in biotechnology, **Biotechna Graesser AP (Australia) Pty Ltd**, a subsidiary of USA-based Biotechna Environmental Technologies Corporation, sells photobioreactors (the BIOCOIL) for culture of algae for aquaculture and other applications. **Australian Biosearch Pty Ltd** supplies molecular and cell biology products, diagnostics kit and reagents.

4.3.4 Chemical, Environment, Other

Industrial Processing

Biotechnology techniques can be applied to industrial processing and can help in lower processing costs, in developing novel precursors, and in waste management. Large firms in this sector include Coogee Chemicals, Canning Vale Weaving and E G Green & Sons.

[4] *Because the Animal Resources Centre is a government agency it is not included in core biotech industry numbers.*

The only core biotechnology firm in Australia targeting this market is **Industrial Biosystems**, a subsidiary of Biotech International. It uses a proprietary xylanase enzyme as a bleaching catalyst in pre-treatment of bleached paper pulp. Its headquarters is in Perth but its main plant is in India as part of a joint venture.

Environment

The Australian environment industry is broadly defined as those firms involved in provision of analytical and waste management services; manufacture of instruments and other equipment for monitoring, reduction and control of pollution and waste; and provision of resources in water, renewable energy, land management and recovery. The Australian industry had a total turnover of $7.8 billion in 1995/96, of which 56% involved government agencies (utilities, public services and research). In the private sector the main components are manufacturing (10% of total), services (9%), agriculture (3%) and mining (2%).

Western Australia has several firms operating in environmental biotechnology: **Artemia Biotechnology Centre**, which specialises in saline ecosystems and hyper-saline waste-water effluent treatment for nutrient recovery and extraction of fine chemicals; **BioLogic International Ltd**, a listed public company which is involved in organic waste conversion using biodigestion. BioLogic's head office is registered in Western Australia but its main operations are elsewhere in Australia and overseas; **Environmental Solutions International Pty Ltd**, which uses bacteria for waste treatment, to address a number of environmental and waste management issues including low and high strength waste-water and sludges; and **Pro Micro Pty Ltd** which consults on microbiological solutions to waste problems and manufactures its own microbial mixes.

Other firms, not included as core, include **Aquabiotics Pty Ltd** which designs and manufactures products to eliminate iron and sulphur reducing bacteria infestations in ground water bores and delivery systems; and **Chemeq Ltd**, a publicly listed company, which researches, and is soon to manufacture anti-microbials for a range of users.

Environmental/waste biotechnology firms in Western Australia were the largest employers, primarily because they are all actively marketing. They had the highest proportion of exporters and can operate more independently as the regulatory pathway is less difficult. Western Australia also has a higher than average share of these firms hence they are a group of some strength. These firms are serving an area of growing need and importance to other economic sectors, particularly manufacturing and mining.

Other Sectors

Western Australia has 19.9% of Australia's total mining production. The main activities within mining are extraction of coal, oil and gas ($5.2 billion), iron ore ($4 billion) and gold production ($3.2 billion). Western Australia's gas output comprises 29% of total national production, its crude oil output is 80% of total production and its gold output is 76% of the Australian total. Over half the State's new investment per annum is going in to mining and the State Government expects substantial expansion in sub-sectors such as oil and gas as a result of new projects and high quality R&D. Employment in the sector in 1997/98 was 16,000 people.

Of the top 44 publicly listed mining companies in Australia, 10 are headquartered in Western Australia. They include Woodside Petroleum, Sons of Gwalia and Aurora Gold. Griffin Holdings and Phosphate Resources are also listed in the Top 1000 private companies.

The high level of mining activity in the State has attracted Australia's only mining biotechnology firms. **Bactech Australia** uses bacteria to process gold ores into gold, using a patented technology that originates from South Africa. **Lakefield Oretest Pty Ltd** works in the field of bacterial leaching of sulphidic minerals. The company has access to a number of bacterial strains and is involved in both vat leach technology and thin-layer heap leach technology. **Pacific Ore Technologies (Australia) Pty Ltd**, a subsidiary of listed Western Australian-based firm Titan Australia, uses it proprietary bacterial culture to process nickel oxides. It is aided in this work by a START grant of $880,000.

There are several other Western Australian firms which have an interest in bioleaching or other aspects of biotechnology. **AMMTEC Ltd,** listed on the Australian Stock Exchange is one of the largest metallurgical and mineral testing consultancies in the world and provides advice on how ore will respond to extractive processing, including bacterial leaching. **Wiluna Gold** has built a plant based on biological sulphide oxidation at its site, and **Peko Rehabilitation Project Pty Ltd** has just received a State WAISS grant to research low-capital in-situ leaching of tailings to recover cobalt, copper and gold.

Western Australia's mining companies are also investing directly in non-mining biotechnology as venture capitalists, in the same manner as many mining companies have invested in information technology.[5] **Britannia Gold** has recently announced that it has obtained the rights to evaluate and commercialise a native-plant-derived anti-cancer agent from Queensland-based Curacel International Pty Ltd. **Duketon Goldfields Ltd**, which has some projects in Western Australia, has just purchased Swiss firm Genetype AG, which has subsidiaries in Victoria and NSW, and has renamed itself **Genetic Technologies Corporation**.

There is an opportunity to link biotechnology and mining in ways that may open up further investment into biotechnology and provide a means of linking fledgling biotechnology activity into the State's main areas of economic strength. This is a particular opportunity given recent initiatives by larger mining firms as venture capitalists.

4.3.5 Food and Beverages

The food industry in Western Australia is also slightly smaller than average compared to the rest of Australia. In 1995/96 the largest sub-sectors were meat and meat products ($824.7 million), other food including confectionery manufacture and seafood processing ($702 million), beverages and malt manufacturing ($579.6 million), and dairy products ($357 million). The Western Australia Government has developed a strategy for developing the food industry. It concentrates on developing export opportunities, attracting finance and overcoming growth impediments. Western Australia's largest food firm is Peters and Brownes.

There are only three food and beverage biotechnology-based firms headquartered in Western Australia: **AquaCarotene Ltd**, a listed public company, grows, harvests and processes natural beta carotene from *Dunaliella salina* culture; **Australian Spirulina Farms Pty Ltd** is working on the development of the production of *Spirulina*, a nutritional supplement, and *Spirulina* products; **Biotest Pty Ltd**, a subsidiary of Biowest Australia, has licensed a diagnostic test to detect the amount of altered genes in foods and sells its diagnostic services to firms around Australia.

[5] *Sons of Gwalia was an early, patient investor in Biotech International, so the phenomenon is not as new as it may seem.*

4.3.6 Support Services for Biotechnology

The service sector is a vital part of biotechnology-related industry. Services such as banking and finance, particularly venture finance, are required to provide funding for research and development over a long time period. Patent and intellectual property advice is needed to protect inventions. Regulatory affairs advice is required to ensure products can be successfully registered and comply with good manufacturing practice.

In Australia, the number of venture capital providers in the market has doubled in the last five years and the Commonwealth Government has also promoted venture investment in technology-based firms through the establishment of five Innovation Investment Funds (IIFs), three of which (Biotechnology Investments Ltd, CM Capital, Rothschild Biosciences) specialise in biotechnology. Institutions such as Colonial First State and SAGE Investments have recently set up funds for the biotechnology sector and there has been a surge in the number of biotechnology-specific pooled development funds.

Respondents were generally critical of the lack of finance available for commercial activities locally, but identified potential sources from overseas and from wealthy individuals.

> *"If you want to raise money don't do it in Australia. If you have a reasonably good business plan you can raise it more easily overseas", Agricultural researcher.*

> *"There are a lot of wealthy people but if you have a good project there are no problems getting money for research", Health researcher.*

The venture capital sector in Western Australia is, however, advancing towards technology based investments. **Genetic and Medical Capital** has recently been established in Perth. It aims to provide the capital resources, infrastructure and expertise necessary to allow developing genetic and medical technology to list on the Australian Stock Exchange. In September another Perth-based firm, Mid-East Minerals, was renamed **Tomorrow Ltd**. It is a new investment firm which will invest in information technology and biotechnology companies with high growth potential. **Foundation Capital** has raised about $60 million of its targeted $75 million Foundation Millennium 2000 Fund. This will initially have a PDF structure but other structures can be added as required to maximise investment potential and tax efficiency. Areas of interest for Foundation Millenium 2000 include biosciences. They are also a short listed bidder for an IIF license (see Chapter 5).

Both **Wray and Associates** and **Kelvin Lord Patent Attorneys** have specialised advisers in biotechnology. Other patent attorneys from interstate are also used by research and industry in Western Australia. **Ernst & Young**, a large accounting firm, has local biotechnology specialists on staff. The **220 Group** of companies comprising AUSTEP, Capital Technologies, First Corporate, Qwen Legal and Corporate as well as TechStart specialise in the needs of fast growth companies with respect to management, capital, intellectual property, corporate, accounting, legal, market development and partnering.

4.3.7 Industry and Consumer Associations

There are several national industry associations which have branches in Western Australia but the only industry association running biotechnology-specific events is the **Australian Biotechnology Association**, which is the peak industry association for individuals and companies interested in development of biotechnology in Australia. One of the ABA's nine

directors is based in Western Australia and the Western Australian Branch of the ABA is the oldest and longest running Branch. Its establishment was initially facilitated by a small grant from the Western Australian Government. In the last two years it has:

- Organised an international conference entitled "Biotechnology, Biodiversity and Biobusiness" in November 1998, in conjunction with the Department of Conservation and Land Management, the Australian Biological Resources Study and Murdoch University;
- Run regular symposia highlighting biotechnology research and business in Western Australia;
- Provided an e-mail based information and awareness service to local members on regulatory and industrial issues; and
- Run an annual high school essay competition for year 11 and 12 students on a biotechnology-related topic with prizes sponsored by industry.

The **Health Consumers' Council** is a consumer body funded by the State Health Department. Its aims are to help the public understand health issues and the health system; to ensure that the health system is accountable for the funds it spends; and to provide access to advocacy, information, training and support. It participates in issues relating to biotechnology through making submissions to government. e.g. comments on the draft Gene Technology Bill 2000.

4.3.8 Manufacturing Capacity

Western Australia is lacking in manufacturing facilities for biotechnology-related products, for example TRI-MED's manufacturing operations have now been outsourced to the USA and Genetica Biotechnologies' manufacturing is done in Brisbane by PanBIO. Elsewhere in Australia there are several firms which manufacture for themselves and sometimes for others. Thus in other major cities there are facilities that can be hired for use by firms which do not have their own capacity (Table 4.5). While SABC does provide access to some facilities for small firms these are limited and have not been taken up by more than three or four firms.

Table 4.5 Examples of Contract Production Companies in Australia

City	Firms
Brisbane	Progen Industries, PanBio
Sydney	Biotech Australia, Cellabs, UNSW
Melbourne	CSL, AMRAD, IDT, CSIRO
Adelaide	GroPep, BresaGen

4.4 Other Factors Influencing Western Australia's Economy

Western Australia has strong and viable mining and petroleum/natural gas industries which contribute substantially to the Australian economy. However, the economic impact of commodity-based industries, especially mining, will gradually decline as resources diminish. Competition from developing countries will also drive down prices and, since Western Australian technologies are regarded as highly efficient now, there will be pressure to upgrade these further for refinement and to enter niche market sectors. At the national level,

Australia's terms of trade have declined over the past 50 years because of our dependence on exporting commodities and resources rather than manufactured goods, which offer greater growth opportunities. There is evidence that this trend is changing but Australia, and particularly Western Australia, remains dependent on these sectors. Although mining now contributes less to the Western Australian economy than it did 10 years ago, relative to the rest of Australia Western, Australia is now more dependent on mining than other states.

Further, the mining industry is a low employment industry and many specialists originate from outside Australia. Profits are readily exported and despite the high revenues generated, the take-home pay of households in Western Australia compared with the Gross State Product is low in Western Australia relative to other States.

There is a clear and consistent increase in knowledge-based industries and manufactured products by the major developed countries. World exports of high technology engineered products are increasing with a trend to high technology rather than low technology manufacturing areas. It is of interest that the Western Australian mining industry recently supported a project called "Minds to Mines" to develop information technology for the mining industry. The strategy is to use existing resources to meet a technology need with future potential across disciplines.

Although these changes are gradual, global political and economic pressure will force Western Australia to look at innovative ways to generate income. There are good arguments for more biological and high technology-related industries in Western Australia which can build a knowledge-based economy. Biotechnology in particular can add to the strengths of the agriculture and mining industries. It is interesting that the recent review of the R&D in the minerals and petroleum industry showed that it is weak and fragmented and did not contribute to the State's knowledge-base relative to its importance in the economy. The report did not investigate the potential role of biotechnology to support the mining industry.

4.5 Greenhouse Gas Emission and Global Climate Change

Australia, as a whole, is particularly carbon-dependent and is under pressure to reduce fossil-fuel-based industrial activities. Although Western Australia is relatively rich in resources, its major industries are strongly dependent on carbon and natural gas supply. In particular, the mining industries are almost entirely fossil fuel based and dependent on coal, petroleum and natural gas. The Western Australian resource industries alone are expected to use up over 75% of Australia's allowable emission up to 2010 under the Kyoto Protocol. Aluminium smelting accounts for about 25% of this quota.

Western Australia is therefore both the major supplier of mineral resources and therefore of wealth to Australia, but also the highest consumer of fossil fuel and contributor to the carbon deficit which Australia is expected to reduce. Certain biological industries can help reduce greenhouse gas emission and offset use of fossil fuel. For example, new tree types which control salinity and grow under harsh conditions can provide multiple environmental benefits.

Climate change can also alter the markets and productivity of Western Australian agriculture, forcing changes in traditional practices. Already, changes in average temperature are reducing the quality of Western Australia's grain and increases in salinity and land degradation have rendered land non-productive. However, climate change will be slow and could allow adaptation to new techniques. It will provide an opportunity for innovative solutions.

4.6 Natural Resources

The vast land area of Western Australia provides the State with a major natural advantage – its natural resources, which, with the exception of mining are largely untapped. This uniqueness was recognised by survey respondents, who listed land, biodiversity and climate range as three of the State's major natural resources.

Australia is one of the eight countries in the world with a "megadiverse" biota. Significantly, of these countries, only Australia has a sophisticated and highly capable science base with which to explore and research this range of natural materials. The regions in Australia with greatest biodiversity are in Queensland and the south-west of Western Australia, with south-west Western Australia the most biodiverse region in Australia. Western Australia is therefore in a unique position in having a rich source of natural material to screen for drugs and novel chemicals.

A Wet Tropics Research Centre has been set up in Dampier by the Australian Institute of Marine Science and $6 million has been allocated to a North West Shelf Environmental management study. This will supplement State funding dating from 1998 and is being undertaken by DEP, CSIRO, AIMS and several oil and gas firms. There is also the Ord Bonaparte catchment Study involving CSIRO and several stakeholders. Recently a Strategic Research Fund for the Marine Environment with funding of $20 million over six years has been established as a joint venture between the CSIRO and the Western Australian State Government.

The Department of Conservation and Land Management has also improved access to its database of flora and fauna samples by licensing Bioprospect Ltd to screen these for active molecules. The scope of this license and the capability of this company are limited however, and further development of these resources will need a well co-ordinated effort of several Government departments together with research groups and companies. Screening of marine organisms is also being conducted by the Australian Institute of Marine Science and this involves several local partners.

4.7 Alignment with Asian Time Zones

Western Australia is in approximately the same time zone as the major population centres of the world including Singapore, Japan and Korea, and is the closest Australian state to South Africa and India. This gives it an advantage over other Australian States in dealings with these countries, which are projected to contain 78% of the world's population by 2025. Asia is also projected to have 45% of world GDP by 2020, with China, India, Indonesia and Japan being ranked in the largest economies.

This geographic location provides Western Australia with a number of opportunities:

- Provision of goods (e.g. health products, food, chemicals) and services (e.g. environmental and waste management services) to Asian economies and South Africa, either alone or in joint ventures;

- Ability to act on behalf of or link with firms in Europe or the USA to take advantage of its alignment with the Asian time-zone;

- Ability to provide technical, organisational or management inputs to Asian firms;
- Being able to draw upon resources, skills and expertise from the business community within the Asian region.

Western Australia cannot be complacent, however, and must work to ensure that its natural advantage in the Asian time zone is converted to State economic benefit. While Western Australia's agricultural exports already target this region, Asian economies are not facing the same resistance to genetically modified crops as has been evident in Europe. Western Australia risks losing these markets if it does not adopt genetically modified crops to satisfy Asian demand.

Singaporean investors are also seeking good biotechnology deals in Australia at present and, with Australian investors, have recently granted $17 million in venture capital funding to establish ES Cell International Pte Ltd (a spin-off from Monash University) in Singapore under Singaporean Government provisions to encourage medical infrastructure investment. Companies in Brisbane are also reporting strong interest from Singaporean investors who urge listings on Asian stock exchanges.

4.8 Public Attitudes

Recent surveys of public attitudes to the environment have shown Western Australia had the highest proportion of people who believed that the quality of the environment had declined. However, there is also a high level of concern about genetically modified crops and general reluctance by consumer groups regarding genetically modified food. The Government must have effective public awareness programs to ensure there is greater public understanding of biological processes if it is to introduce policies and programs which will increase biotechnology research and industry.

New biotechnology-based products could impact positively on the environment and biotechnology-based medicine and waste treatment methods are already well-accepted by the public. However, the present GMO and food labeling debates could limit some agricultural research and commercialisation opportunities. These are significant issues for Western Australia. The State Government has been giving out mixed signals regarding commercial growth of GM crops and these are already damaging local industry, which reports an inability to access technology held overseas because of perceived difficulties of commercial use in Western Australia. The State's equivocal political position was commented on by many respondents.

> *"Until recently the State Government has been conspicuous by its absence in the debate about genetically modified foods", Industry adviser.*
>
> *"AgWA has failed to take the responsibility to have a position on GMOs", Agricultural researcher.*

The State Minister for Primary Industries has now announced establishment of a taskforce to determine the value of GM crops to the State, starting with canola. This has drawn together a number of interest groups and stakeholders in taking a strategic look at the role of biotechnology in the State's farming and agriculture systems. These developments, will at least enable all interest groups to have input into the development of long term strategy and should also increase public awareness of issues in the GM debate.

If the Government takes a balanced and responsible position based on scientific data together with broad public opinion, it can be seen as progressive. Chapter 7 has examples of how governments elsewhere are approaching these issues.

4.9 Conclusions

Areas of industry strength relative to other Australian states are environment/waste management and agriculture.

Western Australia has more biotechnology firms than Queensland, but in relation to other States Western Australian-based firms are small (half the employees), have fewer patents (one-third the national average) and little or no clustering. The lack of clustering is due in turn to low proportions of spin-offs companies from research centres, and this also contributes to the low levels of networking between firms and external organisations.

Generally speaking, the biggest issues facing Australian biotechnology firms are: access to core intellectual property held by multinationals, access to skilled advice/finance and access to markets. These factors affect different market sectors in different ways but all are of concern in Western Australia. The problem is particularly acute in ag-biotech, where multinationals hold much key intellectual prpoerty, and therapeutics, where the regulatory system slows time to market. In both these sub-sectors the market is global, not local, and firms may also need assistance in reaching potential customers.

Focus group participants and survey respondents identified these difficulties but also saw opportunities in the overall strength of the Western Australian economy; the natural resources of biodiversity, time zone and the research system as a whole. Biodiversity is of particular interest for the development of new therapeutics and in environmental and mining biotechnology, where indigenous populations of bacteria can form the basis of remediation products.

Firms do not appear to be taking advantage of the other opportunities presented by location in the Asian time-zone and the ability of the local research system. It appears that Asian firms are already seeking opportunities in Australia but are so far focussing on the Eastern States. Western Australia could be left behind and fail to build on its current strengths despite obvious areas of opportunity.

The environmental and mining biotechnology activity present the greatest opportunities to link biotechnology with economic strengths. Western Australian biotechnology firms should be developing strategies to seek investment from the mining community to help build local strengths. The mining industry is showing some interest as venture capitalists in biotechnology. For example Sons of Gwalia was an early stage patient investor in Biotech International.

At a national level, biotechnology is moving very fast. Western Australian firms need to link in with events at this level and internationally in order to ensure they keep pace.

The analysis in this and the previous chapter show that is an excellent base for a larger biotechnology industry and good grounds for strong support by government and industry for several biotechnology initiatives in Western Australia. There are also good economic reasons for an expanded industry and significant financial support by the State Government matched by federal funds and industry. These are:

- The main export industries in Western Australia, mining and agriculture can use biotechnology processes to improve yield or efficiency and there is a core group of firms which are aimed at these markets and able to expand internationally to form the basis of a biotechnology cluster in Perth.

- The recent report, "Drivers and Shapers of Economic Development in Western Australia in the 21st Century", makes the case for a diversified economy by targeting new and emerging technologies. For biotechnology, this support needs to be selective and there are some organisational and infrastructure issues which require attention.

- Salinity and green-house issues will have a major effect on the Western Australian economy and biotechnology can help address these issues.

- The key agricultural products wheat and barley are now the target for development of genetically modified crops. Markets for Western Australian products will be severely challenged by these new crops.

Significant changes have already taken place during the preparation of this report, and the climate for commercialisation in Western Australia is increasingly positive. The next chapter examines the role of Government in Australia in biotechnology industry development and later chapters place this in an international context.

5 Western Australian Government's Activity in the Australian Context

The growth of commercial biotechnology in Australia and its importance in the international context has led to new Government interest in mechanisms to support the industry and the research system that feeds ideas to it. This chapter describes existing Western Australian State programs and compares these to programs of other states and of the Commonwealth Government.

5.1 Western Australian Government Co-ordination and Responsibilities

At the Ministerial level, the Science and Technology Council co-ordinates implementation of the State's Science and Technology Policy. Under this, the Co-ordination Committee on Science and Technology (CCST) comprises heads of agencies with responsibilities in S&T, together with the Chair of TIAC and a representative of the Higher Education Council. The CCST also has affiliate members from other agencies and can establish and co-opt external representatives onto sub-committees to address particular issues.

Responsibility for biotechnology industry development is spread across several government agencies, based around market sectors:

- Agriculture Western Australia (AgWA) for agriculture;
- Department of Commerce and Trade (DCT) for manufacturing (e.g. food, chemicals including pharmaceuticals) and service industries, and broader issues relating to trade and regional development;
- Department of Conservation and Land Management (CALM) regarding natural and marine nature reserves;
- Department of Environmental Protection for waste management and environmental and emission standards;
- Fisheries Western Australia for fish, marine and aquatic resources and industry;
- Health Department of Western Australia for health standards and services.

An Inter-Departmental Committee on Gene Technology comprising representatives from several departments (and the Ministry of the Premier and Cabinet) has developed Western Australia's position in Commonwealth-State consultations on issues such as national regulatory frameworks for gene technology and labeling of genetically modified foods. The Premier's Department is also chairing an Inter-Departmental Committee of natural resource management agencies to develop a State policy on access to biological resources.

Western Australia has no policy position on the adoption of genetically modified crops and foods. This policy gap is impeding Western Australian companies seeking venture capital and intellectual property for agricultural biotechnology.

5.2 Western Australian Government Programs to Support Industry Development

The Western Australian Government has a range of programs available broadly to firms undertaking R&D, which are administered in the context of the Science and Technology Policy which was released in 1997. In the recent 2000/01 budget, over $70 million was allocated to science and technology. Five State programs are reviewed here: Centres of Excellence, the Medical and Health Research Infrastructure Fund, WAISS, Lotteries Commission and International S&T. None of these, however, are specific to biotechnology, although several biotechnology firms and research organisations have received funding.

The **Centres of Excellence for Industry-Focused Research and Development Program** (Department of Commerce and Trade) aims to increase the State's research capability. It provides infrastructure funding to support and facilitate the establishment of S&T research centres with a significant base in Western Australia. State funding leverages other funding (usually Commonwealth and private sector) and is generally limited to 50% over three years. The Centres, however, are expected to have a minimum life of five years, and must provide a business plan showing how funding during and beyond the period of State support is to be sustained. Most of the assistance has been in the range of $0.25 million to $1 million for hard (buildings and equipment) and soft (key people) infrastructure. Smaller amounts are available to assist in the preparation of business plans and applications for larger grants including Co-operative Research Centres. If the latter are successful they qualify for additional funds at a level determined by the amount of Commonwealth funds brought into the State. The 2000/01 State Budget has provided an additional $5.4 million to maintain existing and establish new centres. Of this, $1.4 million is in new funding.

The total amount of Centres of Excellence funding over the life of the program is $22.422 million. Centres that have a biotechnology component received 30.3% of the total amount funded. Of this, 30% was for centres operating in agriculture, 34% for environment centres, 18% for therapeutics and the remainder to instrumentation. New funding for several centres was announced recently. This included funding for a Centre of Excellence in Cleaner Production to promote the implementation of cleaner production technologies and practices, particularly to smaller to medium sized enterprises in Western Australia. It is not directly involved in biotechnology. The Centre promotes a preventative environmental management strategy that aims to prevent all forms of pollution. As such, it should be encouraged to investigate strategies which involve biotechnology.

Table 5.1: Centres of Excellence Involved in Biotechnology in Western Australia[6]

Organisation	Sector	Approved Grant ($)
Centre for Land Rehabilitation (two separate grants)	Environment	534,000
Centre for Organic Waste Management	Environment	500,000
CRC for Australian Cotton	Agriculture	275,000
CRC for Conservation and Management of Marsupials	Environment	79,000
CRC for Legumes in Mediterranean Agriculture	Agriculture	660,000
CRC for Pest Animal Control	Agriculture	414,000
CRC for Premium Quality Wool	Agriculture	342,000
Environmental Technology Centre	Environment	370,000
State Agricultural Biotechnology Centre	Agriculture	350,000
Western Australian Biomedical Research Institute	Therapeutics	998,000
Western Australian Centre for Microscopy	Instruments	977,000
Total Funding		**5,499,000**

Source: Data supplied by Dept of Commerce and Trade.

The **Medical and Health Research Infrastructure (MHRI) Fund** is administered by the MHRI Council. It funds researchers who have been successful in obtaining grants from competitive peer reviewed grant sources and hence acts as a "top up" for researchers whose R&D has already been recognised nationally (Table 5.2). For example, funding to ICHR covers 30% of infrastructure costs, the remainder coming out of other affiliations.

Table 5.2: MHRIF Funding to Key Research Institutions in Western Australia

Group Funded	Amount ($)
Australian Neuromuscular Research Institute (includes one researcher based at Curtin University)	221,000
Murdoch University	30,000
UWA*	1,550,000
Lions Eye Institute	274,000
Telethon Institute for Child Health Research	825,000
Curtin University**	76,000
Total Funding	**2,981,000**

**Includes $483,000 managed by UWA for the Western Australian Institute for Medical Research (WAIMR).*
*** Researcher co-located at WAIMR. (figures rounded to nearest thousand).*

The Department of Commerce and Trade administers the **Western Australian Innovation Support Scheme** (WAISS), which aims to stimulate business R&D and innovation by small to medium enterprises and to develop these firms' international competitiveness. WAISS is intended to complement other programs at Commonwealth level.

[6] *Two additional CoEs, the Centre of Excellence in Mass Spectrometry and the Centre for Management of Arid Environments, could potentially work in biotechnology in the future. However, according to their directors, they are not currently doing so and have no plans to enter this field.*

Since its inception WAISS has supported 106 projects over 12 funding rounds, with grants totalling $4.9 million. The scheme has generated an additional $1.59 of R&D investment by industry for every WAISS dollar. The recent review of WAISS found that 70% of companies involved in WAISS had improved their performance and that 90% of recipients had increased their rates of commercialisation. Biotechnology-related projects have received a total of $576,750 (11.7% of total funding).

Table 5.3: WAISS Funding for Biotechnology-Related R&D 1993-2000

Company	Project	Amount ($)
Australian Spirulina Farms	Establishment of Spirulina industry in Western Australia.	50,000
Bactech Australia	Control of Thiocyanate toxicity.	74,000
Environmental Solutions International	Development and preliminary design of an Enersludge plant for Western Australia.	50,000
Genetica Biotechnologies	Krusei Diagnostic Test Kit.	45,000
Perth Bone and Tissue Bank	Osteo-induction of insoluble bone gelatin.	50,000
Peko Rehabilitation Project Pty Ltd	Low-capital in-situ leaching of tailings to recover cobalt, copper and gold.	152,000
Tri-Med International Pty Ltd	Development of a home-test kit for *Heliobacter pylori.*	156,000
Total		**577,000**

Source: Data from Department of Commerce and Trade (rounded to nearest thousand).

Respondents spoke positively of WAISS but felt that the grant size was too small. This is a common problem with State level grants in this sector, where the amount firms need to successfully bring technologies to market is much larger than in traditional sectors.

5.2.1 Lotteries Commission

The profits from the sale of lottery products are returned to the community in a variety of ways according to the provisions of the Lotteries Commission Act 1990, for the support of public health services, the arts, and sports organisations. The Lotteries Commission also distributes directly a proportion of the profits from lotteries sales through grant funding programs. Several research institutions have received funding for biotechnology-related and biomedical projects and equipment (Table 5.4). In 1999, such grants made up approximately 1% of Lotteries Commission grants. Guidelines for these grants have recently been amended to encourage collaboration.

Table 5.4: Lotteries Commission Large Grants 1999

Organisation Name	Amount Granted ($)
Curtin University, Department of Bioengineering	50,000
Curtin University, Kalgoorlie Campus	50,000
Royal Perth Hospital Trust Fund	31,000
TVW Telethon Institute for Child Health Research	173,000
UWA, Department of Biochemistry	149,000
UWA, Department of Pharmacology	52,000
UWA, Department of Surgery	5,000
UWA, Department of Anatomy and Human Biology	243,000
UWA, Western Australian Heart Research Institute	54,000
Western Australian Agribusiness Development Centre	50,000
Total	**857,000**

Source: Lotteries Commission Annual Report 1999 (rounded to nearest thousand).

5.2.2 International S&T Collaboration (Department of Commerce and Trade)

This program supports international interaction in science and technology research and commerce. The program, which has operated for three years, has from $80,000-$100,000 per annum. Funding has been used to support a range of biotechnology-related activities including support for Western Australian biotechnology organisations attending international trade shows and conferences (e.g. BioTechnica in 1999 and BIO in 2000); EU and ASEAN briefings on opportunities for research collaboration; and promotion of agricultural and environmental expertise by the Crawford Fund for International Agricultural Research. In 2000/01 funding will be allocated to develop a capability register of Western Australian companies seeking international S&T collaborations within the context of the Department's strategy to facilitate international collaboration.

Respondents were generally critical of the State Government for failing to participate more strongly in conferences such as BIO, which is the largest international conference and trade show and in 2000 attracted 10,200 delegates and 1500 exhibitors.

> *"Western Australia won't be at BIO. There's a feeling that Queensland and Victoria have done the running on that", Business adviser.*

5.3 Biotechnology Related Programs in Other States

Several states are currently competing with each other to establish themselves as centres of biotechnology. While all states have funded medical research infrastructure (through medical research institutes) for many years, many now offer specific support for biotechnology in addition to the competitive industry support programs which offer grants for R&D, business development, etc.

5.3.1 Queensland

The Queensland Government has a range of programs to support new technology-based start-ups. Its main program is an Innovation Start-Up Scheme, which provides competitive grants to support innovative SMEs, start-ups and spin-off companies from public sector research institutions. The first round, currently being assessed has attracted 98 applications. About 10 will be selected, with each to receive approximately $75,000. It has also provided $1 million to support the establishment of a technology incubator in Brisbane. This will assist in the early stages of 10-15 technology-based growth companies at any one time.

Queensland has headed the drive to focus on biotechnology as a core local industry. In 1999, the Premier personally launched a $270 million, 10-year Bioindustries Strategy for Queensland at BIO99, the world's largest annual biotechnology industry conference. An amount of $20 million was allocated in 1999/2000 for development of three major biotechnology research centres, starting with a major Cancer Research Centre at the Queensland Institute of Medical Research. The Centre will be equipped to develop and trial experimental therapies for cancer treatment.

The Government also established the Queensland Bioindustries Office within the Department of State Development to identify and promote emerging biotechnology opportunities. The Bioindustries Office will address regulatory policy, development of business skills and incubation, and strategic alliances at State, national and international levels. In relation to the latter, it has established a formal alliance with Maryland, USA. A Bioindustry Advisory Board has also been established and the Premier's Department has released for discussion a code of ethical practice for biotechnology.

Active political commitment was reinforced at BIO2000 in Boston, where the Premier again headed Queensland's mission and a five-day Bio-partnering Program organised by the Queensland Trade and Investment Office in Los Angeles. The most recent initiative has been development of a program at Queensland University of Technology to provide appropriate expertise to the industry by combining education in biotechnology with education in business at all tertiary levels.

5.3.2 Victoria

The Victorian Government has recently initiated several new programs to support general industry development, including a $20 million Technology Commercialisation Program to deliver business support and development services to start-up technology companies; funding of a new competitive grant program for research infrastructure and a strategic audit of Victorian industry to assess the impact of new technologies. Like Queensland, the Victorian government is also fostering international links, in this case through partnering with Boston.

The Victorian Government announced its new Bio21 strategy in July. Bio21 aims to bring together Victoria's strengths in research to create a network of biomedical research, commencing with a $400 million investment at Parkville, of which the State Government will fund $50 million. The remaining funding will come from the University of Melbourne ($50 million), private donors ($30 million) WEHI ($4 million) and investors ($262 million). The project will house 1,000 scientists, provide space for biotechnology incubators and industry, and create satellite centres linking Melbourne University, the Royal Melbourne Hospital and research institutes.

Individual research institutions in Victoria are also forming alliances that strengthen biotechnology activity in the State. Victoria University and Austin Research Institute have recently announced a partnership to form the Victoria Institute of Biotechnology (VIB), which will be located in Werribee. It will include a centre for drug design and development and will collaborate with other research groups in the Werribee Technology Precinct and develop large-scale fermentation facilities to produce recombinant proteins including antibodies. The VIB will also develop new training programs to provide science graduates with business skills in management of intellectual property and other areas. The group is seeking funding support from the State Government for the initiative.

5.3.3 New South Wales

New South Wales is increasing its investment in health and medical research infrastructure under its Research and Development Infrastructure Program to $20.5 million by 2001/02, an effective doubling. However, this measure addresses the research base rather than industry development.

While it has not committed large amounts of funding to biotechnology-specific activities, it is being advised by a biotechnology working group, under the auspices of the NSW Innovation Council, and has formalised a partnership with San Diego in an effort to stimulate biotechnology linkages. The NSW government has also provided funding for a building to house a Biomedical Business Incubator at the Australian Technology Park, Eveleigh and the State Government also supports firms attending BIO and other trade shows when part of a designated State delegation.

5.3.4 South Australia

South Australia has a range of general support programs include Centres of Excellence incubators, support for development of business entrepreneurs (Executive Fast Track) and enterprise workshops to improve the understanding of technology transfer in the State. The Government also assists with up-front establishment costs for new companies or those relocating to the State, including lease back arrangements and concessions based on total employment generated.

In a recent State Budget and policy statement the Government announced a newly formed Innovation, Science and Technology Council, which will co-ordinate the government effort in supporting R&D, and a Bio Innovation Office to advise the Premier on the development of the biotechnology industry. It has also recently established a Plant and Food Biotechnology Centre at a cost of $4.7 million.

5.4 Commonwealth Programs

Generic Commonwealth programs to support innovation, technology transfer, business R&D and venture finance include:

- **125% tax concession on eligible R&D expenditure** in Australia for profitable companies is a key incentive. Few Western Australian companies benefit from this tax break because they are not of sufficient size to generate tax.

- **Pooled Development Funds** which provide tax-exempt dividends for shareholders, capital gains tax exemption and a reduced corporate tax rate of registered investment companies. There are several PDFs in Western Australia but most are not involved in biotechnology (see Chapter 4).

- **Export Market Development Grants** which support exports by Australian firms; but many of the biotechnology companies in Western Australia do not yet export.

- **Commercialising Emerging Technology (COMET)** which provides support for emerging technology companies to bring their products to market. Two assistance schemes are available under the COMET program. These are Tailored Assistance for Commercialisation and Developing Management Skills. Western Australia has one Case Manager to manage these program and he has had 27 successful applicants.

- **The Innovation Investment Fund (IIF)** program provides matching funds for venture capital investors establishing funds targeted at small, technology-based firms. Two of the five initial licensees under the IIF Program specialise in biotechnology and all are based on the East Coast.

- **R&D START** provides grants and loans up to $15 million at up to 50% of the total R&D expenditure over three years, and is intended for all companies under $50 million turnover, including companies who cannot take advantage of the tax concession. Western Australian firms have been moderately successful, in obtaining grants. From 1997-2000 Western Australia has been awarded 14% (six of 43) grants in biotechnology and biomedical science (value approximately $5 million). The majority of these, however, have been to instrumentation firms (e.g. Q-VIS) rather than biotechnology as defined in this report.

- **Co-operative Research Centres (CRC)** program, which involves formal strategic agreements between universities, government and industry and aims to stimulate the generation of commercial products and services. Western Australia has been awarded five CRCs out of the 67 granted to date, a number roughly in line with per capita rates. Only one (CLIMA), was involved in biological science and biotechnology and CLIMA's funding has not been renewed beyond June 2000. However, Western Australia is also core participant in five other CRCs (Appendix E).

Western Australia has had its proportionate share of successes from grants for basic research administered by the Australian Research Council, and the National Health and Medical Council. Further details are in Appendix E.

5.4.1 Biotechnology-Specific Programs

The Federal Government has established Biotechnology Australia as a multi-portfolio agency. Biotechnology Australia is located within the Department of Industry, Science and Resources, but includes representatives from the Departments of Health and Aged Care; Education, Training and Youth Affairs; Environment Australia; and Agriculture, Fisheries and Forestry. It is directed by a Commonwealth Biotechnology Ministerial Council.

The **National Australian Biotechnology Strategy** was launched in July 2000 and will provide a framework for Government to successfully regulate and promote biotechnology as a key technology of the future. Under the strategy, the Government proposes to facilitate research of biotechnology and its application, while safeguarding human health and the environment, and maintaining consistent regulatory standards.

Of the $30 million budgeted for 2001, $20 million will be used to establish the Biotechnology Innovation Fund which it is hoped will bridge the commercialisation gap between research discovery and an identified commercial product. The Government will seek matching funds for the BIF from the private sector and State governments and the program will begin in 2001. The remaining $10 million will be spread across a number of programs, in particular, $3 million is for the Biotechnology Public Awareness Program; $3.3 million for a study on identity preservation and segregation of supply chains in the food industry (genetically modified/non-genetically modified crops).

In 1999, the Federal Government established the **Interim Office of the Gene Technology Regulator** (IOGTR), pending the passage of legislation to establish the Office of the Gene Technology Regulator (OGTR), which will co-ordinate and oversee all aspects of gene technology regulation in Australia, including the release of genetically modified organisms (GMOs) and genetically modified products. It will co-ordinate the functions of several existing agencies:

- Genetic Manipulation Advisory Committee (GMAC), which has been responsible for making determinations on the safety of activities involving genetic manipulation in Australia;
- Australia New Zealand Food Authority, which is responsible for food safety, assessment;
- National Registration Authority which is responsible for crop and agricultural chemical safety; and
- Therapeutic Goods Administration, which regulates introduction of drugs and medical devices.

The OGTR will co-ordinate applications relating to GMOs, regulate GMOs that fall outside the remit of existing product regulators and harmonise risk determinations. The Gene Technology Bill, which sets out the operations of OGTR has been referred to a Senate Committee, which is currently holding public hearings. The OGTR will have a policy of cost recovery and will work closely with other Commonwealth regulatory agencies, Australian and international experts, State and Territory Governments and the general community.

5.5 Conclusions

The overall Australian picture is one of generic R&D support through various Commonwealth programs. On a population basis, Western Australia has been as successful as other Australian States in the award of NH&MRC and ARC project and program grant funding. Although this is satisfactory for the individual researcher, funding through NH&MRC Research Centres and Research Units program, was low. Institutional research needs block infrastructure funding for it to be competitive in the future, the depth of research support for larger institutions will be increasingly important. Researchers in Western Australia should continue to form alliances and structures which will contribute to gaining block support. It is clear that this is taking place through WAIMR and SABC, etc (see Chapter 3), and various models of institutes (including virtual ones) are being explored to bring together groups in different locations. Researchers, however, noted that the current wide range of funding sources creates difficulties in gaining long term stability and is limiting their capacity to offer top salaries to attract the right people and develop complementary programs in technology-commercialisation.

Western Australia, like the other states, has no biotechnology specific funding programs. Like other states, project and firm-level support concentrates on matching/leveraging Commonwealth funding for state-level activities using competitive grants schemes. Where the other states differ is in their articulation of support for biotechnology, their moves to create clusters around new infrastructure, moves to strengthen international ties through biotechnology-specific "sister" relationships, and their assistance for commercialisation, particularly spin-offs, which are an important source of new firms in biotechnology.

Respondents in Western Australia recognised the high levels of activity in Queensland and Victoria and were concerned that Western Australia would be left behind. They acknowledged Western Australia's efforts to build infrastructure but felt that these were insufficient to support the levels of activity now being seen in other States . Respondents also stressed the need to build equipment around key people as well as equipment.

Overall, while Western Australia's programs offer comparable levels of support for the biotechnology industry to other states, Western Australia needs to articulate a greater level of support in order to build substantial biotechnology expertise and economic benefit. In order reap the rewards of biotechnology activity in the State, the Government needs to:

- Express greater political commitment for research and industry groups working in the field;
- Increase co-ordination at the departmental level in order to focus on building industry strengths;
- Provide greater infrastructure support in areas of existing research strength.

The next chapter examines the international context of biotechnology and provides an outline of regional success factors and case studies of regions which have built up their biotechnology strengths. Western Australia's strengths and constraints according to these success factors are then examined in Chapter 7.

6 Success Factors Identified from International Trends

6.1 Introduction

The USA is the world leader in biotechnology, primarily because of the strength of its research institutions, but also because of the emergence of methods of financing high risk long term biotechnology research through to commercialisation. Other regions have also grown significant biotechnology clusters. Some of these are based around groups of large firms (e.g. North Carolina in the USA and Medicon Valley in Scandinavia), but others have been created from the clusters of predominantly small firms that are typical in Australia. International research has revealed a number of the most important success factors to support regional growth in biotechnology:

- Strong government leadership;
- A strong bioscience research base;
- A strong entrepreneurial environment;
- A feeder layer of growing companies;
- Clustering around research institutions and between companies;
- An ability to attract key staff either through "natural" attractions or government facilitation;
- Availability of venture capital or other finance;
- Well funded and accessible infrastructure;
- Good formal and informal networks.

This chapter summarises the key factors under each of these headings and provides examples of how these factors have been built up where they do not already exist. They provide guidance for Western Australia's strategy to build its biotechnology capacity.

6.2 Success Factors

6.2.1 Strong Government Leadership

Strong government leadership can help to create the necessary conditions for biotechnology to grow in particular regions. The USA is a good example of where state and local government leadership and support are helping biotechnology companies to flourish. A USA survey in 1999 listed 18 types of state and federal support, including schemes supporting venture investment, carry forward of tax losses, R&D tax concessions, capital gains tax exemptions, centres of excellence funding, pilot plant funding, incubators, enterprise zones, business support and drug reimbursement policies. These state-level initiatives are also supported at a political level. In January 2000, USA President Clinton declared "National Biotechnology Month" in recognition of "the enormous potential that biotechnology holds for improving the quality of life in the US and around the world".

Governments of smaller countries with fewer natural advantages are taking a direct approach and are actively co-ordinating biotechnology strategies and funding programs designed to overcome natural disadvantages.

Case Study: Singapore

The Singapore Government has taken a leading role in supporting development of agricultural biotechnology in that country, despite having little agricultural industry. The Institute of Molecular Agrobiology was established in 1995 and aims to establish Singapore as a world-class centre in biotechnology research. The Centre operates in collaboration with the Chinese Academy of Sciences and the Chinese Ministry of Agriculture.

Singapore is also targeting medical biotechnology and the Prime Minister heads a Ministerial Committee which includes ministers from health, education, trade and industry. A multi-disciplinary life sciences executive committee will support the Ministerial Committee and is chaired by the head of the Economic Development Board. These committees are further supported by an international advisory Council established to provide global perspective on the decision-making process. The government aims to attract inward investment and has recently negotiated with Chiron Corporation to establish its first Asian subsidiary with US$30 million funding from the Singapore Economic Development Board.

Governments can also take the lead in helping firms to adapt to new regulatory and market situations. This may be by directly educating firms through funding industry and educational associations to prepare appropriate material.

Case Study: Saskatoon

Twenty-six percent of all Canadian core biotechnology companies are in agricultural biotechnology, with the highest concentration Saskatoon, Saskatchewan. Saskatoon has 700 scientists working on agricultural biotechnology in 30 private companies, together with government and university facilities. Saskatoon's biotechnology sector has had a 286% growth rate since 1991 and is expected to grow to a total turnover of US$200 million by 2005. Companies such as AgrEvo have relocated to Saskatoon because of the local research network, the presence of research institutions and other companies with similar interests.

Saskatoon's main ag-biotech product is canola, where 55% of 13.7 million acres is sown to genetically-modified varieties, primarily herbicide-tolerant. Despite fears about potential refusal of genetically modified agricultural crops by the European Union (a major customer), the government recommends that farmers separate genetically-modified and non-modified varieties to ensure that they can continue to respond to market changes. They recommend that farmers evaluate weed problems and farm systems, and compare production costs and markets when deciding what type of canola to grow.

6.2.2 A Strong Bioscience Research Base

As noted earlier in this report, many biotechnology firms rely on research institutions because they form a source of intellectual property that can be commercialised.

The majority of new biotechnology-based therapeutics, for example, have arisen from basic research which has then been developed and applied to a product. Ongoing basic and applied research is then required in order to provide incremental improvements and identify new applications for existing technologies. It is no accident that strong biotechnology firms have scientific advisory boards made up of leading research scientists and continue to forge strong links with research institutions around the world.

Case Study: Scotland

Scotland has less than 10% of the population of the UK but produces 18% of all first degrees in biological sciences and over 30% of all graduates in medical-related subjects. Biotechnology is part of the Scottish school curriculum for pupils from the age of four and is a component of the minimum qualifications for 17 to 18-year-olds. A number of management development programs have been developed specifically for biotechnology companies to enable executives to develop their business and financial skills. Scotland's strong science base has an international reputation, with major centres in Dundee, Edinburgh and Glasgow. Dundee has the highest concentration of bioscientists in the UK outside Oxford and Cambridge and boasts 12 research institutions working in biochemistry, biomedicine, neuroscience, surgery, forest biotechnology, informatics, pharmaco-epidemiology and crop research. Companies founded by Dundee researchers include Cyclacel (cancer), DDS Medicines (phase 1 clinical trials) and Cypex (measurement of in vitro drug metabolism).

A number of regions around the world are taking a strategic approach to development of biotechnology strengths within the region, by building on areas of strength and bringing existing players together.

Case Study: Newfoundland and Labrador

The regions of Newfoundland and Labrador in Canada have recently developed a comprehensive strategic plan to foster growth in marine biotechnology, an area which has applications in human health, aquaculture, food and the development of industrial compounds. The foundation for this strategic development is the scientific and technical expertise in the region. Research centres include Memorial University which has the Centre for Cold Ocean Resources Engineering, the Canadian Centre for Fisheries Innovation, and faculties in ocean science, chemistry/biology and medicine; the North Atlantic Fisheries Centre; and the Seabright Corporation, the technology transfer arm of the University. The Seabright Corporation has launched several successful companies in biotechnology and runs the Genesis Centre, founded in 1997 as an incubator for high-growth technology-based businesses. The Corporation also formed the biotechnology working group, BioEast, which is designed to provide a networking forum for stakeholders in the biotechnology industry.

Development and co-ordination of the research base creates critical mass for R&D and has an impact on the region as a whole. This makes the region attractive to other firms seeking links with research groups and smaller firms.

Case Study: Scandinavia

MediCon Valley, which incorporates part of Denmark and Sweden, is the largest pharmaceutical and biotechnological growth centre in Scandinavia and one of the strongest in Europe. There are a total of 3 million people in the region, of which 30,000 are employed in the medical industry, which includes many major international pharmaceutical companies. Hospitals in the region conduct 1,200 clinical trials each year and GDP totals US$100 billion. The growth may be attributed in part to grants to universities and hospitals and construction of two large biotechnology centres at universities in the Danish and Swedish parts of MediCon valley. Large firms have been attracted to the area because of the strength of the university research, the existence of many small companies and low rental costs.

6.2.3 A Strong Entrepreneurial Environment

A willingness to take business risks, availability of finance, business acumen, and an overall economic climate contribute to an entrepreneurial environment. Such an environment can be developed partly through individual institutional policies, such as those adopted at the Massachusetts Institute of Technology and the University of California at Berkley.

Case Study: MIT

The Massachusetts Institute of Technology (MIT) negotiates an average of 60 new technology licenses per year, over half of which go to local firms. It supports spin-offs by linking with reliable consulting firms and venture capitalists and by running an entrepreneurship competition which provides funding to students who submit business plans for new ventures which show significant business potential. Since its inception in 1990 the competition has supported creation of over 35 companies with a total value of US$500 million. Companies founded by MIT graduates have created 1.1 million jobs and generate annual sales of $232 billion. The success of these start-ups depends strongly on their technology link to MIT.

Programs have also been developed to offer business training to scientists. These programs concentrate on intellectual property management, commercialisation, market understanding and other issues surrounding commercialisation of research and assist researchers to work with industry partners or to start their own companies.

Case Study: Young Entrepreneurs Scheme

The Biotechnology Young Entrepreneurs Scheme (YES) is a competition run by the Biotechnology and Biological Sciences Research Council in the UK and is funded by public and private sponsorship. The first part of YES involves three regional weekend workshops where teams and their mentors learn how to prepare business plans and establish a bioscience company. Two undergraduate and two postgraduate teams are then selected from each of the three regions to present their plans at competition finals where winners receive £1000. Past participants report greatly increased understanding of science within a commercial setting.

6.2.4 A Feeder Layer of Growing Companies

Regions need companies at different stages of growth to provide a range of employment experiences for employees, and to provide incentives for development of specialised support services. New firms will usually stay in the region if they arise as spin-offs from local firms or research institutions.

Case Study: Canadian Spin-offs

The University of British Columbia's University-Industry Liaison Office (UILO) operates an incubator which has spun off 90 companies in the past 20 years, making it the most successful incubator in Canada. These firms have a survival rate of 80% and include successful biotechnology firms Inflazyme Pharmaceuticals, which has an anti-inflammatory molecule and QLT Photo Therapeutics Inc., which has a biotechnology-based treatment for an eye disease. Twelve spin-offs are listed on stock exchanges and have a combined market capitalisation of more than US$8 billion. The UILO has also supported the filing of 800 patents on behalf of the University.

The ongoing support of the university administration, in partnership with the Provincial government and the National Research Council is critical to the success of the program. These stakeholders have provided funding but have also championed the program, encouraged creativity, supported new initiatives, and empowered the UILO to respond quickly to new opportunities.

Firms can also be encouraged to migrate under business attraction programs which provide incentives for new regional entrants. Many European and USA regions are keen to attract large pharmaceutical and other types of biotechnology firms which provide employment and also bring skills in management, commercialisation and distribution.

Case Study: Houston

Houston, Texas, has depended on mining and oil revenues but after the downturn in oil/gas prices in the 1980s business leaders and government launched an economic development strategy strengthening other business sectors that already had strong roots in the area's economy. In particular it focused on agribusiness and the medical research strengths of Baylor College, the University of Texas MD Anderson Cancer Hospital and other institutions. Houston has attracted biotechnology and pharmaceutical firms by use of State-created enterprise zones, which offer firms refunds on state taxes paid on machinery and equipment, building materials and utilities, based on US$2000 for each permanent job created in a five year period. More than half of the biotechnology companies located in Texas are now located in the Houston region.

Incubators in the USA have grown from 12 in 1980 to 600 by 1998, creating 19,000 companies still in business and 245,000 jobs in the process. A little more than half of these have been sponsored by government and non-profit organisations.

Case Study: Biotechnology Mentoring and Incubator Challenge

In the UK, the government has launched the Biotechnology Mentoring and Incubator Challenge. Commenced in 1996, the scheme promotes provision of services to support start-up companies. In 1998, Oxfordshire won £400,000 to develop an incubator and support facilities within Oxfordshire for start-up biotechnology companies.

6.2.5 Clustering Around Research Institutions and Between Companies

Many biotechnology regions are clustered around key research institutions, primarily because the majority of firms have arisen as spin-offs from these institutions. Once the core of firms has formed, this attracts other firms which may be suppliers to the core group or may wish to create alliances with them. In **Maryland**, for example, local biotechnology industry is clustered around the National Institutes of Health and in **Seattle**, the USA's fourth largest biotechnology cluster, firms are located close to and interact regularly with the Hanson Cancer Institute. **Germany** has set about creating biotechnology clusters through its competitive BioRegio program.

Case Study: Cambridge Bioscience Cluster

The Eastern Region bioscience cluster in the UK is centred on Cambridge and has over 350 firms actively involved in biotechnology, of which half are core biotechnology. Sixty-two percent of firms have been established since 1985 and nearly 20% since 1995. Some 8,000 jobs in the region are specifically related to biotechnology and a further 14,000 jobs are in organisations with some biotech-related activities. A 1999 survey of firms within the cluster found that 40% of respondents considered that linkages with local customers were either very important or critical and 20% attached equal significance to links with suppliers. A quarter of respondents also rated links with local venture capitalists and research institutions as critical or very important. However, these firms were not inward looking and all rated external linkages as equally or more important are their local networks. Firms reported that they benefited from their local cluster because of the presence of similar companies, the presence of large firms and research institutions, the activities of the Cambridge Science Park and the presence of customers and suppliers.

6.2.6 Ability to Attract Key Staff

Management skills are important for biotechnology firms because of their long time to market and complex regulatory framework. Thus, growing firms must be able to attract the staff they need to help them move through the various phases of commercial development and ultimately product launch and distribution. Staff can be attracted by a range of factors including, quality of life, ancillary services (e.g. for children's education) and natural surroundings, as well as specific factors relating to their employment with a particular firm. Similarly research organisations can be enhanced by the introduction of key senior personnel through Professorial appointments of world class researchers to endowed Chairs.

Case Study: Georgia Research Alliance

The Georgia Research Alliance was established in 1990 by the Georgia State Government and since that time has received over $300 million of funding, of which approximately 20% is from the private sector. This funding has leveraged an additional $600 million from the Federal USA Government in increased grants and competitive contracts. As a result, local venture capital investment has tripled, patents awarded have tripled, and industry relationships with university researchers have quadrupled. The Alliance attributes its success to a Government program to recruit eminent international scholars to Georgia to endow chairs with the latest equipment and new laboratories facilities. These individuals figure prominently in most of the major success stories, successfully compete for a disproportionate share of funded research, attract the best graduate students and create the most interest by companies. At the close of 1999 the Georgia Research Alliance had established endowments for 32 eminent scholars in areas which include vaccine development, agricultural biotechnology, water quality and environmental systems, structural biology, technology transfer, molecular biology and biotechnology, sensors and instrumentation, and neuropharmacology. Georgia expects to be among the first five states in the USA with a technology-based economy by 2010.

6.2.7 Availability of Venture Capital

As noted earlier, venture capital has been an important source of funding for biotechnology firms. In California, for example, almost one quarter of biotechnology firms have received venture capital in their first year, compared to 6% of fast-growing firms in the general USA economy.

Case Study: European Venture Capital

The European Venture Capital Association's early stage interest group has grown from 45 members in 1996 to 122 by the end of 1997. Case studies of six biotechnology firms, which together employed less than 20 people on establishment, showed that they grew to a total market capitalisation of almost US$900 million on exit, and employed over 800 people.

6.2.8 Well Funded and Accessible Infrastructure

Infrastructure is an important component of the biotechnology environment as firms rely on highly complex and expensive equipment. Incubators and other shared facilities can help firms, in association with research laboratories, to obtain equipment on a shared basis through co-locating in purpose-built facilities where laboratory space is leased out and equipment is provided as a central resource.

Case Study: MdBIO

MdBIO was originally called the Maryland Bioprocessing Centre and was formed in 1991 to facilitate the finance and construction of a multi-tenant GMP manufacturing facility in Baltimore, Maryland. The project began in response to a need identified by the Maryland General Assembly and was financed through State grants. It is now operated by a private, non-profit company and is governed by a 15-member board of directors, of which 12 are from the private sector. MdBIO runs programs aimed at assisting bioscience companies to develop commercial skills and funds advisers to work with the local bioscience industry and provide strategic business planning, regulatory, marketing and corporate restructuring advice. MdBIO also provides grants to companies to assist them to prepare to manufacture products under GMP conditions in Maryland, to develop products and to upgrade or install their own manufacturing capability. Awards range from US$50,000 to US$200,000 and are only granted under conditions that ensure developments remain in the State.

Technology-based biotechnology firms also need non-biotechnology infrastructure such as information and communications technology, e.g. high performance computing for drug design and chemical visualisation and "DNA chips", which are electronic sensors which have arrays of 10,000-100,000 elements coated with oligo-nucleotides which represent different DNA sequences.

Case Study: Maryland Bioscience Cluster

The State of Maryland has two universities (Johns Hopkins and the University System of Maryland) and several Government agencies including the National Institutes of Health, the Department of Agriculture and the Walter Reed Army Institute of Research. These institutions have particular skills in vaccine development and genomics and have spun off several companies in this field, including the Institute for Genomics Research, Human Genome Sciences, Celera Genomics and MedImmune. The underlying technology base has attracted individuals and firms with complementary expertise, promotes movement of entrepreneurs and key executives between firms and encourages the development of mutually beneficial relationships. Maryland's bioscience employment, which at one time was wholly within government and federal laboratories, is now 36% industry-based. Maryland's 120 companies include 36 which are publicly traded, employ 15,000 people, and have total revenue of over US$2 billion.

6.2.9 Good Formal and Informal Networks

By the end of the 1980's over 80% of every major corporation investing in biotechnology had alliances with other firms or universities for contract R&D, for licensing of technology or distribution of products. Such alliances can be at local, national or global levels. At the local level, they provide support for entrepreneurs and links to research and funding. Such local networks and alliances have played an important role in the growth of California as the leading biotechnology district in the USA. Informal networks can be supported by industry associations, or technology transfer or technology demonstration centres.

At a national or international level, alliances can help firms gain access to skills and facilities not available locally and can help them enter new markets. Such alliances can be forged by individual firms, by associations or by governments.

Case Study: Israel

The MAGNET program, operated under the Israeli Ministry of Industry and Trade, aims to spur development of generic technologies by encouraging collaboration within research institutions and between the research institutions and industry. MAGNET underwrites up to 65% of the budget for particular projects including those in pharmaceuticals and diagnostics. Israel also promotes technological co-operation between with the USA through the USA-Israel Science and Technology Commission. The commission supports long term, high-risk co-operative applied research and development between USA and Israeli companies and academia, as well as assisting the harmonisation of regulatory regimes.

Case Study: Scotland and Maryland Strategic Alliance

Senior industry and Government leaders from Scotland and Maryland (USA) have signed a strategic alliance to accelerate the growth of the biotechnology industries in both regions over the next two years. As a direct result of the closer links between the two regions, four Scottish companies have already secured deals worth more than £1.5 million with Maryland firms. Signatories hope that the alliance will give rise to further associations between two of the worlds leading biotechnology communities, following the announcement of the alliance in March. The agreement, led by Scottish Enterprise, is seen as a significant achievement for Scotland's flourishing biotechnology industry given Maryland's status as one of the premier life science centres in the USA. The signing ceremony was one of the focal points of a 27-strong trade mission which included 10 biotechnology companies and three universities.

6.3 Conclusion

Each of the international regional case studies here emphasises a particular factor which contributes to success. In California, for example, research has concluded that the strength of the local biotechnology industry stems not from particular economic factors but the "high-tech/biotech" culture of the region itself. Regional strength is not measured by the numbers of firms alone but also by their local clustering and their inter-organisational links.

From Western Australia's perspective the lessons of other Australian states and overseas regions is that there is no single mechanism that can lead to the development of a successful biotechnology-based industry.

The next chapter goes on to analyse these general success factors as applied to Western Australia. This will identify the areas where concerted effort may contribute to development of biotechnology capacity in both the research system and local industry.

7 Opportunities and Constraints for Biotechnology in Western Australia

7.1 Introduction

The analysis thus far has demonstrated that Western Australia has assembled a number of the building blocks which should enable it to develop a much larger relevant income producing, biotechnology industry. However, despite this base and a need of some of its main industry sectors to use biotechnology, the State has not exploited its advantages as much as other Australian states and other regions. It risks forfeiting an opportunity to link its research base with a growing world economy centred on areas of economic importance to Western Australia.

The opportunities which form the best prospects for Western Australia are those which ensure that companies remain linked to the local region either through links to R&D, use of natural resources or solution of problems particularly related to Western Australian industry. This way, as companies grow, they are linked to the local environment, are less likely to relocate elsewhere and hence the benefits of local clustering will start to be seen.

At the regional level, stakeholders need to agree to work together to develop areas of strength and introduce joint programs and activities which will overcome identified weaknesses. Where the decision has been made to move into new areas, there is also a need for substantial funding to build up the expertise required at the research and business level. Government leadership in supporting these initiatives is essential.

The structure of this section reflects the international lessons of the previous chapter and discusses some examples of activities in Western Australia. In general, we do not believe finance, infrastructure or the research base to be particular constraints in Western Australia at present. Some positive factors, such as clusters, will arise naturally once certain other factors have been addressed.

7.2 General Success Factors in Western Australia

The potential for a biotechnology-based industry in Western Australia will be examined against the success factors identified from international trends.

7.2.1 Strong Government Leadership

The most critical constraint on development of biotechnology industry in Western Australia is lack of Government and Parliamentary leadership and commitment to creating a viable industry, as discussed in Chapter 5. Until recently, the State Government has not articulated any public commitment to biotechnology. If it is to decide that biotechnology should be a key area of growth, then it must make a public statement to that end and must establish a co-ordinating mechanism to enable the relevant interested government agencies to work together to help local industry.

Government must also take the lead in anticipating public attitudes and helping to shape them, especially in view of the public concern about genetically-modified food but general acceptance of recombinant vaccines and therapeutics. Leadership by Government in other states of Australia has had the effect of catalysing both industry and research to focus on the potential benefits of biotechnology and the synergies that can be obtained through co-operative projects and informal networks.

7.2.2 A Strong Bioscience Research Base

Overall, Chapters 3 and 4 showed that the calibre of academic and business related research is strong although the scale small and the areas of public sector strength do not match those in the private sector. By all criteria, the success rates of grant applications, student intake and completions and academic ranking are equal to or better than other centres in Australia on a population basis.

7.2.3 Competition Among Research Groups

According to all criteria which were analysed, it is apparent that some areas of medical and agricultural research in Western Australia are strong and world class. The emergence of consortia such as WAIMR, WABRI, WABC and SABC are drawing together researchers with similar interests.

Existing centres of strength in biotechnology need to be recognised and mechanisms established to ensure that they can work together to build regional strengths. Both informal and formal working arrangements can ensure that complementarities are strengthened and overlaps are decreased. WAIMR, for example, has already held a seminar of local researchers to increase informal information flow between those involved in medical research. WABRI intends to provide a service to help commercialise biomedical research for both Curtin and Murdoch Universities.

7.2.4 Building on Research Strengths

Chapter 3 shows that the key current sectors which provide opportunities for the State are agricultural biotechnology plus selected areas of medicine and health. These build on existing infrastructure and research strengths in public sector research and in firms.

7.2.5 Agricultural Biotechnology

As noted earlier in this report, the introduction of genetically-modified crops contributes to environmental sustainability (by reducing the need for chemical sprays) and to the development of functional foods for better health. At present the current generation of agricultural biotechnology products are concentrating on traits such as insect resistance. The next generation will focus on improved nutrition, processing qualities and a high value-added crops.

Global sales from transgenic crops were estimated at US$75 million in 1995, growing to US$235 million in 1996 and US$670 million in 1997. Transgenics will grow at 45% per annum over the next decade. The global market for transgenic crops is projected to reach US$3 billion in 2000 and US$5 billion in 2005. At present, Australia has less than 1% of transgenic crops grown worldwide. Major transgenic crops worldwide are soybean, corn, cotton, canola and potato. With the exception of canola, none of these figure prominently in Western Australia's production at present.

Wheat is the second largest food crop in the world and Australia is the world's third largest exporter of wheat, although a relatively minor grower of wheat on world terms. Until recently, wheat has been difficult to modify genetically but work is now underway on production of "Roundup ready" wheat varieties. The introduction of these varieties will provide considerable advantage to large wheat-growing countries such as Canada. Australia as a whole, and Western Australia in particular, risks losing export markets if it does not also adopt genetically modified varieties, which provide growers with advantages and lower production costs.

Western Australia can capitalise on its strengths in agricultural research by identifying key areas of focus that will benefit the State and tie in closely with the current skills at SABC. Other areas of opportunity are in traditional Western Australian crops such as wheat and barley, legume research, floriculture based on native West Australian flowers and development of plant varieties in response to climate change and salinity.

7.2.6 Medical Biotechnology

More than 70 biotechnology-based therapeutics have reached the market since the early 1980s and several hundred are in the pipeline. New products target cancer, AIDS, auto-immune disorders and infection, among other things. The release of the human genetic sequence will provide a further boost to biotechnology research for human therapeutics and diagnostics. About US$36 billion is spent each year on R&D in pharmaceuticals. In Australia, R&D in this field has increased six-fold between 1985/86 and 1995/96. Research institutions are an important source for patents and new firms in this sector. Medical biotechnology represents the activity of the majority of biotechnology start-ups in USA and Australia.

In medical research, Western Australia's strength is indicated by its relative success per capita in NH&MRC program grants. There are several areas of important medical research that should be supported in the longer term. Ophthalmology, childhood health and human genetics, leukaemia, respiratory disease, neuromuscular disease, human genetics, diagnostics and research into drug and vaccine development are prominent. The fledgling co-ordination being introduced by WAIMR and WABRI also provides an opportunity to bring existing medical researchers together and to concentrate on key strengths.

7.2.7 Marine Biotechnology

The new research programs on the North West Shelf and development of a research centre in Dampier are currently limited to minimising environmental damage from industry development by cataloguing the biodiversity and environmental monitoring. Study of Western Australian marine organisms as sources of new chemical entities for the development of products in a range of sectors including therapeutics, cosmetics, diagnostics and manufacturing has recommenced, however, and there is great scope to expand this activity further.

Agreements on access to the Western Australian marine biota are being finalised between the State Government and AIMS.

This opportunity could be explored by creating links through either informal means or the establishment of virtual centres along the lines of WAIMR. There would need to be clear agreements in terms of intellectual property ownership and use, and alliances with firms that could further develop research. The expansion of aquaculture to include new species of fish,

marine invertebrates and algae also requires greater research but, given the great marine biodiversity in Western Australia as well as the available range of climate and habitats, has significant potential for the development of new industries.

7.2.8 Bioinformatics and Computational Analysis

There are several opportunities to build expertise in emerging areas, particularly bioinformatics, which has an opportunity to link in with both agriculture and health and medicine, a particular focus being on identification of genetically modified foods, DNA analysis for disease and analyses of organisms. These need strong infrastructure support and would benefit from collaboration among research groups. Recent initiatives (e.g. WABC) need to be developed within a broad State strategy, which includes promotion of increased co-operation between research institutions.

7.2.9 Strong Entrepreneurial Environment and Spin-offs

The formation of start-up companies by research institutions or collaborations between institutions and existing local companies are frequently the method of choice to commercialise innovation. This requires skills in protecting and exploiting intellectual property and most frequently by continued direct involvement of the researcher in the commercial venture.

There is a strong entrepreneurial drive among businesses and a moderate rate of start-ups in Western Australia, but few opportunities to license research into larger companies. In general, however, there appears to be a lack of awareness of commercial skills and management among public sector researchers. A lack of follow-through of innovation into start-ups or valuable licenses is reflected in the low number of patents, low numbers of alliances, and small numbers of research spin-offs described in Chapter 3. Western Australia, along with many other Australian states, has not yet developed a mechanism for linking science with strong business training although there are models overseas (see previous chapter) and the existing Enterprise Workshop scheme, which operates across Australia, might be usefully adapted to this end.

7.2.10 A Feeder Layer of Growing Companies

Western Australia is distinguished from other states in Australia by a natural focus on two major revenue-earning sectors of the Australian economy notably mining and agriculture. Western Australia also has a significant proportion of environment/waste management biotechnology firms. Mining and environment/waste management have been generally slow to adopt biotechnology and agriculture has been inhibited by public concerns about genetically modified foods and a changing regulatory environment. Nevertheless, significant benefits are likely to come from improvements to processes as well as products. These sectors also require specialist industry skills, and major outlays on equipment and field trials.

7.2.11 Mining

Bioleaching and bioremediation provide opportunities for the application of biotechnology to the mining sector. The Parker Centre has developed a research program into bioleaching, three mining biotechnology firms operate in Western Australia and a number of research groups are investigating bioremediation techniques. This market sector provides and opportunity for Western Australia to take a lead role in biotechnology applications for the mining industry.

7.2.12 Environment

Australia has 80,000 contaminated sites with a potential clean-up cost of $A5–8 billion. Global surveys estimate the biotechnology-based environmental market at about US$50-75 billion per annum, growing at twice the rate of the total environmental technology market. Given Western Australia's industrial strengths in this field, there should be opportunities to develop local markets further and expand into other states and overseas.

The relatively robust industry-based research in environment/waste has recently been supported by the establishment of the Centre for Organic Waste Management and the Environment Technology Centre at Murdoch University and the Centre for Cleaner Production in Curtin University under the State's Centres of Excellence Program.

7.2.13 Clustering Around Research Institutions and Between Companies

The SABC is an example of close networks between Western Australian research groups and industry facilitated by co-location and relying on specialised skills and equipment in the public sector research environment.

Case Study: The State Agricultural Biotechnology Centre (SABC)

The SABC was set up following a recommendation by the Mulcahy Committee in 1990 with major initial funding from the Federal Government. Subsequent funding has come from a number of sources, including the Centre of Excellence program and support by the local agricultural biotechnology community. Its success after five years is recognised through attraction of funding and participation from companies, research corporations and academic groups. Success factors for the SABC are:

- *Good leadership in planning and advocacy for the centre to gain support by the main local stakeholders. Planning was similar to emerging overseas models for incubators and high quality central facilities. There has been continuing leadership in management and in attracting appropriate partners to the Centre;*
- *The Centre meets a significant local need and generates strong support from Government, industry and producers based on the expected returns which will come to the State. This is particularly important to maintain the profile and relevance of the Centre and to ensure continued funding;*
- *The research base for the centre is of high standard and there is a broad pool of expertise across several institutions (Murdoch, AgWA and UWA) which are active participants in the centre. Notably, the Centre has focused on quality research and providing the infrastructure for collaboration which has already produced several important outputs. Included are the biotechnology services laboratory of AgWA, The Centre for Bioinformatics and Biological Computing and the Rumen Biotechnology Group. This has two effects; the biotechnology companies involved have access to technology and experts who are familiar with biotechnology and secondly, there is an inclusive management style which attracts wide involvement of people outside the centre leading to valuable outcomes;*
- *Good initial funding and a program to maintain a strong technology and equipment base to ensure that the Centre remains at the cutting edge. The SABC now projects an image as a competent and well-resourced centre which gives confidence and capability.*

However the SABC still remains small by comparison with other centres elsewhere and lacks a critical mass of associated researchers. There will be a severe limitation on equipment, core staff and space if there is an increase in size or activity.

A number of other mechanisms are being tried in Western Australia to stimulate collaboration and generate business outcomes from research. Most of these are early in development and not yet amenable to analysis, for example, WAIMR or the Institute for Molecular Genetics and Immunology, which focus on medical technologies.

7.2.14 Ability to Attract Key Staff

Western Australian industry relies on a relatively small pool of individuals for leadership. As discussed in Chapter 5, respondents gave highest importance to the calibre of staff and identified a lack of skills in taking projects through to commercial completion. We found several examples where new appointments to university positions (e.g. Dr Mike Jones at SABC) had made a real difference in initiating new projects and alliances, and particular individuals who had real vision in establishing firms to exploit the State's strengths. There needs to be a mechanism for ensuring that such individuals continue to be identified, and when necessary, to bring new skills into the State.

Considering the strength of the environment and waste management industry sector in Western Australia and its importance to the mining and petroleum industries, it would be particularly advantageous to strengthen the research disciplines in these areas.

Access to experienced management is also closely linked to the ability of small firms to grow into large firms. At the most senior level, staff placements from outside Western Australia are highly beneficial and can also lead to collaborations and linkages. There is considerable expertise among the managers of the biotechnology companies in Western Australia but they are few and experience is limited to the size of organisations.

7.2.15 Availability of Venture Capital or Other Finance

In our view, access to venture capital for worthwhile ventures is not a major limitation in Western Australia and is comparable to other Australian states. In common with other regions, early stage funding remains a limiting factor in exploiting research, and financiers do not generally provide sufficient management or strategic advice for their investers. The advent of new Western Australian-based venture funds and interest by the mining industry in diversifying into biotechnology may provide a much-needed boost in this area.

7.2.16 Good Formal and Informal Networks

Proximity or accessibility to specialised business advisers in the biotechnology sector is an important component of the functioning industry cluster. Such advisers are generally scarce in Western Australia, but there are good linkages to other specialised advisers elsewhere in Australia and overseas. There is potential for local provision of such advice as firms grow beyond a virtual stage. Significant changes to the commercialisation offices and practices in the main universities will alter the opportunities and incentives for researchers taking their research to market.

Industry associations and professional societies are important for informal networking amongst both industry and research groups and also support promotion of the benefits of biotechnology to the local community. It would be valuable if those which were identified as active in Chapter 4 – for example, the Australian Biotechnology Association, Licensing Executive Society and The Australian Institute of Management – could be encouraged to work together to meet some of the needs of the growing industry. For instance, the ABA and

AIM could work together to offer business seminars to biotechnologists, while the ABA and LES could also co-operate in running local seminars and workshops of interest to both memberships. Regional associations could also initiate contact with other industry groups in order to identify synergies between biotechnology techniques and traditional industry sectors.

7.2.17 Isolation from Other Centres

While Western Australia is somewhat geographically isolated, the global nature of biotechnology, the general ease of transport of its products and the enabling support of information technology mitigates against this argument. It is apparent, however, that groups from Western Australia do not participate in international meetings on biotechnology such as BIO or Biotechnica, nor do they attend ABA meetings in the Eastern States. A large part of the motivation to develop commercialisation strategies elsewhere has come from these interactions. It is essential that Western Australian firms and research groups form these linkages in order to learn from other firms and better understand the strategies being adopted to support the industry elsewhere in Australia and overseas.

The case studies in Chapter 6 highlighted the fact that formal international linkages contribute to the development of a local biotechnology industry.

7.2.18 Well Funded and Accessible Infrastructure

Federal and State Government support has provided Western Australia with a competent although small infrastructure, which can be used to develop new companies and products. Some specialised support services and funding have been lacking, but overall many of these appear to have recently improved. In order to increase the biotechnology industry and to make it more appropriate to Western Australia's needs and the scale of activity globally, substantial increase in infrastructure is required.

7.3 Company Case Studies from Western Australia

At the company level, many successful Western Australian based firms are closely tied into local resources and economy.

Case Study: Environmental Solutions International Pty Ltd

The company started as part of the Campbell Group and has its own technologies for processing waste water and sludge. ESI has remained profitable and highly competitive against international companies. It identifies three major success factors:

- *High quality of technically competent people recruited from the industry to seek new solutions to environmental problems;*
- *Ability to apply progressive innovation and focus to achieve clean and non-polluting waste management. This provides an outcome and products in an area which are particularly important to Western Australia but are also exportable;*
- *Initial Federal government funding via START grant and other seed money from State sources was fundamental in getting started.*

ESI believe that additional help could have been provided at low cost to the Government by using the Government purchasing power to set up the first scaled-up demonstration plants as has been the case in Germany and France. This is particularly important in the environment/mining waste management where the cost of scale-up from the lab would be financially out of reach of small development companies.

Western Australian firms have also been able to leverage both local and international networks to develop strong markets and market recognition.

Case Study: Cognis Nutrition and Health Pty Ltd (formerly Betatene)

The company identified an area of technology for which there is a growing world market and used local know-how and natural environment to gain an advantage. Its success is evident from its ranking as the world's largest producer of natural beta carotene from the world's largest algal plant, and achieving recognition as Australia's Exporter of the Year for Agribusiness in 1999. Its success is gained through:

- *Leading research capability and specific expertise on Dunaliella algae through the company founders;*
- *Ideal location in Western Australia for such farming, including land which is available at low cost;*
- *International marketing by multinational parent company.*

The success factors given above relate to regional strengths which support local industry. It is apparent that companies in Western Australia could be located elsewhere except where there are particular industries which have essential links that support their activities, for example, betacarotene (accessing natural resources), mining and agriculture. Companies in the medical area have close links to the research sector but as they grow, other downstream linkages may dominate their location decisions.

Many companies are in start-up phase and other companies originating in Western Australia have had to relocate or form branches interstate to reach markets or be close to investors or strategic partners. We do not believe that these moves are necessarily failures of Western Australian biotechnology commercialisation; indeed, in some cases, they reflect successful company growth and provide linkages. However, they could also indicate past deficiencies in taking products to market, forming partnerships or a lack of investment capital for major company expansion in Western Australia.

Case Study: Biotech International Ltd

The company developed from a start-up in Western Australia in 1986 into a significant Australian listed enterprise. It relocated its head office to Brisbane and then to Sydney after purchase of Agen Biomedical Ltd in 1999. Two divisions of the company remain active in Western Australia, based on existing company technology. Industrial Biosystems Pty Ltd produces commercial enzymes for paper pulping (with the main process operations now contracted in India) and Jemaka Pty Ltd produces consumables for molecular biology research. Although the head office has moved from Western Australia, the company retains activities in Western Australia and has diversified across the country.

Case Study: Meditech Research Ltd (formerly Hyal Pharmaceuticals)

Meditech is an example of a company that has recently consolidated its position in the biotechnology field and relocated its head office to Perth. Two years ago the company was 60% controlled by Hyal Pharmaceuticals in Canada, however, a recent buy-out by Australian investors resulted in Meditech now being 100% Australian owned. Success factors include its ability to identify excellent projects and top people with whom to collaborate and its outward looking management. The company's most mature project is its anti-cancer treatment at Monash University in Melbourne, with human trials shortly to commence at Royal Melbourne Hospital. A treatment for HIV, melanoma and asthma, is being developed though Curtin University with funding in excess of $1 million from the Industry Research and Development (IR&D) Board.

7.4 Conclusions

Western Australia has some of the building blocks required to enable it to develop into a strong regional cluster. However, key components listed in Chapter 6 are lacking and need attention if the State is to build on its existing strengths and participate successfully at a global level. In order to capitalise on this opportunity, Western Australia will need to:

- **Increase infrastructure support** for agricultural biotechnology, biomedical biotechnology and environmental and marine R&D;
- **Further develop its research base** by focussing biotechnology research in areas of highest value-added potential;
- **Maintain its high competitiveness** in grant funding and in attracting world research leaders;
- **Adopt best practice** in formation of spin-offs in biotechnology-based and non-biotechnology-based therapeutics firms. This is a task primarily for local research institutions;
- **Encourage clustering** by promoting opportunities for researchers in research institutions and firms to work together on specific projects;
- **Create better networks** by strengthening links between public sector R&D and local industry and users;
- **Create links to other potential users** by targeting potential users of the output of biotechnology research e.g. use of canola as a manufacturing feedstock;
- **Ensure existing networks are maintained** by enabling researchers to travel internationally and to build business relationships with companies elsewhere in Australia for product development, manufacturing and clinical trials;
- **Strengthen formal and informal networks** established by organisations such as ABA, SABC, WAIMR and WABRI and seek areas of further collaboration;
- **Develop national and global networks** by developing a strategy for interacting with multi-national corporations to ensure access to patented genes as well as to develop market access strategies.

There are a number of very promising opportunities in biotechnology which build on the State's research output and link into its significant economic and natural resources. The following chapter presents alternative pathways for Western Australia's biotechnology development.

8 The Way Forward

Western Australia can take advantage of the present window of opportunity presented by biotechnology-based industries if it is prepared as a State to make appropriate commitments.

8.1 Current Activities

If Western Australia continues along at the current rate of activity, it is likely that the biotechnology industry in the State will remain fragmented and, in the main, will be unable to capitalise on the substantial local research resources. While organisations such as SABC will continue to be the focal point in some sectors such as agriculture, continuing difficulties with management of intellectual property and lack of linkages with multinational corporations are likely to mean that the potential for agricultural biotechnology in the State is not realised.

There is good potential for research commercialisation to occur around centres such as SABC, WAIMR, WABRI and specialised institutes. The linkages between the research system and industry are low-key or ad hoc and the synergies of clustering are unlikely to be fully realised.

Although there are signs of an increase in availability of venture capital, the attitudes of universities and lack of entrepreneurial climate within them still makes spinning off biotechnology firms difficult. In this situation, the number of new company formations will continue to be driven by individuals in the private sector rather than commercialisation of research from universities, medical institutes and the CSIRO. Asian investors are likely to find linkages with Eastern States rather than Western Australia and the biotechnology graduates that emerge from Western Australia's research institutions will continue to find work outside the State.

8.2 Step Change in Investment, Government Commitment and Focus

If Western Australia wants its biotechnology-based industry to grow and to develop products and services that benefit the State both directly and indirectly, then it needs to address the constraints identified and make a concerted effort to draw together a strategy which can shape how the State responds to the opportunities also identified in Chapter 7.

8.3 Conclusions and Recommendations

8.3.1 Conclusion 1 (Reference Section 5.5)

Overall, while Western Australia's programs offer comparable levels of support for the biotechnology industry to other States, Western Australia needs to articulate a greater level of support in order to build substantial biotechnology expertise and economic benefit. In order to reap the rewards of biotechnology activity in the State, the Government needs to:

- Express greater political commitment for research and industry groups working in the field;
- Increase co-ordination at the departmental level in order to focus on building industry strengths;
- Provide greater infrastructure support in areas of existing research strength.

Recommendation 1

In recognition of the enabling aspect of biotechnology when applied across all industry sectors, it is recommended that a Biotechnology Strategy be developed through the Department of Commerce and Trade and the Co-ordinating Committee of Science and Technology and incorporated into the State's Science and Technology Policy.

This strategy should contain programs which:

- Actively promote biotechnology enabled industry in Western Australia;
- Build a strong R&D base for biotechnology in Western Australia;
- Support properly controlled trials of biotechnology based processes and products in Western Australia;
- Support the development of business plans for the application of biotechnology across all sectors of industry including:

  (i) health and medicine,
  (ii) agriculture,
  (iii) mining and mineral processing,
  (iv) environment and waste management, and
  (v) marine industry.

8.3.2 Conclusion 2 (Reference Section 4.9)

The analysis in this and the previous chapter show that there is an excellent base for a larger biotechnology industry and good grounds for strong support by Government and industry for several biotechnology initiatives in Western Australia. There are also good economic reasons for an expanded industry. These are:

- The main export industries in Western Australia, mining and agriculture, can use biotechnology processes to improve yield or efficiency and there is a core group of firms which are aimed at these markets and able to expand internationally to form the basis of a biotechnology cluster in Perth;
- The recent report, "Drivers and Shapers of Economic Development in Western Australia in the 21st Century", makes the case for diversified economy by targeting new and emerging technologies. For biotechnology, this support needs to be selective and there are some organisational and infrastructure issues which require attention;
- Salinity and greenhouse issues will have a major effect on the Western Australian economy and biotechnology can be used to address these;
- Key agricultural products, wheat and barley, are now the target for development of genetically modified crops and markets for Western Australian products will be severely challenged by these new crops.

Recommendation 2

The Strategy should establish separate biotechnology funding to be used to implement the programs and business plans contained in the State's Biotechnology Strategy.

8.3.3 Conclusion 3 (Reference Section 6)

Each of the international regional case studies here emphasises a particular factor which contributes to success. These factors, however, do not operate in isolation and regional growth plans typically address many of these issues in parallel. In California, for example, research has concluded that the strength of the local biotechnology industry stems not from particular economic factors but the "high-tech/biotech" culture of the region itself. Regional strength is not measured by the numbers of firms alone but also by their local clustering and their inter-organisational links.

From Western Australia's perspective, the lessons of other Australian states and overseas regions is that there is no single mechanism that can lead to the development of a successful biotechnology-based industry.

Recommendation 3

It is recommended that the Biotechnology Strategy contains programs which:

- Strengthen and encourage the commercialisation of biotechnology based research in universities, Government agencies and other institutions – this includes clarifying institutional policies on sharing royalties between researcher, research entity and students;

- Facilitate seminars through ABA, AIM and AICD to raise the awareness of researchers in:

  (i) funding start-ups,
  (ii) duties and responsibilities of directors, and
  (iii) the availability and source of grants and other government assistance available for industrial research;

- Facilitate the clustering of newly formed companies either through an incubator program or through facilities around research institutions such as SABC at Murdoch University or Sir Charles Gairdner/UWA for a biomedical facility.

8.3.4 Conclusion 4 (Reference Section 7.4)

Western Australia has some of the ingredients required to enable it to develop into a strong regional cluster. However, key components listed in Chapter 6 are lacking and need attention if the State is to build on its existing strengths and participate successfully at a global level. In order to capitalise on this opportunity, Western Australia will need to:

- **Increase infrastructure support** for agricultural biotechnology, biomedical biotechnology and environmental and marine biotechnology R&D;

- **Further develop its research base** by focussing biotechnology research in areas of highest value-added potential;

- **Maintain its high competitiveness** in grant funding and in attracting world research leaders;

- **Adopt best practice** in formation of spin-offs in biotechnology-based and non-biotechnology-based therapeutics firms. This is a task primarily for local research institutions;

- **Encourage clustering** by promoting opportunities for researchers in research institutions and firms to work together on specific projects;

- **Create better networks** by strengthening links between public sector R&D and local industry and users;

- **Create links to other potential users** by targeting potential users of the output of biotechnology research eg. use of canola as a manufacturing feedstock;

- **Ensure existing networks are maintained** by enabling researchers to travel internationally and to build business relationships with companies elsewhere in Australia for product development, manufacturing and clinical trials;

- **Strengthen formal and informal networks** established by organisations such as ABA, SABC, SAIMR and WABRI and seek areas of further collaboration;

- **Develop national and global networks** by developing a strategy for interacting with multi-national corporations to ensure access to patented genes as well as to develop market access strategies.

Recommendation 4

The successful application of biotechnology as both an enabler and problem solver across industry and as a development tool for new industries, is assisted by the fostering of linkages and networks. It is recommended that the proposed State Biotechnology Strategy contain programs which will:

- Support the Western Australian branch of the ABA so as to facilitate inter and intra State events which raise awareness of issues relating to biotechnology based industries;

- Support through the overseas offices of the Department of Commerce and Trade and Austrade, international linkages with biotechnology based institutions in the USA, Singapore, Ireland, India and Israel;

- Use the State's very successful Centres of Excellence program;

- Leverage and add value to Commonwealth funding that eventuates through Biotechnology Australia and discussions on the Biotechnology Innovation Fund.

8.3.5 Conclusion 5 (Reference Section 3.4)

Access to business management staff and attraction of world leading researchers is an issue of particular importance to Western Australia due to its location. In large part, this is an issue of retaining Western Australian graduates and providing better career opportunities to build up the depth of talent. However, it is clear that some of the current successes are due to the appointment to key positions of researchers and business managers from outside Western Australia. Thus, Western Australia will need to be an attractive location to both home-grown graduates and postgraduates as well as researchers from elsewhere in Australia.

Recommendation 5

It is recommended that the proposed State Biotechnology Strategy contain a program which funds key international researchers in biotechnology by providing:

- Endowed chairs for five years;
- Well funded post-doctoral fellowships;
- Attractive support and facilities, and scholarships for students to build the research groups.

The main criterion for choice of key researcher should be excellence, then, defining a particular field of expertise. The business plans in the proposed Biotechnology Strategy for each sector will help define areas of expertise that will contribute most to the State. Case studies indicate that these key researchers will in turn attract funding, equipment, facilities and other good researchers and students.

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Appendices

Appendix A: Steering Committee and Consultant Team

The membership of the Technology and Industry Advisory Council (TIAC) Steering Committee for this project is listed below:

Dr Lesley Borowitzka	TIAC Member (Chairperson)
Ms Leslie Chalmers	TIAC Member
Professor Anthony Tate	TIAC Member
Professor Lance Twomey	TIAC Member
Associate Professor Michael Borowitzka	Murdoch University, School of Biological Sciences & Technology Chairman, Western Australian Branch, ABA
Dr Ian Edwards	Grain Biotech Australia Pty Ltd
Dr Sue Meek	Department of Commerce and Trade
Mr Earl White	Executive Officer, TIAC

The Steering Committee was assisted in its task by:

Dr Lyndal Thorburn	Advance Consulting & Evaluation Pty Ltd
Dr Kelvin Hopper	Aoris Nova Pty Ltd

Additional assistance was provided by:

Advance Consulting & Evaluation Pty Ltd
Sarah Adams, Eunice Farram, Robin Flag, Suzette Raison de Kori

Aoris Nova Pty Ltd
Joan Dawes, Katherine Irvine, Vimala Sarma

Appendix B: Western Australian Biotechnology Firms

Table B.1: Western Australian Biotechnology Firms

Name	Sector Class	Employees in WA
AMMTEC Ltd	Mining	
Aquabiotics Pty Ltd	Environment	3
AquaCarotene Ltd*	Food & Beverages	3
Artemia Biotechnology Centre Pty Ltd*	Environment	25
Australian Biosearch Pty Ltd	Supplier	9
Australian Spirulina Farms Pty Ltd*	Food & Beverages	3
Bactech (Australia) Pty Ltd*	Mining	4
BioLogic International Ltd*	Environment	3
Biomax Pty Ltd	Environment	
Bioprospect Ltd (formerly Bio-Gene Bioprospecting)*	Therapeutics & Diagnostic Manufacturing	6
Biotechna-Graesser AP Castella Pty Ltd	Supplier	6
Biotest Pty Ltd*	Food & Beverages	4
Biowest Australia Pty Ltd*	Agricultural Biotechnology	10
Chemeq Ltd	Environment	6
Cognis Nutrition & Health Pty Ltd*	Therapeutics & Diagnostic Manufacturing	16
DNA-ID Labs Pty Ltd*	Therapeutics & Diagnostic Manufacturing	3
Environmental Solutions International Pty Ltd*	Environment	45
Enzymatics Ltd*	Therapeutics & Diagnostic Manufacturing	3
Fisher Biotec Pty Ltd*	Supplier	4
Genetica Biotechnologies Pty Ltd*	Therapeutics & Diagnostic Manufacturing	4
Grain Biotech Australia Pty Ltd*	Agricultural Biotechnology	15
ID + Plus Ltd*	Agricultural Biotechnology	8
In Vitro Technology Pty Ltd/Embryotech*	Therapeutics & Diagnostic Manufacturing	40
Industrial Biosystems Pty Ltd*	Industrial Processing	5
Inovax Ltd	Therapeutics & Diagnostic Manufacturing	
Insulin Mimetics Pty Ltd*	Therapeutics & Diagnostic Manufacturing	5
Lakefield Oretest Pty Ltd	Mining	6
Lawley Pharmaceuticals Pty Ltd	Therapeutics & Diagnostic Manufacturing	
Meditech Research Ltd*	Therapeutics & Diagnostic Manufacturing	2
Microgene Pty Ltd*	Agricultural Biotechnology	4
Ozgene Pty Ltd*	Supplier	7
Pacific Ore Technologies (Australia) Pty Ltd*	Mining	10
Peko Rehabilitation Project Pty Ltd	Mining	
Pro Micro Pty Ltd*	Environment	12
Provalis plc*	Therapeutics & Diagnostic Manufacturing	2
Tissue Technologies Pty Ltd *	Therapeutics & Diagnostic Manufacturing	2
TRI-MED Pty Ltd*	Therapeutics & Diagnostic Manufacturing	11
Uropath Pty Ltd	Therapeutics & Diagnostic Manufacturing	4
Wiluna Gold	Mining	

**Indicates core biotechnology companies.*

Appendix C: Major Centres and Equipment Inventory

Western Australia has already developed some exemplary institutes and centres which act as foci for a specific technology and serve numbers of research groups, and is continuing the drive towards constructive consolidation It is important to emphasise that much high-technology equipment can be used across a broad range of research fields, and that in this context biotechnology must not be considered in isolation.

Western Australian Centre for Microscopy (WACM)
WACM, a collaborative centre involving UWA, Curtin, Murdoch and Edith Cowan Universities, was granted Centre of Excellence status by the Western Australian Government in 1998. The main facilities are located at UWA in the Centre for Microscopy and Microanalysis, but scanning and transmission electron microscopes are also located at Murdoch University and scanning EM facilities at Curtin University. The focus of the Centre is the development and use of electron, laser and light microscopic techniques, which have been applied largely to materials characterisation. However, work has also been conducted on the structure and function of seagrass, and advanced microscopic techniques are essential to biotechnology in such areas as drug design.

Western Australian Biomedical Research Institute (WABRI)
WABRI is a recently established centre of Excellence, which currently involves two nodes:

- The Centre for Molecular Technology and Therapeutics at Curtin University's Schools of Biomedical Science and Pharmacy;

- The Centre for the Biomolecular Control of Disease at Murdoch University's Division of Biomedical and Veterinary Science.

The amalgamation of the available resources is a positive initiative that has increased the availability of cutting edge equipment to a number of research groups. The Institute now has valuable resources in molecular biology, transmission and scanning electron microscopy, confocal microscopy and other analytical procedures including cell sorting, musculo-skeletal analysis and elemental analysis.

Western Australian Centre of Excellence in Mass Spectrometry (CEMS)
This Centre was formed in 1999 as a Joint Venture between Curtin University, UWA and CSIRO to consolidate the resources and expertise in mass spectrometry which have developed in Western Australia, and is headquartered at Curtin University. Usage is not, however, restricted to the Joint Venture partners, but also includes Edith Cowan and Murdoch Universities as well as Government instrumentalities and industry. The facility includes state-of-the-art organic and inorganic mass spectrometry equipment, with the recent addition of a Time of Flight ICP-MS and a stable isotope facility (see Table C.1). Research associated with this Centre involves a broad range of fields, including metallurgy, mineral exploration and earth sciences, as well as environmental, agricultural and other biological research areas contributing to biotechnology. The ToF-ICP-MS will be used by Fisheries Western Australia for fisheries stock management, including an analysis of the distribution of metals (a prime cause of discolouration) within the growth rings of cultured pearls.

Western Australian Institute for Medical Research (WAIMR)
WAIMR is a new research institute, which will involve UWA, Curtin and Murdoch Universities, and the Royal Perth, Sir Charles Gairdner (SCGH), and Fremantle Hospitals. Thus it aims to integrate the medical research efforts of the major research institutions in Western Australia, but although it will have dedicated research laboratories at Royal Perth Hospital it will concentrate on networking rather than co-location of teams. Nevertheless, optimal use of facilities is more likely under this type of structure than with isolated groups. Gene targeting and transgenic facilities have recently been established on the SCGH campus. DNA analysis equipment, cell sorting and imaging equipment will also be added to the facilities.

Western Australian State Agricultural Biotechnology Centre (SABC)
The SABC, located at Murdoch University, is the major centre for agricultural biotechnology in Western Australia. It houses a variety of facilities to support its research activities, including a glasshouse for transgenic plants which is the only such purpose-built glasshouse in Western Australia. There are also substantial secure facilities for the growth and manipulation of plant, viral, fungal and bacterial cultures. The molecular biological equipment is state-of-the art, with a sequence detection system supported by the more routine DNA sequencers and PCR machines. The Centre also has a capillary electrophoresis system with imaging densitometers, a confocal scanning laser microscope and micromanipulation equipment as well as its own MALDI-TOF mass spectrometer. A robotic workstation facilitates assay development and routine large-scale screening. The SABC also has strong computational capability and houses the Western node of ANGIS.

These resources are used in collaborative research with a wide range of Australian and overseas public and private sector organisations, including several local companies, all Western Australian universities, three CRCs, CSIRO, Agriculture Western Australia, the GRDC, the Institute Pasteur, the University of Alaska and the USDA National Animal Research Centre.

Other Collaborative Western Australian Foci of Major Equipment
The development of collaborative foci of major equipment in Western Australia is not restricted to the Centres. Other examples, which are important as resources for biotechnology, include:

UWA Department of Chemistry
The Department of Chemistry at UWA houses an NMR facility and has recently acquired a 600 MHz high-field NMR spectrometer for use in solution studies and dynamics of biopolymers, large synthetic molecules and small bioactive molecules. This machine services research at UWA, Murdoch, Curtin and Edith Cowan Universities and the Western Australian Maritime Museum. Projects include its use in rational drug design, structure-function studies of enzymes and immunophilins, the development of novel inhibitors of Phytophthora and of glycosidases, and analysis of plant responses to adverse environments.

UWA Crystallography Centre
The Crystallography Centre at UWA has functioned as a leading national structural determination facility for 25 years. It has recently acquired new generation area-detector low temperature X-ray diffractometer facilities, which will permit the enhancement and extension of existing small molecule structure determination activities and the initiation of macromolecular studies. The latter are particularly relevant to the needs of the biotechnology sector.

Western Australian Bioinformatics Consortium

This is a newly established group, which will be the focus of bioinformatics expertise in Western Australia. In a relatively small research community it is essential that such expertise be concentrated in a single group, as the only feasible approach to remaining at the forefront of a rapidly expanding field which is also a platform for the biotechnology industry. Moreover, in this case any problems of distance are surmounted by the provision of an inexpensive workstation.

Additional Biotechnology-Related Major Equipment in Western Australia

Significant additional biotechnology-related facilities exist within the Western Australian universities, though their use is often largely restricted to the department in which they are housed. It may be possible to increase access for other groups in some cases, but existing usage is often high enough to restrict this option. A detailed listing of individual items is given in Table C.1.

In summary:

Table C.1 Major Equipment and Centres of Expertise in Western Australia

Organisation	Technology	Equipment
Australian Neuromuscular Research Institute	Molecular biology	DNA sequencer
Centre for Molecular Immunology and Instrumentation (UWA)	Molecular biology	DNA sequencer with ALF Express
		Oligonucleotide synthesiser
		Gel scanner
	Bioinformatics	Computing suite
Centre for Human Genetics, Edith Cowan University	Molecular biology	DNA sequencer
	Mass spectrometry	MALDI-ToF mass spectrometer
Lions Eye Institute	Molecular biology	DNA sequencer
Murdoch University	Mass spectrometry	MALDI-ToF mass spectrometer
Murdoch University Division of Science and Engineering	Culture	Large scale fermenter
		Pilot scale algal culture facilities
		Nutrient analysis facility
	Molecular biology	Sequence detection system
Royal Perth Hospital Department of Clinical Immunology	Molecular biology	DNA sequencers (2)
	Immunogenetics	Biomer 2000 ELISA/DNA workstation
		Light cycler
		Microscope/motorised stage
Royal Perth Hospital Department of Pathology	Electron microscopy	Transmission electron microscopes (2)
Telethon Institute for Child Health Research	Molecular biology	Sequence detection system
	Cellular immunology	Cell sorter (FACS)
UWA, Crystallography Centre	X-ray crystallography	Low temperature area-detector X-ray diffractometers for small molecules and macromolecules
UWA, Department of Biochemistry	Protein/peptide analysis	Protein sequencer
		Fluorimager
		Peptide synthesiser
UWA, Department of Chemistry	Nuclear magnetic resonance	600 MHz high-field NMR spectrometer
UWA, Department of Medicine	Analysis	Gas chromatograph-mass spectrometer
		Cell sorter (FACS)
UWA, Department of Microbiology, QEII	Molecular biology	DNA sequencer
	Analysis	Cell sorters (FACS) (2)
UWA, Department of Pathology, QEII	Electron microscopy	Transmission electron microscope
		Cryoultramicrotome

Table C.1 Major Equipment and Centres of Expertise in Western Australia (Cont'd)

Organisation	Technology	Equipment
UWA, Department of Pharmacology, QEII	Immunohistochemistry, etc	Confocal microscope
Western Australian Biomedical Research Institute; Curtin node	Electron microscopy	Scanning EM
	Molecular biology	DNA sequencer
		Oligonucleotide synthesiser
		Peptide synthesiser
	Analysis	Cell sorter (FACS)
		Gas chromatograph-mass spectrometer
Western Australian Biomedical Research Institute; Murdoch node	Electron Microscopy	Scanning EM
		Transmission EM
	Cell biology	Confocal microscope
	Musculo-skeletal analysis	Sonography system
		X-ray equipment
	Analysis	Elemental analysis system
Western Australia Centre of Excellence in Mass Spectrometry	Mass spectrometry	Inductively coupled plasma MS
		Laser ablation-ICP-MS
		Thermal ionisation MS
		Sensitive high resolution MS
		Time-of-Flight-ICP-MS
		Stable isotope MS
Western Australia Centre for Microscopy and Microanalysis	Electron, laser and light microscopy	Analytical high resolution TEM
		Scanning EM with spectrometer analytical facility
		Scanning EM (2)
		Electron microprobe analyser
		Confocal laser scanning microscope
		Scanning EM (Curtin)
		Scanning EM (Murdoch)
		Transmission EM (Murdoch)
Western Australia State Agricultural Biotechnology Centre	GMOs	Glasshouse and secure plots for transgenic plants
	Handling	Micromanipulation equipment
	Molecular biology	Quantitative PCR
		DNA sequencer
		Sequence detection system
	Analysis	Capillary electrophoresis system with imaging densitometers
	Mass spectrometry	MALDI-TOF mass spectrometer
	Assay development	Biomek robotic workstation
	Bioinformatics	Computational network (ANGIS node)

Appendix D: Inventory of Public Sector Research

Table D.1 Biotechnology-Related Research in Agriculture

Institution	Biocontrol		Weed Control	Horti-culture	Molecular Markers		Novel Plants		Pest Diagnosis		Plant Pharma-ceuticals	Rhizobium Research	Rumen Research	Soil Research
	Animal	Plant			Animal	Plant	Crop Varieties	Transgenic	Animal	Plant				
AgWest			+	+			+					+		
CLIMA*	+	+[c]				+	+	+				+		+
CRC for Pest Control	+[a]													
CRC for Quality Wheat						+	+							
CSIRO*	+[a]		+				+							+[f]
CBCD	+				+				+					
SABC	+	+[b,c]			+	+[e]		+	+	+			+	
WAHRI			+[d]			+								
Curtin (Environ. Biol.)				+							+			
Murdoch (Science & Eng.)		+			+	+	+	+		+		+	+	
UWA (Botany)								+						
UWA (Agriculture)				+		+	+	+			+			

** Both institutions are involved in Mediterranean agriculture research.*

[a] *vaccine control*
[b] *genetic engineering of plants for resistance to nematodes and fungi*
[c] *genetic engineering of plants for resistance to viruses*
[d] *control of herbicide resistance in weeds*
[e] *includes International Lupin database*
[f] *bacterial bioremediation of herbicide pollution*

Table D.2 Biotechnology-Related Research in Medicine

Institution	Asthma	Childhood Research	Drug Development	Gene Therapy	Molecular Genetics	Molecular Techniques	Molecular Therapy	Vaccine Development
Australian Neuromuscular Institute				+	+			
CRC for Asthma	+				+			
Institute for Child Health	+	+	+		+	+	+	+
Lions Cancer Institute			+	+		+		
Lions Eye Institute				+		+		
PathCentre					+	+[e]		
SABC					+	+[f]		
Urological Research Institute					+	+		
WAIMR	+[d]			+[c]	+[d]	+		
Edith Cowan (Human Genetics)		+			+[d]	+		
Curtin (Biomedical Science)	+		+[a]		+	+ [g]	+[b]	
Curtin (WABRI)	+		+		+	+	+	+
UWA (Biochemistry)					+[d]	+		
UWA (Immuno-genetics Research Foundation)					+	+		

[a] *diabetes drug*
[b] *asthma treatment with IL-5*
[c] *treatment of mesothelioma patients*
[d] *genetic predisposition to disease*
[e] *diagnosis of viral and bacterial infections*
[f] *diagnosis of parasitic infections*
[g] *monitoring and controlling of methicillin-resistant S.aureus*

Table D.3 Other Biotechnology R&D in Western Australia

Institution	Algal Biotech	Bio-Informatics	Bio-Pharmaceuticals	DNA Probes	Etho-Pharmacology	Industrial Microbiology	Mining	Microscopy	Tissue Culture
AIMS	+		+	+					
AJ Parker Centre							+		
Australian Neuromuscular Research Institute								+	
Curtin (Environmental Biology)	+ [a]				+ [b]				
Curtin (Biomedical Science)				+					
Murdoch (Science & Engineering)	+	+	+	+ [c]		+ [e]			+ [d]
SABC		+							+
UWA (Anatomy & Human Biology)								+	+
UWA (Centre for Microscopy & Microanalysis)								+	
UWA (Immunogenetics Research Foundation)		+		+					
WAIMR		+		+					

[a] *toxins from phytoplankton*
[b] *aboriginal bush medicine*
[c] *DNA probes for the identification of species (meat, fish and plants)*
[d] *micropropagation of eucalyptus and sandalwood*
[e] *includes fermentation technology*

Appendix E: Western Australian Funding from Federal Grant Programs

Table E.1 START Grant Agreements for 1997/98

State	Number	Rate Per 100,000
New South Wales	34	0.53
Victoria	53	1.13
Queensland	18	0.52
South Australia	15	1.00
Western Australia	**11**	**0.60**
Tasmania	6	0.32
ACT	3	0.97
NT	0	0.00
Total	**140**	**0.74**

Source: AusIndustry. Small and large grants combined, commercial loans not included.

Table E.2 START Grants for 1997/98 (Biotechnology and Biomedical Science)*

Grant Type	Western Australia	Queensland	South Australia	National Total
Small	2 ($1.34m) (3%)**	2 ($1.46m) (3.4%)**	0	101 ($42.74m)
Large	1 ($2.16m) (2%)**	1 ($1.5m) (1.4%)**	2 ($4.67m) (4.2%)**	41 ($109.92m)

**Source: AusIndustry, Canberra and Perth Offices.*
*** Percent of National Total funds.*

Only one of the three Western Australian companies listed above is considered a core biotechnology company. The two companies receiving small grants were Q-Vis and Sirtex Medical, both of which are companies which produce instruments. Provalis PLC, a company working in the human therapeutics sector, received the large grant but has most of its operations in the UK.

Co-operative Research Centres

The CRC program has created more than 60 CRCs with an annual government funding of $111 million from the Department of Industry, Science and Resources, (DISR). About 24 of these have a significant biotechnology focus. While Government funding continues, the CRCs are expected to increasingly generate and access their own funds.

In 2000, there were 65 CRCs in all states, five of them with headquarters in Western Australia. There is little to choose between the more populous states in terms of CRC location on a per capita basis.

Table E.3 Location of CRC Headquarters by State (2000)

State	Number	% Total CRCs	Per 100,000 Population
New South Wales	16	24.6	0.25
Victoria	16	24.6	0.34
Queensland	11	16.9	0.32
South Australia	6	9.2	0.40
Western Australia	**5**	**7.7**	**0.27**
Tasmania	3	4.6	0.63
ACT	6	9.2	1.94
Northern Territory	2	3.0	1.05

Source: CRC program.

Three of the five CRCs based in Western Australia are in the mining and energy sector, reflecting the State's strength in this area. Of the five, only one (CLIMA; CRC for Legumes in Mediterranean Agriculture), was involved in biological science and biotechnology and CLIMA's funding has not been renewed beyond June 2000. However, Western Australia is also core participant in the following biotechnology-related CRCs (the participating institution is in brackets):

- CRC for Asthma (UWA);
- CRC for Quality Wheat Products and Processes (Agriculture Western Australia);
- CRC for Pest Animal Control (Agriculture Western Australia);
- CRC for Premium Quality Wool (Agriculture Western Australia);
- CRC for Weed Management Systems (Agriculture Western Australia).

In the biotechnology-related CRCs, there is State involvement (Agriculture Western Australia) in five of the centres but industry involvement in only one (CRC for Asthma).

Australian Research Council (ARC)

The ARC is the main funding body for basic research other than medical research in Australia. In 2000, the ARC is funding about 4000 small, medium and large research projects. From 2001, a new National Competitive Grants Program will replace a major portion of the ARC's existing programs. The ARC will be re-organised and will appoint program managers in six areas including biological sciences and biotechnology.

The Large Grants are the most significant to the purely academic community and their awards therefore reflect the reputation of the successful institution. The per capita figures indicate that for Large Grants, Western Australia has a similar success rate to that of Queensland but that this is low in relation to all other states except the Northern Territory.

The SPIRT program, on the other hand, is designed to strengthen links between industry and higher education institutions and to ensure Australia has appropriately skilled personnel. In order to achieve this aim the Government provides funds to support the placement of staff in industry. Industry partners are required to provide matching funds. SPIRT grants therefore indicate the strength of projects with potential for commercialisation. Western Australia's performance in

SPIRT grants is similar to that of Victoria and Tasmania, but again significantly better only than that of the Northern Territory. South Australia, with a lower population density than Western Australia, is markedly more successful in terms of both Large Grants and the SPIRT program. The relative success of Western Australia has not changed from previous years (Economic Consulting Services, 1998).

Table E.4 ARC Grants (2000)

State	Number		Per 100,000 Population	
	Large Research Grants	SPIRT	Large Research Grants	SPIRT
NSW	226	159	3.6	2.5
Victoria	159	95	3.4	2.0
Queensland	83	85	2.4	2.5
South Australia	56	38	3.8	2.6
Western Australia	**45**	**34**	**2.5**	**1.9**
Tasmania	14	10	3.0	2.1
ACT	33	18	10.7	5.8
Northern Territory	4	2	2.1	1.1
Total	**620**	**441**		

Source: ARC

Eleven institutions were also awarded the status of Special Research Centres in 2000, but there are none in Western Australia. There will be no application round for these Centres in 2001.

Comparison of Western Australian Universities

The UWA, the largest university, had the highest number of grants for both Large Grants and SPIRT (Tables E.5 and E.6)). Biological sciences are quite well represented with an average of 24% of the Large Grants, although there were no grants in this area at Curtin University. When comparing by staff numbers, UWA is the most successful in large grants (1 grant per 76 staff) followed by Murdoch University (1 grant per 192 staff).

Table E.5 ARC Large Grants Awarded to Universities (2000)

University	Curtin	Edith Cowan	Murdoch	UWA
Number Awarded	5	2	6	32
Biological Sciences	0	1	3	7

Source: ARC

Curtin was the most successful of the four universities in obtaining SPIRT grants, succeeding in half its applications. When comparing by staff numbers, Murdoch leads with 1 grant per 185 staff, followed by UWA (1 per 281 staff).

Table E.6 Breakdown of SPIRT Grants Awarded to Universities (2000)

University	Curtin	Edith Cowan	Murdoch	UWA
Applied for	16	17	17	34
Funded	8	6	7	13
% Success	50	35	41	38

Source: ARC

The ARC also funds the **International Researcher Exchange Scheme (IREX),** which now supports applications for substantive collaborative research with overseas partners. As this mechanism is independent of geographical isolation it is a potentially important source of funding for Western Australia. In 1999, the IREX scheme awarded grants and fellowships totalling $2,511,726, of which 20% were in the biological sciences and a further 3.8% in agricultural, veterinary and environmental sciences. Western Australian universities received $180,187 (7% of the total) in IREX funding, 84% of which was awarded to UWA. Three of these grants ($37,435; 21%) were potentially related to biotechnology.

National Health and Medical Research Council (NHMRC)

The NHMRC funds biomedical research, and success in NHMRC grants funding indicates strengths which can flow on to the biomedical aspects of biotechnology. Although on a per capita basis Western Australia is more successful in obtaining grants from the NHMRC than from the ARC, this is true for all states except the ACT. The per capita average for these three years for the state is 7.8, compared to 6.4 for Queensland and 7.9 for NSW, but it is still much lower than that for South Australia (13.3), Victoria (12.7) and the Northern Territory (8.8). Other states' medical research institutes also receive block grants which should be added to competitive grant data to give the total picture. Most NHMRC funding ($15 million for 2000) was awarded to the UWA and its collaborators.

Table E.7 Summary of NHMRC Grant Funding (all grants)

	Number			Per 100,000 Population		
State	**1997**	**1999**	**2000**	**1997**	**1999**	**2000**
NSW	483	521	505	7.6	8.2	7.8
Victoria	550	614	608	11.8	13.1	13.1
Queensland	228	207	228	6.6	6.0	6.6
South Australia	191	201	203	12.8	13.5	13.7
Western Australia	**124**	**151**	**156**	**6.8**	**8.2**	**8.5**
Tasmania	17	16	16	3.6	3.4	3.4
ACT	29	36	30	9.4	11.7	9.7
Northern Territory	14	18	18	7.4	9.5	9.5
Total	**1,636**	**1,764**	**1,764**			

Source: NHMRC

Western Australia, Queensland and South Australia are compared for a few selected types of grants (1997 and 2000). In general, Western Australia is competitive with the other two states, and a comparison of the data for 1997 and 2000 indicates that its relative success has improved. The recent award of a large research centre to Queensland skews the total figure for 2000. However, Western Australia is the only one of these states with no funding of Research Units for both 1997 and 2000.

Western Australia also received the least amount of grant money compared to the other two states. However, the State fared better in the Capital Funding Grants. A one-off Commonwealth funding of $20 million for health and medical research institutes has been approved for seven institutions; two in New South Wales, four in Victoria and one in Western Australia. The Western Australian Institute for Medical Research (WAIMR) received $3 million for a gene targeting facility to produce genetically modified mice.

Table E.8 NHMRC Grant Types Awarded to Western Australia, Queensland and South Australia (2000)

Grants**	Western Australia	Queensland	South Australia	National Total
Project	106 ($11.2m) (11%)*	166 ($14.45m) (13%)*	131 ($12.28m) (11%)*	1,132 ($107.49m)
Program	3 ($2,026,344) (13%)*	1 ($180,649) (1%)*	5 ($4,427,381) (28%)*	21 ($15,543,383)
Research Units		1 ($684,201) (25%)*		4 ($2,786,237)
Research Centres		1 $5,093,653 (19%)*		6 $26,865,271
Training Awards	39 ($1,126,171) (8%)*	48 ($1,650,656) (11%)*	40 ($1,253,645) (9%)*	468 ($14,620,100)
Total All Grants	**156 ($15,054,490) (9%)***	**228 ($22,704,799) (13%)**	**203 ($19,853,426) (11%)***	**1,764 ($176,097,961)**

Source: NHMRC
** Percent of National Total funds (to the nearest whole number).*
*** There are no Equipment Grants for 2000.*

Appendix F: Higher Education and Research Statistics

Table F.1 Higher Education in Science/Health/Biology-Related Subjects 1999

University	Agriculture	Health Related**	Science*	Veterinary	TOTAL Science/Health/ Biology Related	TOTAL Students	*Percent of Total Students at that University*	*Percent of Total Science/Health/ Biology Students in Western Australia*	*Science/Health Students per Head of Population*
Curtin University of Technology	546	4,347	2,366	0	7,259	24,005	*30.2*	*36.8*	
Edith Cowan University	0	1,893	2,938	0	4,831	19,259	*25.1*	*24.5*	
Murdoch University	0	95	2,227	377	2,699	10,660	*25.3*	*13.7*	
UWA	423	1,266	3,239	0	4,928	13,333	*37.0*	*25.0*	
University of Notre Dame	0	0	0	0	0	110	*0.0*	*0.0*	
TOTAL – Western Australia	969	7,601	10,770	377	19,717	67,367	*29.3*	*100.0*	*1.08*
TOTAL – Australia	11,515	77,710	111,959	1,772	202,956	686,267	*29.6*		*1.08*
TOTAL – Queensland	2,324	11,906	19,611	525	34,366	121,537	*28.3*		*0.99*
TOTAL – South Australia	1,393	7,841	6,936	1	16,171	49,037	*33.0*		*1.09*

** Includes all science students - not just biology.*
*** Includes all health related courses. UWA is the only university in Western Australia with a medical school and associated teaching hospital.*

Table F.2 Business Training

University	Business Admin.	% of Total Students at that University
Curtin University of Technology	8,816	36.7
Edith Cowan University	4,434	23.0
Murdoch University	*3,033	28.5
UWA	2,995	22.5
University of Notre Dame	28	25.5
TOTAL – Western Australia	19,306	28.7
TOTAL – Australia	178,771	26.0
TOTAL – Queensland	31,310	25.8
TOTAL – South Australia	10,553	21.5

** Includes basic business training for biotechnology students.*

Appendix G: Respondents

This appendix includes information on respondents to the various survey instruments used for this study. Table G.1 lists the names of those who responded in written form only to the questionnaire that was circulated in January 2000, as well as other written responses to questions asked in the course of the project. Table G.2 lists those who were also interviewed in February 2000 or by phone in February and March 2000.

Table G.1 Written Responses

Name	Position	Affiliation
Mr Ian Longson	Exec. Director Program Coordinator	Agriculture Western Australia
Dr Martin Houchin	CSIRO Minerals Program Manager: Base and Precious Metals	AJ Parker CRC Hydrometallurgy Program
Mr Steve Carlsson		Aquabiotics Pty Ltd
Mr Dan Chesson	Marketing and Public Rel. Consultant	AquaCarotene Ltd
Mr Luke de Ruyck	Aquaculture Engineer	Artemia Biotechnology Centre
Prof. Philip Thompson	Director	Asthma and Allergy Research Institute Inc
Mr Graeme Thallon	Managing Director	Australian Biosearch
Ms Jude Newberry	Administrative Secretary	Australian Neurological Research Institute
Dr Marie Bogoyevitch	Regional Director, Western Australia	Australian Society for Biochemistry and Molecular Biology
Ms Caroline Parsons	Executive Director	Australian Society for Microbiology
Dr Jim Cummins	Communications Officer	Australian Society for Reproductive Biology
Mr Paul Miller	Technical Manager	Bactech
Mr Rajendra Kurup		Biomax Pty Ltd
Mr Greg Eaton		Bioprospect Ltd
Dr Peter Keating	Director	Bioscience Pty Ltd
Dr Ian Edwards	Research Director	Biowest Australia Pty Ltd
Prof. S.D. Bradshaw	Head	Centre for Native Animal Research
Ms Carol Dowse	Coordinator	Centre for Organic Waste Management
Prof. Ed Barrett-Lennard	Director	Centre for the Management of Arid Environment
Prof. John De Laeter	Director	Centre of Mass Spectometry
Dr Graham J.H. Melrose	Chairman and Chief Executive	Chemeq Ltd
Ms Emma Booth	Senior Marketing Officer	CSIRO Minerals
Mr Mick Poole	Director	CSIRO Plant Industry
Prof. Murray J. McGregor	Director	Curtin Univeristy, Muresk
Nicole Workum	Research Associate	Curtin University. Centre of Excellence in Cleaner Production
Dr Brian Plewright	Senior Research Fellow	Curtin University of Technology
Mr Chris Hewitt	Partner	Deacons Graham & James
Prof. Alan Bittles	Co-Director	Edith Cowan University. Centre for Human Genetics
Mr Denis Glennon	Managing Director	Environmental Solutions International Ltd
Mr David Johnston	Chief Executive Officer	Enzymatics Ltd
Mr Peter Ferguson	Senior Manager	Ernst & Young Perth
Ms Lisa Parker	Grains Research Officer	Farmers Federation (WAFF)
Mr Chris Fisher	Director	Fisher Biotech Pty Ltd
Mr Robert Roget	Director	Genetic & Medical Capital Ltd
Ms Jayne Hallowell	Administration Manager	Grain Biotech Australia Pty Ltd
Mr Peter Portmann	Seed Commercialisation	Grain Pool of Western Australia
Mr Josef Pfistershammer	Managing Director	ID + Plus Pty Ltd
A/Prof. Erik Helmerhorst		Insulin Mimetics
Dr Bruce Bellinge	Director	InVitro Laboratory Pty Ltd
Mr John Angove	General Manager	Lakefield Oretest
Prof. Bruce Gray	Medical Director and Director	Lions Cancer Institute
Ms Anna Brew	Business Development Manager	Lions Eye Institute
Mr Kelvin Lord	Director	LordCo
Mr Mark Scully	Research Officer	Medical and Health Research Infrastructure Council
Hon. Jim Scott MLC	Member for Sth Metropolitan Region	Western Australia, Greens
Mr Frank McKenna	Senior Research Microbiologist	Microgene Pty Ltd
A/Prof. L Evans	Director	Muresk Institute of Agriculture-Aquatic Science Research
Dr Frank Koentgen	Director and Chief Executive Officer	Ozgene Pty Ltd
Mr Colin Hunter	Director	Pacific Ore Technologies Pty Ltd
Ms Jenny Edwards	Communications Officer	Pest Animal Control CRC
Mr Ed Reed	Consultant Microbiologist	ProMicro Pty Ltd
Mr Neill Hodgen	Executive Administrative Officer	Royal Perth Hospital-Centre for Clinical Immunology and Biomedical Statistics
Dr Sam Vasikaran	Head of Department	Royal Perth Hospital-Dept Core Clinical Pathology and Biochemistry
Mr Glenn Smith	Chief Executive Officer	TRI-MED
Dr Paul Watt	Senior Research Officer – Division of Leukemia and Cancer Research	TVW Telethon Institute for Child Health Research
Ms Roz Jaworski	Administration	Urological Research Centre
Dr Greg Pooley	Centre Manager	UWA, Centre for Microscopy and Microanalysis
Ms Maxine Cutter	Administrative Officer	UWA, Dept of Anatomy and Human Biology
Ms Trisha Lee	Market. & Communications Manager	Western Australian Farmers Federation

Table G.2 Personal Interview and Questionnaire

Name	Position	Organisation
Dr Sue Sutherland	Senior Projects Manager	Fisheries Western Australia (now at AgWA)
Dr Warren Grubb	Professor	Curtin University of Technology
Mr Trevor Bridle	Technical Director	Environmental Solutions International
Dr John Hamblin	Director Research	Export Grains Centre Ltd
Dr Matthew Bellgard	Bioinformatics Group	Murdoch University
A/Prof. Michael Borowitzka	Associate Professor Director Director	Murdoch University, ABA Australian Spirulina Farms Pty Ltd and Biotechna-Grasser AP
Prof. George Stewart	Dean of Science	UWA
Prof. Colin Sanderson		Western Australian Institute for Medical Research
Prof. Peter Klinken	Director	Western Australian Institute for Medical Research
Ms Celia Cornwell		Agriculture Western Australia
Mr David Hodgson	Crop Research Institute	Agriculture Western Australia
Dr Steve Wilton		Australian Neuro-Muscular Research Institute
Mr John Hodder	Director	Biogene Ltd
Dr Stewart Washer	Managing Director	Biotest Pty Ltd
Prof. Roger Dawkins	Director	Centre for Molecular Immunology and Instrumentation
Dr Robert Dunlop	General Manager	Industrial Biosystems Pty Ltd
Prof. RCA Thompson	Director	Institute for Molecular Genetics and Animal Diseases
Prof. Andrew Thompson	Professor of Parasitology	Murdoch University
Dr Lesley Borowitzka		Cognis Australia
Mr Gary Cox	Partner	Wray & Associates
Mr David Pass	Director	Animal Resources Centre
Mr Ian Passmore	Executive and Scientific Officer	Australian Neuromuscular Research Institute
Mr Mike Rhodes		Bactech Australia Ltd
Dr Robert Bower		Grain Biotech Australia Pty Ltd
Hon. Jim Scott MLC	Member for Sth Metropolitan Region	Greens Western Australia
Ms Michelle Kosky	Executive Director	Health Consumers Council of Western Australia
Mr Jim Murphy	Chair	Western Australia Potato Marketing Board
Dr Piroska Rakoczy	Principal Research Fellow	Lions Eye Institute
Dr Mal Washer MP		Member for Moore (Western Australia)
Prof. Pat Carnegie	Professor of Biotechnology	Murdoch University
Prof. Lyn Beazley	Professor	Developmental Biology, UWA
Prof. Craig Atkins	Botany Department	UWA
Prof. Mike Jones	Director	SABC
Dr Rob Potter	Research Fellow	SABC

Table G.3 Focus Group Members

Name	Affiliation	Focus Group
Mr Neil Rothnie	Chemistry Centre of Western Australia	Agriculture/Food
Ms Patty Salvati	Biotest Pty Ltd	Agriculture/Food
Prof. Mike Jones	SABC	Agriculture/Food
Prof. David Day	UWA	Agriculture/Food
Ms Leslie Chalmers*		Agriculture/Food
Dr Sue Meek	Western Australian Department of Commerce and Trade	Agriculture/Food
Dr Sue Sutherland	Western Australian Dept of Agriculture	Agriculture/Food
Dr Celia Cornwell	Western Australian Dept of Agriculture	Agriculture/Food
Dr Robert Dunlop	Industrial Biosystems Pty Ltd	Environmental/Waste
Prof. Tony Tate*	Murdoch University	Environmental/Waste
Mr Rob Meecham*	TAFE aquaculture	Environmental/Waste
Mr Paul Piercy*	TIAC Member	Environmental/Waste
Dr Sue Meek	Western Australian Department of Commerce and Trade	Environmental/Waste
Prof. Richard Dawkins		Therapeutics/Diagnostics
Prof. Andrew Thompson		Therapeutics/Diagnostics
Dr Jackie Wilce	UWA	Therapeutics/Diagnostics
Prof. Tony Tate*	Murdoch University	Therapeutics/Diagnostics
Mr Rob Meecham*	TAFE Aquaculture	Therapeutics/Diagnostics
Ms Michelle Kosky	Health Consumers Council of Western Australia	Therapeutics/Diagnostics
Dr Sue Meek	Western Australian Department of Commerce and Trade	Therapeutics/Diagnostics
Prof. Attikiouzell	UWA	Therapeutics/Diagnostics
Ms Prudence Ford	Health Department	Therapeutics/Diagnostics
Dr Lesley Borowitzka*	Cognis	General
Dr John Hamblin	Export Grains Council	General
Prof. Pat Carnegie	Murdoch Institute	General
Mr Peter Why	IASP	General
Mr Paul Piercy*	Westrack and Chair Pilbara Regional Development Commission	General
Dr Sue Meek	Western Australian Department of Commerce and Trade	General

**Also TIAC member.*

Appendix H: The Western Australian Technology and Industry Advisory Council (TIAC)

Background
The Technology and Industry Advisory Council (TIAC) was created by legislation in 1987 (Technology Development Amendment Act - No. 32 of 1987) and was continued under Section 20 of the Industry and Technology Development Act 1998.

TIAC was preceded by the Technology Review Group 1978-83, and the Science, Industry and Technology Council (SITCO) 1983-87.

Council is made up of representatives from various sectors of the State's economy who, in terms of the relevant Act, use their varied background and experience to provide independent policy advice to the Minister so as to make a significant contribution to the development of strategies relating to the State's economic development.

Members of the Council are appointed by the Minister, under Section 22 of the Industry and Technology Development Act 1998 so as to be representative of the interests of the people of the State.

TIAC reports through the Minister to Parliament under Section 26(1) and Section 26(2) of the Industry and Technology Act 1998.

TIAC reports under the Financial Administration and Audit Act 1985 through the Department of Commerce and Trade under Section 26(3) of the Industry and Technology Development Act 1998.

Objectives of the Industry and Technology Development Act 1998
The objectives of the Industry and Technology Development Act 1998 under Section 3 are:

(a) To promote and foster the growth and development of industry, trade, science, technology and research in the State;

(b) To improve the efficiency of State industry and its ability to compete internationally;

(c) To encourage the establishment of new industry in the State;

(d) To encourage the broadening of the industrial base of the State;

(e) To promote an environment which supports the development of industry, science and technology and the emergence of internationally competitive industries in the State.

Functions of the Western Australian Technology and Industry Advisory Council
The Council, under Section 21 of the Act is required to:

(a) Provide advice to the Minister, at the initiative of the Council or at the request of the Minister, on any matter relating to the objects of the Industry and Technology Development Act 1998;

(b) Carry out, collaborate in or produce research, studies or investigations on any matter relating to the objects of this Act, including matters relating to:

(i) the role of industry, science and technology in the policies of Government,

(ii) the social and economic impact of industrial and technological change,

(iii) employment and training needs and opportunities relating to industrial, scientific and technological activities in the State,

(iv) the adequacy of, priorities among and co-ordination of, scientific, industrial and technological activities in the State,

(v) methods of stimulating desirable industrial and technological advances in the State,

(vi) the application of industrial, scientific and technological advances to the services of the Government,

(vii) the promotion of public awareness and understanding of development in industry, science and technology.

The Ministerial advice takes the form of reports and discussion papers which undergo a public consultation phase before submission to the Minister.

Participation on State and Federal Government Advisory and Funding Committees and Councils

Council has accepted invitations for representation and participated in:

(a) The State's Co-ordination Committee on Science and Technology;

(b) The Steering Committee for the CSIRO National Centre for Petroleum and Mineral Resources Research;

(c) The "State Funding Advisory Committee" (SFAC);

(d) The State's "Information and Communications Policy Advisory Council" (ICPAC);

(e) The Department of Commerce and Trade's "Technology Operations Group" (TECHOP);

(f) The Federal Government's "Commonwealth, State and Territory Advisory Council on Innovation".

Promotion and Public Awareness Raising Activities

Council's promotional and pubic awareness raising programs consist of two main types:

(a) The 2020 Breakfast Seminars, which are short, economic development focused, information dissemination events;

(b) The Science and Technology Forums which were established under the State's Science and Technology Policy in April 1997 in order to "raise the awareness of science and technology in the community and increase the community's input in the State's directions in Science and Technology".

Financial Provisions

The expenses of Council are provided for under Section 15 of the Industry and Technology Development Act 1998 via the Western Australian Industry and Technology Development Account.

Present Membership

Mr John Thompson *TIAC Chairman* Managing Director Scientific Services Ltd	
Mr Rex Baker Chairman Executive Committee/Board of Directors Worsley Alumina Pty Ltd	***Dr Nigel Radford*** Chief Geochemist Normandy Group
Dr Lesley Borowitzka Manager Technical Marketing Cognis Nutrition and Health Pty Ltd	***Mr Bruce Sutherland*** Managing Director Gunn Sutherland Corporate Pty Ltd
Ms Leslie Chalmers Senior Consultant Management Consulting Service PricewaterhouseCoopers	***Professor Tony Tate*** Executive Dean Science and Engineering Murdoch University
Mr Rob Meecham Director of the Business Development Unit South Metropolitan of TAFE	***Professor Lance Twomey*** Vice Chancellor Curtin University
Mr Richard Muirhead Chief Executive Officer Department of Commerce and Trade	***Mr Lloyd Zampatti*** Chairman Bretts Limited Group

PUBLIC COMMENT
REPLY SHEET

TO: THE EXECUTIVE OFFICER
WESTERN AUSTRALIAN TECHNOLOGY AND INDUSTRY
ADVISORY COUNCIL

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