2

Potential for industrial development based on bioprospecting

The need for new products and processes

2.1 New products and industrial processes are needed because many of those currently in use are not sustainable.[1] They are not sustainable for several reasons.

- Supplies of raw materials may be limited, as in the case of petrochemicals which provide the feedstock for many industrial products. A time when oil will no longer be an economical raw material can be foreseen.
- The environmental impacts of current industrial processes are creating increasing problems, including contamination of air, land and water, and contributing to global warming. As the human population on the planet grows, these impacts are likely to become ever more intense unless changes are made.
- In the past, as resistance to commonly used drugs and agrichemicals developed, new products were found. More recently, prospects for development as replacements have been harder to find, and a different approach is called for.

2.2 The world's biota represents a source of raw materials that has the potential to replace petrochemicals as an industrial feedstock and to provide novel chemicals for use in drugs and other products. Australia is well placed to contribute these raw materials and to benefit from their use.

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1 Australian Academy of Science, Submission no.19, p. 1.

Australia's potential

Biological resources

2.3 With 10-13 per cent of the world's biodiversity, Australia is one of the 12 most diverse regions in the world.[2] Its biological resources include plants, animals and microorganisms living on land, below ground, in inland waters, and at sea. Australia's bioregions span a range of climates from tropical to Antarctic and from dry to wet.[3] Their species are adapted to these varied environments, having evolved metabolic pathways that produce the chemicals they need to survive. In such biodiversity, Australia has a rich source of chemicals and their means of production.

2.4 In addition, there is a high level of endemism among Australian species. That is, many of our species occur only in Australia - in the case of plants and animals, 75 per cent of them.[4] Figure 2.1 shows this endemism for several groups of organisms. With the right mix of scientific skill, commercial entrepreneurship and government regulation, Australia can capitalise on this uniqueness for the benefit of the nation.

2.5 We do not yet know how extensive the benefits from our biodiversity are. The soil, rainforests and the marine environment were nominated as probably the richest sources for biodiscovery,[5] but much of the biota is poorly known.[6] However, Australia has a vast exclusive economic zone in the waters surrounding the continent. This zone is the third largest of any country in the world.[7] According to scientists at the AIMS, marine biodiversity, especially from deep sea environments, represents one of the richest sources of novel compounds on the planet.[8]

2 Environment Australia, Transcript of evidence, 4 June 2001, p. 62; Australian Institute of Marine Science, Submission no. 27, p. 1.

3 Associate Professor Robert Capon, University of Melbourne, Submission no. 6, p. 5.

4 CSIRO, Submission no. 14, p. 14.

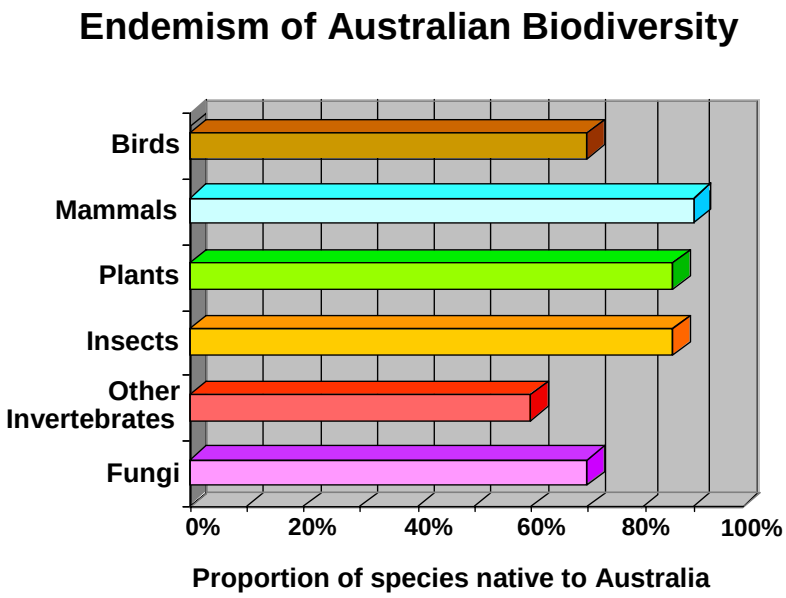
5 Victorian government, Submission no. 34, p. 1.

6 Royal Society of Western Australia Inc., Submission no. 8, p. 1.

7 CSIRO Marine Research, 'Oceans: Our need to know', http://www-ocean.ml.csiro.au/LeafletsFolder/oceansourneedtoknow.html, accessed 10 August 2001.

8 Australian Institute of Marine Science, Committee briefing, 3 May 2001.

Figure 2.1 Endemism of Australian biodiversity



Source: CSIRO, Submission no. 14, p. 14.

Supporting factors

2.6 Australia differs from the other mega biologically diverse regions of the world in being the only one of them that is a developed nation.[9] This gives Australia a head start over these other countries in our capacity to use our biological resources. It also puts us in a good position to compete with other developed countries in developing bioindustries based on biological resources.

2.7 Australia has a well developed science base with the skills, infrastructure and financial resources needed to catalogue the country's biological resources and to perform sophisticated research and development (R&D).[10] State and Commonwealth programs provide support for research into and conservation of biodiversity. Biotechnology R&D is funded by both the public and private sectors. Recent Commonwealth initiatives include the National Biotechnology Strategy (NBS), and the Biotechnology

9 Invest Australia, 'Biotechnology', http://www.isr.gov.au/invest/Industry_Sectors/Biotechnology/biotechnology.html, accessed 10 August 2001; Australian Institute of Marine Science, Submission no. 27, p. 1.

10 CSIRO, Submission no. 14, p. 9; Australian Academy of Science, Submission no. 19, p. 3; EcoBiotics Pty Ltd, Submission no. 18, p.1.

Centre of Excellence and the Biotechnology Innovation Fund announced in *Backing Australia's Ability*.[11]

2.8 Established chemical and biotechnology industries provide the potential for developing biodiscoveries from the local biota. In addition, an innovative, efficient primary industries sector exists that could cultivate any crops from which new chemicals might need to be sourced.[12] A stable political system, uncorrupted public administrative systems, and a well developed legal system provide intellectual property (IP) protection and a regulatory framework for bioprospecting and the commercialisation of biodiscoveries.[13] They also contribute to a financial climate conducive to investment.

Bioprospecting in Australia

2.9 According to Biotechnology Australia (BA), Australia has a relatively immature bioprospecting industry, in which only a small number of companies and organisations are involved. Table 2.1 lists a selection from the companies engaged in bioprospecting to illustrate the range of activity that is occurring. The industry is characterised by networks among companies, and links with universities and large drug and agrichemical companies.[14] Industries based on bioprospecting are, as CSIRO commented, 'only in their infancy'.[15]

2.10 Although significant bioprospecting activity is occurring, much of it results in the sale of unprocessed samples, and the financial returns on these sales are small. According to EcoBiotics, 'overall, the value or return from many of the current bioprospecting activities to the Australian economy and the broader community is highly questionable'.[16] More widespread value adding is needed and is possible.

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11 Biotechnology Australia, Submission no. 25, pp. 13-14; *Backing Australia's Ability: an innovation action plan for the future*, 2001, http://www.isr.gov.au/iap/Policy_Launch/backing_Aust_ability.pdf.

12 CSIRO, Submission no. 14, p. 9; Australian Academy of Science, Submission no. 19, p. 4.

13 Environment Australia, Transcript of evidence, 4 June 2001, p. 62.

14 Biotechnology Australia, Submission no. 25, pp. 5, 8.

15 CSIRO, Submission no. 14, p. 29.

16 EcoBiotics, Submission no. 18, p. 5.

Table 2.1 Some companies and organisations involved in bioprospecting in Australia

Institution	Partners	Research field
Australian Institute of Marine Science	AMRAD, Nufarm, National Cancer Institute	cancer, HIV, neuropathology, infectives
James Cook University	Pharmamar, Biomar	cancer, neuropathology
CSIRO Entomology	Rhone Poulenc Rorer, Biodiscovery	various
CSIRO Bioactive Molecules Initiative		infectives, cardiovascular
Southern Cross University Phytochemistry Centre (SCUCP)		Australian native plants
Flinders University	Novartis	
Venom Supplies Pty Ltd		venoms and venom products
BioProspect Ltd		plant products
Bio-Gene Technology Pty Ltd		various
Australian Phytochemicals Ltd (subsidiary of BioProspect, situated at SCUCP)		plant products
Novogen		legume plant products
University of Melbourne (Marine Natural Products research group)		algae and sponges
Chemistry Centre (WA)		foods, agriculture/ plants, general natural product chemistry
Griffith University	AstraZeneca, Queensland Herbarium and Museum	plant products

Source *Based on Llewellyn, 'Drug discovery from biodiversity in Australia', April 2000, from by Biotechnology Australia, Submission no. 25, p. 9.*

2.11 Several organisations and companies that made submissions to the inquiry are engaged in value adding to their bioprospecting activities. The value adding may include screening extracts from plants, microorganisms and marine organisms for bioactivity, and isolating the active compounds and characterising them. Some of these processes are carried out for the companies' own research programs; others are performed under contract to others.[17]

2.12 An example of value adding was provided by AstraZeneca R&D Griffith University (AZGU) which has collected over 24,000 samples, mostly from Australia. It has also identified the structure of over 460 compounds, of which 37 per cent are new to science. AZGU's high input screening laboratory can process 100,000 samples a week.[18]

17 Cerylid Biosciences, Transcript of evidence, 25 June 2001, pp. 84, 85.

18 AstraZeneca and Griffith University, 'Natural drug discovery in Australia's wilderness laboratory', pamphlet.

2.13 Bioprospecting is largely driven by the demands from subsequent biodiscovery processes, and tends to be cyclical. Bioprospecting activities are currently subdued, with a ready supply of material awaiting screening.[19]

Actual and potential Australian biobased products and processes

2.14 A range of bioproducts are on the market and more are being developed. They include drugs, cosmetics, herbicides, pesticides, and agents for bioremediation and mining.

- CSIRO's submission listed two cases of its work with bioremediation:
  - ⇒ using microorganisms to clean up the toxic effluent from gold mines; and
  - ⇒ removing pesticide residue from the surface of fruit and vegetables, from soil, from industrial wastes, from water, or from human effluents, by adding pesticide-degrading enzymes derived from insects and microorganisms.

  The latter is being commercialised by agreement with Orica.[20]
- Although microorganisms have been used for many years to extract copper and gold from ores, 'the real potential of biotechnology in mining remains to be realized'.[21] CSIRO and others are searching in hot terrestrial and underwater environments for novel microorganisms that can metabolise sulphides at high temperatures. The performance of these organisms may be improved by genetically modifying them.[22]
- CSIRO's work has also led to the production of biopesticides.
  - ⇒ Insect fungal diseases are being used to control insect pests. Biocane was developed from a strain of the soil dwelling fungus, *Metarhizium anisopliae*, and is being marketed to control greyback canegrub, a serious sugarcane pest.[23] Another Metarhizium based product developed by CSIRO is Green Guard for locust and grasshopper

19 Cerylid Biosciences, Transcript of evidence, 25 June 2001, p. 83; CSIRO, Submission no. 14, p. 21; Australian Institute of Marine Science, Submission no. 27, p. 8.

20 CSIRO, Submission no. 14, p. 27.

21 J A Brierley & C L Brierley, 'Present and future commercial applications of biohydrometallurgy', *Hydrometallurgy*, vol. 9(2-3):233-239, 2001 Feb.

22 CSIRO, Committee briefing, 27 November 2000.

23 CSIRO Entomology, 'Bio-control of cane pest a commercial reality', Press release, 2 May 2000.

control, which is being manufactured by Seed Grain and Biotechnology Australia Pty Ltd and tested by the Australian Plague Locust Commission.[24]

⇒ Ecogrow is CSIRO's partner in producing nematodes for the control of turf beetles.[25]

⇒ The *Bt* gene inserted into cotton varieties grown in Australia provides an alternative to applying chemical pesticides as a means of controlling the caterpillars of *Helicoverpa* species.[26]

- BioProspect has identified a Queensland eucalypt, the leaves of which contain compounds with insecticidal properties more powerful than pyrethrum. The same laboratory tests show that it is virtually non toxic to both mammals and plants. A selective breeding program is being commissioned by BioProspect in conjunction with the Queensland Department of Primary Industry, and further development of the compounds will be carried out by multinational companies in collaboration with and under license from BioProspect, but using expertise from Australian universities.[27]

- The extracts of several animals living on the Great Barrier Reef have the ability to selectively kill weedy plants while being harmless to crops. This property makes the active ingredient a potential candidate for use as a herbicide, and is being commercialised by the research team from AIMS and James Cook University (JCU) that discovered it, in association with Nufarm.[28]

- Many marine organisms are protected from damage by UV light by a group of compounds which they can synthesise or accumulate from their diet. The protective qualities of these compounds are the basis for AIMS' work on developing a sunscreen from them.[29]

- An example of the potential for drug development from Australian fauna is provided by the pain killing properties of peptides from cone shell venom. Some of these peptides operate differently from existing

24 'Fungal pesticides', http://www.ento.csiro.au/research/biotech/bot07.htm, accessed 9 February 2001.

25 CSIRO, Committee briefing, 27 November 2000.

26 CSIRO, Committee briefing, 27 November 2000.

27 BioProspect Ltd, Committee briefing, 6 July 2001.

28 Australian Institute of Marine Science, *Annual Report 1999-2000*, p. 15; Australian Institute of Marine Science and James Cook University, Committee briefing, 3-4 May 2001.

29 W C Dunlop, B E Chaler, W M Bandaranayake & J J Wu Won, 'Nature's sunscreen from the Great Barrier Reef, Australia', http://www.aims.gov.au/pages/research/projects/sunscreens/pages/sunscreens02.html, accessed 13 June 2001.

pain killers and offer promise for relief of intractable pain. They are being developed by AMRAD and the University of Queensland (UQ).[30]

2.15 From this small number of examples of biobased products and processes, it is clear that novel results have been obtained. More effective products have resulted, from processes which have less environmental impact, and they cost less than conventionally produced ones.

2.16 Other biobased industries that might be developed either from Australia's biota or from imported stock received relatively little attention in the evidence provided to the inquiry. (Perhaps these industries were not seen as 'high technology', as specified in the terms of reference.) Included here are medicinal plant products and functional foods for which a growing market has been identified. The proposed development of Cellulose Valley based at Lismore in northern New South Wales is based in part on the expansion of crops and processing facilities to supply this market.[31] Australia might also have the capacity to raise crops of plants genetically engineered to produce desirable substances, such as biopolymers.

2.17 Biofuels could become significant if the cost of petrol were to escalate greatly; ethanol is already being produced from sugar cane in small quantities.[32] In addition, large companies like Dupont are developing bioindustries which will use genetically modified bacteria grown on sugar to produce substances, such as polyesters, which are currently produced from petrochemicals. It is envisaged that the bioreactors involved in these industries would be situated regionally.[33]

How big is the potential?

2.18 Submissions to the inquiry were confident about the potential for using Australia's genetic resources.[34] AFFA referred to the 'clear potential for industries based on bioprospecting in Australia', and CSIRO to the 'huge potentials' offered by industries based on bioprospecting.[35] BA asserted

30 'Industry partnership provides next-generation painkilling drugs', http://www.uq.edu.au/research/world-class/collaborations/stories/1.html, accessed 13 June 2001.

31 Southern Cross University, Submission no. 17, p. 1.

32 Biotechnology Australia, Submission no. 25, p. 12.

33 Dupont Australia, Committee briefing, 6 June 2001.

34 For example, Faculty of Natural Resources, Agriculture and Veterinary Science, University of Queensland, Submission no. 31, p.1.

35 Department of Agriculture, Fisheries and Forestry - Australia, Submission no. 25, p. 2; CSIRO, Submission no. 14, p. 29.

that, 'through biotechnologies such as bioprospecting, bioprocessing and related biotechnologies, Australia is developing innovative products and fast-growing enterprises, attracting international investment and creating high-value employment'.[36] AIMS believed that Australia would become ' a world leader in how it facilitates, manages, and brings to commercial reality, discoveries made from bioprospecting'.[37]

2.19 It is well known that the multinational drug companies make very large incomes from successful new drugs, and about a quarter of all drugs have been developed from naturally occurring substances. In 1997, for example, the annual sales revenues from the three top selling drugs of natural origin varied from US$0.9 billion for taxol to US$3.6 billion for Zocor. However, the chance of successfully developing a drug from a natural product falls anywhere between 1:5,000 and 1:10,000, and successful development costs US$231 - 500 million.[38] As little as only 0.1 per cent of genetic resources examined may have potentially useful constituents. In addition, much of the development of drugs is carried out outside Australia, even when the initial discoveries are made here. According to the Western Australian government:

> [Pharmaceutical] production facilities tend to be concentrated in geographic hubs, either close to major markets or where government incentives and / or prevailing socio-economic conditions provide substantial cost savings. Australia does not conform to any of these scenarios.[39]

2.20 It was suggested to the committee that higher returns relative to costs might be generated in Australia from biodiscoveries made for purposes other than drug development. For example, the nematode biopesticide developed by CSIRO raised $200,000 in 1999, and was expected to raise $2 million in 2000-01 and $10 million a year thereafter.[40] Fine chemicals derived from marine organisms are sold for amounts ranging from US$316 to over US$20,000 per milligram.[41]

2.21 Some attempts have been made to estimate the global worth of discoveries that might be made from particular ecosystems. An example is

36 Biotechnology Australia, Submission no. 25, p. 13.

37 Australian Institute of Marine Science, Submission no. 27, p. 1.

38 Environment Australia, Submission no. 29, p. 53, quoting K ten Kate and S A Laird, *The Commercial Use of Biodiversity: Access to Genetic Resources and Benefit-Sharing*, Earthscan Publications, London, 1999.

39 Western Australian government, Submission no. 32, p. 1.

40 CSIRO, Committee briefing, 27 November 2000.

41 Original Oceanz, Smart Ventures Industry Group, Committee briefing, 4 May 2001, quoting Calbiochem catalogue.

US$147 billion for rainforest, a figure that does not include the worth of fungi which is quoted at US$9 billion per year. AIMS pointed out that, given the much greater biodiversity in the sea, it is reasonable to assume that the value of natural products derived from it would be even higher than from rainforest.[42]

2.22 In addition to the economic value of bioprospecting to industry, value may also be extracted by the owner of biological resources in the form of fees paid for samples, annual or flat fee payments for access to particular areas or collections, royalties, and other deals. For example, in an agreement between the Western Australian Department of Conservation and Land Management (CALM) and the company, AMRAD, AMRAD was granted exclusive access to a species of smokebush that yields conocurovone. Conocurovone has anti cancer properties. In return, AMRAD agreed to provide CALM with US$730,000, a share in royalties, and first right of refusal to conduct research on the active compound. AMRAD also provided US$320,000 for further research in Western Australian on smokebush patents.[43]

2.23 It was suggested to the committee that monetary returns to the owner of the resource from these payments are unlikely to be large at this stage, and should not be seen as a significant source of funds.[44] Only a very small proportion of samples lead to the development of successful products, lead times are often long, and the returns from commercial successes may be diluted as they are distributed among various stakeholders.[45] The boom from bioprospecting that was predicted by some in the early 1990s appears not to have eventuated.[46]

2.24 However, while companies are not prepared to make large upfront payments for permission to bioprospect, payments for the recollection of material that yields promising leads can be expected.[47] In addition, royalties from successfully commercialised biodiscoveries can be secured through benefit sharing arrangements. Non monetary benefits, such as increased knowledge about the biota as a result of bioprospecting, also underscore the benefits that ownership of the resource can bring.

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42 Australian Institute of Marine Science, Submission no. 27, p. 18.

43 Environment Australia, Submission no. 29, pp. 24, 52, quoting ten Kate and Laird, 1999.

44 Victorian government, Submission no. 34, p. 2.

45 Environment Australia, Submission no. 29, pp. 28-9.

46 Biotechnology Australia, Submission no. 25, p. 17, quoting 'Bio-prospecting and benefit-sharing', report on a workshop organised by the United Nations Environment and Development and Novartis UK, 1999.

47 Australian Institute of Marine Science, Submission no. 27, pp. 5, 7.

Conclusion

2.25 The views summarised in the last section are optimistic about the potential of bioprospecting to contribute to economic development. They are tempered, however, by some caution about how, and how far, Australia will benefit. The committee is very concerned that this caution may inhibit bioprospecting and the development of industries based on biodiscovery. The committee believes that there is immense potential for Australia to use its biological and the other strengths enumerated earlier in this chapter to compete with the best in the world in an era dominated by biotechnology. This era is in its infancy but growing with immense rapidity. Australia must not be left behind in developing its biological resources, and the skills and knowledge to use them, in what will become the basic industrial technology of the future.

2.26 The committee's intention in compiling this report is to accelerate the nation's progress towards capturing the benefits of bioprospecting through the development of IP and bioindustries. Most of the report is devoted to considering what is needed for Australia to maximise the benefits that flow from bioprospecting, by making best use of its natural advantages and its strengths as an advanced nation.

2.27 The committee believes that it is imperative that bioprospecting and the downstream developments from biodiscovery are incorporated as vital parts of Australia's push to develop industries based on biotechnology. The wide range of applications to which biotechnology can be put offers a great wealth of benefits which Australia must capture fully before others do so. Were Australia to fail in this respect, it would not only deny itself access to the increasing revenues that can be expected from bioprospecting and bioprocessing, but also to improvements to individual health and welfare and to the environment.