Biological Resources Centres: Essential Infrastructure for the Life Sciences, Biotechnology and Education

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SUMMARY

In order to maximise Australia's competitiveness in the life sciences and biotechnology, and to provide world class higher education in the biological sciences, there is an urgent need to develop a national infrastructure of Biological Resources Centres comprising Australian Collection(s) of Microorganisms (ACM) and an Australian Microbial Resources Information Network (AMRIN) to provide integrated internet access to a comprehensive range of quality assured microbial and cell cultures and associated molecular biology resources and information. Lack of this infrastructure is impeding current and future progress in many areas of the life sciences, biotechnology, and education compared with Europe, Japan, and the USA which have developed either centralised, or decentralised but coordinated, facilities to support research and innovative bioindustries. These facilities underpin research and development in a wide range of disciplines and are needed in Australia to provide essential biological resources and services such as:

1. Microbial and cell cultures for applications in industry; biotechnology; human, animal and plant health; research; molecular biology; education; and quality assurance testing.
2. Molecular vectors, genomic DNA, DNA clone libraries, and genetic strains for application in molecular biology research and biotechnology.
3. Internet accessible information on Australian microbial diversity, cultures, and genetic resources.
4. *Ex-situ* conservation of Australian microbial diversity for current and future applications.
5. Expertise and services for isolation of cultures for specific applications; screening of strains for specific traits; identification of cultures for research, industry, testing laboratories, biosecurity; and taxonomic characterization and nomenclature for patents and other purposes.
6. Sources of microorganisms for discovery of new natural product opportunities for bioindustries including novel enzymes, biopolymers, pharmaceuticals, and genes.
7. Sources of microorganisms for use in bioremediation, industrial processes and biotransformations, pollution control, microbial inocula for soil and plant health.

Biological Resources Centres are essential for research and development in the life sciences, for advances in the quality of the environment; agriculture; and human, animal and plant health; and for the commercial development of biotechnology.

The definition and criteria for infrastructure funding need to be broadened to include biological resources in order to maintain an internationally competitive environment for current and emerging research and development in the life sciences and biotechnology in Australia.

1. AUSTRALIA'S FUTURE RESEARCH INFRASTRUCTURE NEEDS

In order to maximise Australia's competitiveness in the life sciences and biotechnology there is an urgent need to develop a national infrastructure of Biological Resources Centres comprising Australian Collection(s) of Microorganisms (ACM) and an Australian Microbial Resources Information Network (AMRIN) to provide integrated internet access to a comprehensive range of high quality microbial and cell cultures and associated molecular biology resources and information.

The OECD Directorate for Science, Technology and Industry, Committee for Scientific and Technological Policy recognises that "Biological Resource Centres are an essential part of the infrastructure underpinning life sciences and biotechnology. They consist of service providers and repositories of the living cells, genomes of organisms, and information relating to heredity and the functions of biological systems. BRCs contain collections of culturable organisms (e.g. microorganisms, plant, animal and human cells), replicable parts of these and viable but not yet culturable organisms (e.g. genomes, plasmids, viruses, cDNA banks), as well as databases containing molecular, physiological and structural information relevant to these collections and related bioinformatics.

BRCs must meet the high standards of quality and expertise demanded by the international community of scientists and industry for the delivery of biological information and materials. They must provide access to biological resources on which R&D in the life sciences and the advancement of biotechnology depends.

Biological resource centres are essential for R&D in the life sciences, for advances in the quality of the environment, agriculture, and human health, and for the commercial development of biotechnology".

[From *Biological Resource Centres: Underpinning the Future of Life Sciences and Biotechnology* (OECD Directorate for Science, Technology and Industry, Committee for Scientific and Technological Policy, 2001)]

Currently, there are several institutional collections in Universities, CSIRO, and government and private research institutions with the potential to form a core of a national infrastructure of Biological Resources Centres in Australia (Sly, 1998). However, these existing facilities are under funded and understaffed by international standards. There has been no mechanism available to fund biological collections at an appropriate level and no awareness or willingness by government to recognise that these facilities underpin science and biotechnology and are essential to meet Australia's national strategic needs and to achieve many of the National Research Priorities. Currently, existing facilities, which are under resourced by international standards, fall under the responsibilities of a wide range of government departments including science, industry, health, agriculture, environment, and education. There has been a long-term reluctance, against the trend in other countries, to recognise national strategic needs in this area in Australia and to fund a national infrastructure for collections and information resources. Regrettably, no one department has emerged as a leader. It is time that a national perspective prevailed. This will require recognition that biological resources and culture collections are an all of government responsibility. Leadership is required to develop a national policy and infrastructure support to bring recognition and coordination of these facilities under one umbrella.

Lack of this infrastructure is impeding current and future progress in many areas of the life sciences, biotechnology, and education compared with Europe, Japan, and the USA which have

developed either centralised, or decentralised but coordinated, facilities to support research and innovative bioindustries. These facilities underpin research and development in a wide range of disciplines and are needed in Australia to provide essential biological resources and services.

International Examples of Biological Resources Centres

Examples of facilities available to scientists and biotechnology in other countries which provide the biological resources, expertise and information which is the subject of this proposal can be observed at the following websites:

American Type Culture Collection (ATCC) [www.atcc.org]
Belgium Coordinated Collections of Microorganisms (BCCM) [www.belspo.be/bccm]
Centraalbureau voor Schimmelcultures (CBS) [www.cbs.knaw.nl]
German Collection of Microorganisms and Cell Cultures (DSMZ) [www.dsmz.de]
Japan Collection of Microorganisms (JCM) [www.jcm.go.jp]
United Kingdom National Culture Collection (UKNCC) [www.ukncc.co.uk]

National Research Priorities

The availability of properly resourced Biological Resources Centres in Australia will make a major contribution to achieving national research priorities including *An Environmentally Sustainable Australia* (understanding environmental systems, transforming existing industries, sustainable use of biodiversity), *Promoting and Maintaining Good Health* (diagnosis and prevention of microbial diseases), *Frontier Technologies* (biotechnology, bioremediation, material sciences, nanotechnology, biosensor technology, biomaterials, biopolymers), and *Safeguarding Australia* (critical infrastructure, protecting Australia from invasive diseases and pests, bioterrorism).

Government Recognition of Need

At least two government reviews have recognized the importance of biological resources including microorganisms as a source of new frontier opportunities for bioindustries in Australia, and the need to strengthen and support culture collections of microorganisms to provide the necessary resources to underpin the life sciences and the development of strong and competitive biotechnology.

The following quotations from government documents are intended to illustrate the strategic context in which this proposal is being made. They not only demonstrate the individual importance of the distinctive fields of microbial biodiversity, microbial resources, bioinformatics and biotechnology, but also that these fields are inexorably interwoven and interdependent.

1. Recommendations from *The National Strategy on the Conservation of Australia's Biological Diversity, 1992*

"Strengthen *ex-situ* conservation, including the provision of adequate resources to relevant institutions and organizations, by:

(a) establishing or strengthening networks of culture collections of microbial species, including those of medicinal, agricultural and industrial importance."

"Accelerate research into taxonomy, geographic distribution and evolutionary relationships of Australian terrestrial, marine and other aquatic plants, animals and microorganisms, priority

being given to the least known groups, including non-vascular plants, invertebrates and microorganisms....."

2. From *Bioprospecting: Discoveries changing the future* (House of Representatives Standing Committee on Primary Industries and Regional Services, August 2001)

1. "Overcoming impediments in establishing Australian bioindustries

Recommendation 1

The committee recommends that the Commonwealth government:

- Increase funding for baseline studies of the Australian biota;
- Target additional funds for collecting activities in bioactive hot spots;
- Fund a larger volume of taxonomic work than at present and ensure sufficient young taxonomists are being trained to undertake this work;
- Provide more funding to maintain and expand existing collections so that they provide comprehensive coverage of Australian biota, including microorganisms;

Recommendation 2

The committee recommends that the Commonwealth government provide additional funding for digitizing and networking information about all of Australia's biological resources.

Recommendation 3

The committee recommends that the Commonwealth government, in consultation with state and territory governments, industry and research community:

- Develop a national strategy for bioinformatics; and
- Assist in funding its implementation so that the necessary infrastructure and skills are available to provide efficient access to information about Australia's biota.

Research Fields Dependent and Enabled by Biological Resources Infrastructure

Implementation of the recommendations made in this proposal and in recommendations to government will have a direct beneficial effect on the following disciplines:

Microbial Diversity

- Australian Biodiversity research
- Taxonomy
- Evolution and genomics
- Ecology

Microbial Resources

- Australian Collections of Microorganisms (ACM)
- *Ex-situ* conservation
- Supply of microbial cultures
- Supply of molecular vectors
- Supply of DNA

- Identification of microorganisms

Microbial Bioinformatics

- Australian Microbial Resources Information Network (AMRIN)
- Internet site for Australian microbial resources
- Integrated electronic catalogue access
- Research network support

Microbial Biodiscovery and Biotechnology

- Environmental microbial genomics
- Gene discovery and expression
- Natural products discovery
- Enzymes
- Pharmaceuticals
- Biopolymers
- Molecular diagnostics

National Benefits and Outcomes from Biological Resources Centres

Implementation of the recommendations made in this proposal leading to the support of Australian Biological Resources Centres comprising a national network of Australian Collections of Microorganisms and an Australian Microbial Resources Information Network would deliver the following benefits and outcomes:

1. **Access to microbial cultures for applications in industry; biotechnology; human, animal and plant health; research; molecular biology; education; and quality assurance testing including:**
    - Cultures for biotechnology applications
    - Cultures for research and discovery
    - Taxonomic type and reference cultures
    - Cultures for Australian Standard methods
    - Control cultures for standard methods of analysis
    - Cultures from Australian research publications
2. **Access to information on Australian microbial diversity, cultures, and genetic resources including:**
    - Cultures maintained in Australian culture collections
    - Location of cultures with specific characteristics
    - Links to gene sequences
    - Links to literature
3. ***Ex-situ* conservation of Australian microbial diversity including:**
    - Microbial species diversity
    - Evolutionary and genetic diversity
    - Metabolic diversity
    - Ecological and biogeographic diversity
    - Strain diversity of human, animal, and plant pathogens
    - Environmental gene clone libraries
4. **Systematic study of Australian microorganisms**
    - Description of novel endemic species
    - Clarification of taxonomic relationships
    - Evolution of Australian microbial diversity

- Co-evolutionary relationships with native flora and fauna
- Endosymbiotic microorganisms

5. **Access to expertise and services for:**
    - Isolation of cultures for specific applications
    - Screening of strains for specific traits
    - Identification of cultures for research, industry, testing laboratories, biosecurity
    - Taxonomic characterization and nomenclature
    - Microbial preservation methods for *ex-situ* conservation
6. **Discovery of new natural product opportunities for bioindustries:**
    - Novel enzymes
    - Biopolymers
    - Pharmaceuticals
    - Genes
7. **Discovery of natural microorganisms for:**
    - Bioremediation
    - Industrial processes and biotransformations
    - Pollution control
    - Microbial inocula for soil and plant health

2. THE COMMONWEALTH'S RESEARCH INFRASTRUCTURE FUNDING SCHEME

There is no doubt that the Commonwealth's Research Infrastructure Funding System has had a major beneficial impact on the progress of many areas of research. It has allowed Australian research in many disciplines to maintain international competitiveness and foster international collaboration in areas where Australia's geographical position, biota, or expertise makes collaboration attractive or indeed unique. In many areas this has resulted in Australia's international success in science and technology.

There are two major factors which compromise the success of the infrastructure funding system to meet future needs. Firstly, the qualifying criteria are too restrictive and focussed on physical items of infrastructure. It is essential to maintain this level of support for physical and technological infrastructure but in addition to broaden the criteria to include biological and bioinformatics resources. Many areas of emerging research will not only depend on sophisticated equipment, but increasingly in many areas of medical, environmental, and agricultural research and in innovative bioindustries involving biotechnology, nanotechnology and material science will depend on repositories of biological material and associated bioinformatics resources. Future funding systems must recognise the shift in the needs of emerging areas of science and broaden the narrow criteria for qualification for funding. Secondly, there needs to be a recognition that provision of equipment or physical facilities is only part of the picture. Infrastructure also needs to take into account the need for the professional expertise to maintain and operate the infrastructure and this is particularly important for biological resources which must be maintained in a viable and genetically stable state in the long term.

3. THE ACQUISITION, DEVELOPMENT AND OPERATION OF RESEARCH INFRASTRUCTURE

A review of practices in other countries with well developed Biological Resources Centres indicates that governments recognise that these facilities underpin and enable many areas of research and industry and are essential national infrastructure for the life sciences and biotechnology. There is a

recognition that these facilities require government support for core activities and that it is not possible to rely on full cost recovery without compromising quality and long term objectives for science and industry. Forcing collections to full cost recovery influences the policies for accession of cultures and provision of services to meet current commercial realities and compromises the ability of collections to accession a wider range of cultures with potential long term value. For example, no one would have predicted the importance of the curious thermophilic bacterium *Thermus aquaticus* and that this bacterium isolated from Yellowstone National Park in the 1960s and accessioned in the American Type Culture Collection would have been used to produce the *Taq* DNA polymerase enzyme for the development of the PCR test which has revolutionised biological research and biotechnology in the 1990s and beyond. Such advances rely on opportunity to bring together independent discoveries in science.

Biological Resources Centres will need government support for core activities. They will need high quality facilities but also need to be staffed by excellent taxonomists, molecular biologists and bioinformatics specialists. As taxonomic expertise has been run down across the biological disciplines, biological resource centres will become the centres of taxonomic expertise to manage these resources and to provide high level research training in taxonomy and identification for young PhD and postdoctoral scientists.

4. PROCESSES FOR DOMESTIC RESEARCH INFRASTRUCTURE COLLABORATION AND ACCESS

Collaboration within the Australian research and industry communities with respect to microbial culture collections has been explored over a long period of time by members of the Australian Society for Microbiology Special Interest Group on Culture Collections with support from most scientific disciplines (see below). However, while there is strong support, progress has been limited by the absence of national policy, strategic framework, and the unavailability of a direct government funding mechanism to match support provided by research and university institutions. In 1998, Sly reviewed the state of Australian microbial resources and explored the national benefits to be derived from the concepts outlined in this proposal. On the basis of infrastructure in other countries and in consideration of existing resources in Australia, Sly (1998) proposed alternative models for the development of Australian Collections of Microorganisms (ACM) and an integrated electronic Australian Microbial Resources Information Network (AMRIN). (Sly, L. I. Australian Microbial Diversity. Microbiology Australia 19:27-35, 1998; Australian Microbial Resources http://www.smms.uq.edu.au/acm). The concept received strong support from a wide range of organisations representing the major biological science and biotechnology disciplines including:

Australian Academy of Science
CSIRO
National Association of Testing Authorities
Australian Biotechnology Association
Australian Genome Research Facility
Australian Institute of Biology
Australian Institute of Food Science and Technology
Australian Society for Biochemistry and Molecular Biology
Australian Society for Infectious Diseases
Australian Society for Medical Research
Australian Society for Microbiology
Australian Water and Wastewater Association
Australian Mycological Society
Australasian Plant Pathology Society
Royal College of Pathologists of Australasia

Currently, Sly is coordinating another initiative to progress the concept and facilitate collaboration. An application is being developed and coordinated by the author for a proposal under the ARC Research Network scheme for an Australian Microbial Resources Research Network (AMRRN). An application for seed funding to prepare a proposal is nearing completion for submission in September 2003. Seed funding will be used to obtain agreement by participants on how the Network will operate and whether information will be centralised or decentralised. In either case, standards for data collection and validation need to be agreed. It is probable that a decentralised network of specialist Australian collections of microorganisms working in close association with expert taxonomists will be the favoured model. An important issue is to determine how the collections will be coordinated and the conditions of membership. Agreement also needs to be reached on the quality standards to be met by collections for the microbial resources and information associated with these collections. One possibility is that a few service collections will undertake to meet standards for accreditation as NATA accredited Reference Material Providers, while a second tier of research collections will complement the reference collections but not have to meet the same quality criteria. The agreement of host institutions, researchers, and information sources on in-kind support and on-going commitment needs to be discussed. The initiative will allow detailed consultations with participants and other stakeholders on the proposed models. This will be achieved by initial site visits by the Network coordinator, Associate Professor Lindsay Sly, and local meetings in all capital cities, followed by a Workshop to be held in Brisbane in December to reach a consensus agreement on the best model and how this model could be developed and be brought to fruition within the framework of the ARC Research Network Scheme.

The proposed Research Network through its coordinated website will facilitate collaboration between researchers and between researchers and industries to encourage innovative science and biotechnology. The website will not only provide access to microbial resources for research and industry, but will also maintain databases of research expertise for example in taxonomy and identification, or with particular taxa of microorganisms to assist in efficient access to this expertise.

The proposed Australian Microbial Resources Research Network will draw together under one umbrella high quality research and researchers working in a range of disciplines including Microbial Diversity, Taxonomy, Evolution and Genomics, Ecology, Identification, Culture Collections, and Bioinformatics, as well as researchers in Biodiscovery and Biotechnology. Participants currently hold 23 ARC research grants amongst them, providing an indication of the importance of these resources to research.

If successful, the AMRRN initiative will help to rectify the current fragmented approach and provide a national focus but will need infrastructure funding if it is to achieve its full potential and reach the standard of similar facilities in other countries. If adequately funded it will have a significant impact and provide an impetus to Australian research and development by overcoming current deficiencies in infrastructure and inefficiencies due to major difficulties experienced by researchers to gain access to microbial cultures and information on these cultures. The Network will thus be an enabling initiative which will bring together existing resources, while providing a framework for future development and funding initiatives. It will provide a means to encourage researchers to accession valuable cultures in collections for future research and exploitation, as well as making available control cultures used in standard methods of analysis. Thus AMRRN will establish essential basic collaborative infrastructure to meet national strategic needs in the life sciences, biotechnology, industry, and educational sectors. It will commence a process to overcome a long recognised deficiency in Australian scientific infrastructure not addressed by previous programs.

The strong level of collaboration in this AMRRN initiative is evidenced by the following list of scientists who will participate:

AUSTRALIAN INSTITUTE OF MARINE SCIENCE
Dr David Bourne, Townsville

AUSTRALIAN QUARANTINE AND INSPECTION SERVICE
Dr Peter Stephens, Northern Australia Quarantine Service, Darwin

CSIRO
Dr Susan Blackburn, CSIRO Marine Science, Hobart
Dr Gary Dykes, Food Science Australia, Brisbane
Dr Ailsa Hocking, Food Science Australia, Sydney

FLINDERS UNIVERSITY
Prof David Catcheside, Adelaide

GRIFFITH UNIVERSITY
Dr Bharet Patel, Brisbane

LATROBE UNIVERSITY
Dr Joanne Santini, Melbourne

MACQUARIE UNIVERSITY
Prof Peter Bergquist, Biotechnology Research Institute, Sydney
A/Prof Michael Gillings, Key Centre for Biodiversity, Sydney
A/Prof Hatch Stokes, Department of Biological Science, Sydney

MURDOCH UNIVERSITY
A/Prof Michael Borowitzka, Perth

NORTHERN TERRITORY UNIVERSITY
A/Prof Karen Gibb, Darwin

NSW AGRICULTURE
Dr Ric Cother, Australian Collection of Plant Pathogenic Bacteria, Orange
Dr Michael Priest, Plant Pathology Herbarium, Orange

PLANT HEALTH AUSTRALIA
Dr Simon McKirdy, Canberra

QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES
Dr Athol Klieve, Agency for Food and Fibre Science, Brisbane
Dr Ala Lew, Agency for Food and Fibre Science, Brisbane
Dr Roger Shivas, Plant Pathology Hebarium, Brisbane

QUEENSLAND UNIVERSITY OF TECHNOLOGY
Dr Phil Giffard, School of Life Sciences, Brisbane

SOUTH AUSTRALIA HEALTH DEPARTMENT
A/Prof David Ellis, Mycology Unit, Womens and Childrens Hospital, Adelaide

UNIVERSITY OF MELBOURNE
Dr Peter Janssen, Department of Microbiology and Immunology, Melbourne

UNIVERSITY OF NSW
Dr Rick Cavicchioli, Department of Microbiology, Sydney
Professor Peter Rogers, Biotechnology, Sydney

UNIVERSITY OF QUEENSLAND
Dr Elizabeth Aitkin, School of Life Sciences, Brisbane
A/Prof Ross Barnard, Biotechnology Program, Brisbane
Prof Robert Birch, School of Life Sciences, Brisbane
A/Prof Linda Blackall, Advanced Wastewater Management Centre/CRC Environmental Biotechnology, Brisbane
Dr Paul Burrell, School of Molecular and Microbial Sciences, Brisbane
Prof Robert Capon, Institute of Molecular Biosciences, Brisbane
Dr Peter Dart, School of Land and Food, Brisbane
Dr Gary Dykes, School of Land and Food, Brisbane
Dr Mark Fegan, School of Molecular and Microbial Sciences/CRC Tropical Plant Pathology, Brisbane
Dr John Fuerst, School of Molecular and Microbial Sciences, Brisbane
A/Prof Peter O'Donoghue, School of Molecular and Microbial Sciences, Brisbane
Prof John Mackenzie, School of Molecular and Microbial Sciences/CRC for Biosecurity, Brisbane
Professor Scott O'Neil, School of Life Science, Brisbane
Dr Steve Reid, Biotechnology Program, Brisbane
Dr Justin Ridge, School of Molecular and Microbial Sciences, Brisbane
Dr Mark Schembri, School of Molecular and Microbial Sciences, Brisbane
A/Prof Lindsay Sly, School of Molecular and Microbial Sciences, Brisbane
Dr Christine Yeates, Advanced Wastewater Management Centre, Brisbane

UNIVERSITY OF THE SUNSHINE COAST
Dr Ipek Kurtboke, Sunshine Coast

UNIVERSITY OF SYDNEY
Dr Andrew Holmes, Department of Microbiology, Sydney

UNIVERSITY OF TASMANIA
Dr. John Bowman, Department of Agriculture, Hobart

WESTERN AUSTRALIA HEALTH DEPARTMENT
Dr T Inglis, Perth

5. PROCESSES FOR INTERNATIONAL COLLABORATION AND ACCESS

The World Federation for Culture Collections and the OECD Directorate for Science, Technology and Industry, Committee for Scientific and Technological Policy (2001) recognise that biological resources in culture collections are a world resource which needs to be accessible across national boundaries for the orderly progress of science and biotechnology. While Australian scientists have access to international resources, Australia cannot depend on other countries to conserve and maintain its microbial resources. Issues such as geographic isolation, quarantine regulations, shipping delays and rising costs, and timely access to biological resources, information and

expertise is a national responsibility which can be best resolved by the provision of high quality infrastructure as discussed above.

Many culture collections are already individually Affiliate Members of the World Federation for Culture Collections and provide data to the WFCC World Data Centre for Microorganisms (WDCM) in Japan. Incidentally, the World Data Centre for Microorganisms was first established at the University of Queensland in 1972-1986, but in the absence of infrastructure support by Australian governments was transferred to Japan in 1986 following an international tendering process. The establishment of Australian Biological Resources Centres will stimulate a sense of collaboration within Australia and foster a national identity. A strong international collaboration with the WDCM will be maintained through internet linkages. The proposed AMRIN would collect more detailed information on strain characteristics than the WDCM. Collaboration with the WDCM would be essential and good electronic links between AMRIN and the WDCM for updating of information would need to be developed to foster international collaboration.

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