Australian Academy of Science

Research and innovation in Australia:
a policy statement

SEPTEMBER 07

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President's foreword

In a world where information is only a click away, the competitiveness of nations such as Australia will be tested increasingly by a new world order. Developing nations including China and India understand with unquestioned certainty that inventive international science and technology are the keys to socioeconomic well-being and prosperity. If as a nation Australia is to retain any advantages in the global market-place it needs to invest much greater effort in the years ahead, in education, training and research in science and technology. Australia needs to forge stronger strategic alliances in science and technology, not only with its traditional collaborating partners in Europe and in North America, but with developing countries as well.

Australia's current competitive advantage in science and technology could be eroded quite rapidly. Australia's contribution to global knowledge is only about two per cent, but is of a quality that permits early access to emerging technologies and new opportunities in equal and respectful partnerships. The global challenges in the years ahead demand that Australia build on its enviable reputation as a leader in science and technology. Research at the national and international level is imperative for continued economic prosperity and community well-being. This claim seems evident not only to the scientists among us but also to the Productivity Commission whose report of *2007 Public Support for Science and Innovation* commissioned by the Australian government, found that widespread and important economic, social and environmental benefits derive from Australia's investment of public monies in science and innovation.

The Academy of Science's 2007 policy statement *Research and innovation in Australia* identifies ten actions that Australia must take to maintain a strategic economic position in a world where many other nations have a competitive advantage through low wage systems and the sheer size of their markets. These ten actions are aimed at optimising the nation's potential and building on the nation's ingenuity.

Where might Australia profit from international science leadership? The broad impacts of climate change and the need to reduce greenhouse gas and other emissions require increased research into climate monitoring and into mechanisms to reduce the impacts on the environment. It is also leading to a worldwide race to develop renewable energy alternatives, including solar technologies in which Australia has a record of innovation. Australia is also part of international R&D into carbon sequestration to allow clean exploitation of Australia's fossil fuel reserves and to safeguard critical coal export markets. In addition, biomedical and health management advances are needed to address the continuing devastation from HIV/AIDS in many countries, as well as the potential threat from bird flu and other pandemics. These represent unprecedented challenges and opportunities for the Australian scientific and business communities that require near-term strategies to sustain the development of our research infrastructure and capabilities, the commercialisation of research and the development of technology by industry.

Major international research facilities and projects in Australia, such as the Square Kilometre Array radio telescope currently under consideration, are also important vehicles to attract international collaborators and raise the profile of Australian research. The Australian Synchrotron and OPAL research reactor are examples of significant additions to Australia's research infrastructure to perform world-class research that will attract important international collaborations.

The following policy recommendations address national priorities for meeting the challenges ahead. They include halting the decline in the supply of researchers and technologists through initiatives at all stages of primary to tertiary education, as well as creating rewarding careers for researchers and developing their international networks. Our researchers and visiting scientists need to be able to undertake world-class research in Australia and to be engaged in major projects both in Australia and overseas. The Australian research community also needs to promote its research achievements and opportunities for collaboration more effectively through international networks. These research priorities need to be matched by the commercialisation of technologies by Australian industries, which continue to be below international benchmarks in most sectors.

Professor Kurt Lambeck, PresAA FRS
President
Australian Academy of Science

Recommendations

1. That Australia increases its support for the national R&D effort to ensure that it retains an internationally competitive science capability to underpin the nation's industrial, commercial, environmental and economic position among leading world economies.
2. That Australia examines the implications of the continuing relatively low level of private sector investment in R&D and creates policy settings that encourage greater innovation.
3. That Australia further addresses the critical lack of suitably qualified science and mathematics teachers, and expands programs to encourage high school students to study science and mathematics.
4. That Australia maintains a long-term commitment to basic research funding in universities, and ensures that the Research Quality Framework (RQF) results in additional funds for high-quality research.
5. That Australia continues to invest in the future by building on the Higher Education Endowment Fund (HEEF) for capital works and research infrastructure in universities.
6. That Australia provides support for publicly-funded research organisations sufficient to maintain their core capabilities, on which their competitiveness as world-class research providers depends.
7. That Australia increases its level of support for existing research centre schemes and develops new 'International Research Centres', and that the research fellowship awards be substantially expanded, particularly for early- and mid-career researchers.
8. That Australia makes a long-term commitment to maintaining first class national research infrastructure facilities and promotes Australian access to international facilities.
9. That Australia gives urgent attention to nurturing rewarding and secure career paths for talented early-career researchers.
10. That Australia recognises the importance of engagement with the international scientific community and uses science more effectively as a tool in foreign policy.

Introduction

Australia's current competitive advantage in science and technology could be eroded quite rapidly as the effects of globalisation challenge the world order. Australia's contribution to global knowledge is only about two per cent, but is of a quality that permits strong, productive, long-term international partnerships. The global challenges in the years ahead demand that Australia build on its enviable reputation as a leader in science and technology. Research at national and international levels is imperative for continued economic prosperity and community well-being.

As the Governor-General, His Excellency Major General Michael Jeffrey AC CVO MC, said in his address to the 2007 annual dinner of the Australian Academy of Science[1]:

'Unquestionably every challenge facing mankind – and there are many – will need critical contributions from science if we are to find timely, intelligent and socially responsible solutions to those challenges. I think, particularly, of finding ways to slow down global climate change and the increasing frequency of extreme events. I think of mitigating the impact of pandemics, such as HIV/AIDS and influenza. I think of attending to the particular needs of an ageing population, that is in itself a testimony to the outcomes of medical research, but – in turn – is demanding even more from our medical researchers.

If Australia can maintain a strong presence in science, we'll not only be the beneficiaries of our own innovation, but also well-networked into the global community and thus alert to emerging opportunities and new technologies internationally.'

In 2006 the Australian Government commissioned the Productivity Commission report *Public Support for Science and Innovation*[2] that found widespread and important economic, social and environmental benefits from Australia's investment of public monies in science and innovation.

The Academy shares this view and contends that the long-term prosperity of the nation cannot be assured unless government and business are prepared to substantially invest in science and technology research and development.

1 Address by his Excellency Major General Michael Jeffery AC CVO MC Governor-General of the Commonwealth of Australia on the occasion of address to annual dinner of the Australian Academy of Science, Great Hall Parliament House, 3 May 2007. www.gg.gov.au/governorgeneral/speech.php?id=222

2 Productivity Commission, 9 March 2007. *Public support for Science and Innovation*. Research Report, Canberra. www.pc.gov.au/study/science/finalreport/index.html

Building a competitive Australia

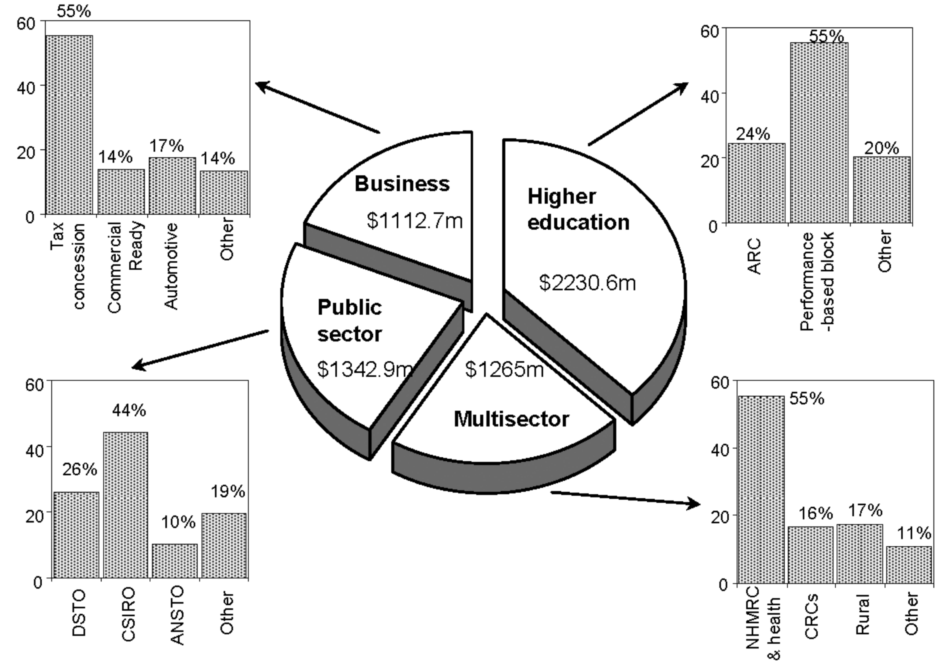
Recommendation 1

That Australia increases its support for the national R&D effort to ensure that it retains an internationally competitive science capability to underpin the nation's industrial, commercial, environmental and economic position among leading world economies.

The distribution of Australian government spending on science and innovation, 2005–06, as provided by the Productivity Commission is given in Figure 1.[3] The level of government investment in R&D as a percentage of GDP remains around the fourth or fifth highest among 30 OECD countries.

The Academy acknowledges that input measures do not necessarily equate to outputs. However, governments around the world continue to equate investment in R&D with future economic development. The EU has targeted GERD (Gross Expenditure on R&D) at 3.0% of GDP by 2010. In comparative global terms, the situation in Australia is serious. In 2004–05 Australia's GERD/GDP ratio remained below the OECD average of 2.26%, at 1.76%.[4] This figure places Australia at rank 18 in a list of 30 OECD countries. Percentage growth in expenditure on R&D since 2002–03 was highest for the private non-profit sector (up 37.2% or $133.6 million) and lowest for the government sector (up 2.8% or $68.6 million). New and higher targets must be set for Australia to remain internationally competitive.

Figure 1 **Australian Government spending on science and innovation**
2005-06



Source: Productivity Commission, 9 March 2007. *Public Support for Science and Innovation.*

3 Productivity Commission, 9 March 2007, page XVIII.

4 Australian Bureau of Statistics, 8112.0. *Research and experimental development, all sector summary, Australia, 2004-05.* www.abs.gov.au/Ausstats/abs@.nsf/7d12b0f6763c78caca257061001cc588/07e66f957a46864bca25695400028c64!OpenDocument

The Academy remains concerned that the sustained boom in primary exports, with the consequent robust growth in GDP is masking an underlying weakness in our strategic capacity to develop knowledge-intensive industries and to address pressing environmental, social and other issues. ABS information[5] reveals that the bulk of business research and development expenditure is in the research fields of engineering and technology, along with information, computing and commercial sciences. Expenditure in areas that underpin the new knowledge intensive industries, transform existing industries and deal with problems central to the future health of our society is very small by comparison. As discussed under specific recommendations below, this weakness manifests itself in a number of ways, including in an increasingly apparent shortfall in graduating scientists and engineers; falling university enrolments in the enabling sciences, mathematics and engineering; the continuing decline in the relative level of funding available for university research; a very low number of researchers employed by industry compared with world standards; and a dramatic fall-off in the number of high school students opting for the hard-core science subjects.

These same weaknesses impact on Australia's ability to address the major environmental and social issues on the national agenda. A scientifically well-educated public, as well as scientists and social scientists specialising in these critical areas, are necessary to appreciate, understand and investigate these issues, as well as to develop policies that will facilitate the necessary changes in activities.

It could be argued that the government should be taking advantage of the current healthy economic conditions to strengthen Australia's export competitiveness in the non-primary goods sectors, to protect the future economy against further deterioration in the global terms of trade in primary exports.

The Academy acknowledges the Australian government's support for the nation's R&D effort, with current expenditure on innovation programs at a record level of $6.5 billion in 2007–08.[5] It is noted that sector performance for science and innovation, expressed as percentages, distributes the largest share of funds to higher education (36%), followed by Australian government scientific agencies (24%) and then the business enterprise sector (21%). But it is also noted that support for science and innovation as a proportion of total government expenditure will drop to 2.83% in 2007–08 from 2.89% in 2006–07.[6]

Private investment in research and development

Recommendation 2

That Australia examines the implications of the continuing relatively low level of private sector investment in R&D and creates policy settings that encourage greater innovation.

The Academy notes the Australian Bureau of Statistics (ABS) report[7] that BERD (Business Expenditure on R&D) grew by 10% from 2002–2003 to 2003–2004, and as a percentage of GDP, rose slightly from 0.87% to 0.89% over the same period. While not over-interpreting small year-to-year variations, the Academy remains concerned that the level of BERD remains well down in the bottom half of OECD countries. Some 30 years of essentially bi-partisan support for measures to increase the relative level of BERD have had little effect, although under the 150% tax deduction regime that existed prior to 1996, BERD had been rising slowly but steadily.

For BERD, Australia sits in 20th position at a level of 0.9% of GDP. Sweden heads the list at 3.0% and the average for all OECD countries is 1.5%[8]. Australian businesses spent $7.2 billion on R&D in 2003–04, up 10% on the previous year and the highest level recorded. But the available data show clearly that Australia is still lagging behind on BERD.[9]

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5 Department of Education, Science and Training. *Budget Information 2007– at a Glance*. www.dest.gov.au/portfolio_department/dest_information/publications_resources/resources/budget_information/budget_2007_2008/at_a_glance.htm

6 Department of Science, Education and Training. *2007-08 Science and Innovation Budget Tables, Table 1. Summary of major Australian Government support for science and innovation through the budget and other appropriations – actual cost in year incurred.* www.dest.gov.au/ministers/bishop/budget07/bud39_07.pdf

7 Australian Bureau of Statistics, 8112.0

8 OECD database, 2005–06. http://www2.oecd.org/ecoinst/queries/index.htm

9 Vaughan G, 2006. *Government assistance programs*. ATSE Focus. www.atse.org.au/index.php?sectionid=855

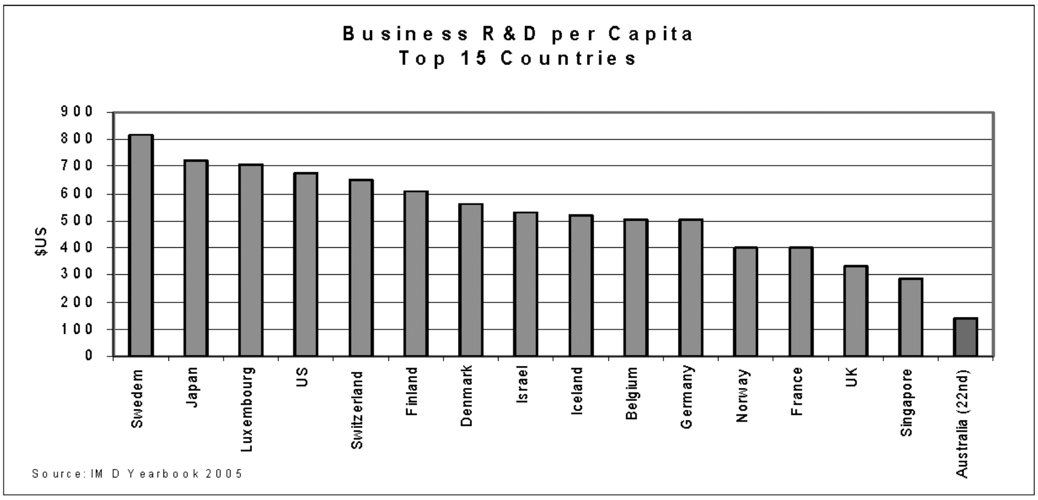

Figure 2. Australia is lagging behind on business expenditure on R&D (BERD).[10]

Government has a leadership responsibility for creating the right environment across Australia for the growth of innovative industries. This environment should provide real incentives for business to undertake R&D and to innovate, and those incentives should be both simple to understand and use. This is important because the administrative costs of accessing incentives can quickly reduce their real value. In addition, the nature of research and development in many industries is long-term so business needs to have confidence in the policy settings before it will invest.[11]

The Global Competitiveness Report[12] identifies seven innovation factors, of which BERD is one, against which 125 countries are ranked. Other areas where Australia ranks poorly include the availability of scientists and engineers (rank 35), the degree to which companies pioneer new products and processes (rank 35), innovation (rank 24) and government procurement of technology products based on technical performance rather than price (rank 30). A close examination of the impact of government policies on business innovation needs to be undertaken.

The 2007 ALP directions paper[13] commented that analysis of the seven subindexes that comprise the innovation pillar identified only two areas of notable competitive advantage for Australia: in intellectual property protection (rank 10) and in the quality of scientific research institutions (rank 16).

The current resources boom masks the underlying downward trend in manufactured exports, particularly in advanced and high technology goods. The inescapable conclusion is that there is serious under investment in R&D by Australian business that warrants government attention.

10 Victorian Innovation Economy Advisory Board, 9 March 2007. *Issues concerning taxation and incentives for business innovation, including R&D*. www.diird.vic.gov.au/corplivewr/_assets/main/lib60032/submissionproposal_final.pdf

11 Victorian Innovation Economy Advisory Board, 9 March 2007.

12 Schwab K, Porter ME, Lopez-Claros A, 2006. *The Global Competitiveness Report 2006–2007*. World Economic Forum Geneva, Switzerland.

13 Rudd K and Carr K, April 2007. *New Directions for innovation, competitiveness and productivity – New directions paper and a ten point plan for innovation in Australia*. Australian Labor Party.

School level science and mathematics education and awareness

Recommendation 3

That Australia further addresses the critical lack of suitably qualified science and mathematics teachers, and expands programs to encourage high school students to study science and mathematics.

In an increasingly complex world, an informed citizenry that can take personal responsibility for informed decision-making needs a fundamental understanding of science and technology. It is not only those who go on to creative, scientific and highly skilled jobs that benefit from a science education. All children benefit from being taught to think in a scientific, disciplined way. As argued by Davies[14]:

'A solid science education enhances and promotes the development of critical thinking skills. This is because such an education encourages students to put extra effort into searching for and attending to evidence that contradicts what a person currently believes; it also cultivates a willingness to change one's mind when the evidence starts mounting against a position. In this way the scientific method is very useful because it helps detach the student from pre-formed ideas and positions, keeping them open for re-evaluation. This is partly because science is an explanatory activity. In general, the scientific theories are constantly re-framed in order better to understand data which seem to require or admit explanation. In reasoning in such a way scientists continually gain explanatory advantage, but prove nothing finally. New data, including the success of new theories, constantly emerge.'

There should be a nationally coordinated set of curricula for the sciences. There has been some action in this area at the primary school level. In 1994, the Academy initiated a program *Primary Investigations*[15] that provides primary school teacher resource books and student books, coupled with in-service training and support for teachers, to guide a process of 'hands on' activities designed to stimulate understanding and knowledge of basic scientific principles.

This program was widely regarded as being very successful, and has been further developed as *Primary Connections*, that links the teaching of science with the teaching of literacy in primary schools. The program is a partnership between the Academy and the Department of Education, Science and Training (DEST). It has been developed in collaboration with a large number of key groups involved with the teaching of science and literacy.

The Academy is very pleased with the positive conclusions of an independent review of the *Primary Connections* program.[16] At the time of writing, more than 55,000 curriculum resource units have been provided to teachers across all states, territories and jurisdictions. The Academy is now looking at ways in which these models might be extended to the secondary school level, with a national pilot project, *Science by Doing*, supported by DEST.

A direct link in the causal chain leading to the looming shortage of scientists and engineers is the lack of high school students opting to study science subjects. The 2003 report *Mapping Australian science and innovation*[17] states:

'…participation by year 12 students in science subjects is a significant factor in ensuring not only a supply of candidates for undergraduate science degrees, but an adequate level of S&T literacy amongst the population as a whole.'

The report then goes on to point out:

'…physical science enrolments have fallen from 81,842 in 1991 to 66,504 in 2000, while total year 12 enrolments have increased from 183,257 to 185,810 over the same period.'

A report commissioned by the Australian Council of Deans of Science[18] found:

'…that the proportion of students taking physics subjects is two thirds of what it was in 1989. The picture for chemistry is also gloomy and for maths it is worse.'[19]

[14] Davies WM. *A cautionary note about the teaching of critical reasoning*. The University of Melbourne, Australia. http://tlu.ecom.unimelb.edu.au/papers/203.Davies.HERDSA.PR.pdf

[15] *Primary Investigations* – The science program for primary schools. www.science.org.au/pi

[16] Hackling M and Prain V. *Primary Connections Stage 2 Trial: Research Report*. www.science.org.au/reports/pcreport1.htm

[17] Department of Education Science and Training, October 2003. *Mapping Australian science and innovation.*

[18] Dobson IR and Educational Policy Institute, February 2007. *Sustaining science: University science in the twenty-first century*. Australian Council of Deans of Science. www.acds.edu.au

[19] Dorothy Illing, 9 July 2007. *Fewer students learn high-demand skills*. The Australian. www.theaustralian.news.com.au/story/0,24897,22040316-12332,00.html

Enrolments in maths fell by a third from 1989 to 2005. The decline occurred against growth in higher education, with student numbers doubling over the same period.

Another DEST report[20] highlights the insufficiency of highly trained teachers in science, technology and mathematics, and a number of factors that mitigate the effectiveness of science teaching in schools as currently practised. A more recent paper[21] again highlights the low level of science training among high school science teachers; for example 25% of year 12 physics teachers have not studied physics beyond the first year of university. Another recent study lays the blame with the way science is taught in schools.

The Academy notes that there are programs in place to raise high school student awareness and interest in science generally, such as the National Innovation Awareness Strategy, implemented as part of the *Backing Australia's Ability* package, but also notes that this strategy was basically a continuation of previous science awareness programs that had targeted high school students, particularly at the period around years 9 and 10 when they are considering career decisions.

The Academy welcomes the announced funding of $457.4 million over four years to provide direct assistance to school students through national literacy and numeracy vouchers. It also notes a commitment of $53.2 million to reward schools that have been successful in raising literacy and numeracy standards.[22]

School leavers are seemingly choosing university courses solely on the basis of the subsequent employment opportunities that it will offer, but are missing out on learning how to think and on preparation for self-directed, lifelong learning. A main goal of education involves developing general thinking skills, particularly critical-thinking skills which are the essence of scholarly debating and something common to both the 'hard' and 'soft' sciences and the humanities alike. Unfortunately, students are not acquiring these skills as much as they could and should. An education in science is itself an education in a disciplined way of thinking.

Davies explains that 'critical' in this context means that students are educated to present supporting reasons for their positions on various topics to logically demonstrate the points being made. This does not necessarily amount to being rhetorically convincing, but rather being able to logically demonstrate points and be able to devise workable inferences from plausible premises to plausible conclusions. Unexamined convictions about various products and processes strike right at the heart of rational deliberation.[23]

University research

Recommendation 4

That Australia maintains a long-term commitment to basic research funding in universities, and ensures that the Research Quality Framework (RQF) results in additional funds for high-quality research.

The increased competitive funding for research arising from increases in government funding for the Australian Research Council (ARC) and National Health and Medical Research Council (NHMRC) has been welcomed by the Academy. However, the Academy cautions against an expectation that an ever-increasing proportion of funding can be obtained from the private sector. The ability of a university to attract private sector research contracts or grants depends on the quality of its core research capability, which is largely driven by public sector funding, especially competitive grants. The current figure of about 30% as the proportion of research funding derived from private sector sources would seem about optimal although not all agree with this conclusion. In a study of commercialisation of university research, Yencken and Gillen[24] found:

'Australian university revenue from intellectual property licensing royalties and research contracts has been below that of some other countries studied. Analysis suggests that this results from

[20] Committee for the Review of Teaching and Teacher Education, October 2003. *Australia's teachers: Australia's future – advancing innovation, science, technology and mathematics*. Department of Education, Science and Training.

[21] Centre for the Study of Higher Education, April 2005. *Who's teaching science: meeting the demand for qualified science teachers in Australian secondary schools*. University of Melbourne.

[22] Hon Julie Bishop media release, 8 May 2007. *Students to benefit from new literacy and numeracy vouchers*, BUDB 25/07. www.dest.gov.au/ministers/bishop/budget07/bud25_07.htm

[23] Davies WM. *A cautionary note about the teaching of critical reasoning*.

[24] Yencken J and Gillin M, 2006. *A longitudinal comparative study of university research commercialisation performance: Australia, UK and USA*. www.atypon-link.com/EMP/doi/abs/10.5555/impp.2006.8.3.214

problems in both demand (low business investment in R&D and hence low technology absorptive capacity) and supply; that is, lack of time and lack of incentive for academic researchers to develop contacts with and meet the expectations of industry and other research users for technology that works.'

In the context of funding university research, the Academy recognises that the cost of maintaining a world-class research capacity rises faster than the general cost of living, as new technology enhances the capability of research equipment and facilities necessary to strive towards world parity. Attempting to increase the level of private sector sources to too high a level would have the effect of 'quarrying' the intellectual capital of the university, ultimately compromising the integrity of its core research capability, thus reducing its capacity to provide the quality research required.

The Academy reiterates its support for the concept of a research assessment process within the framework of the higher education system, now being implemented as the RQF, so long as this is a cost effective mechanism that results in increased funding for quality research.

Two principles of concern to the Academy are that the concept of excellence is central to the definition of quality of research, regardless of where the research is undertaken; and that the RQF process is intended to inform the allocation of block infrastructure grants (including research infrastructure block grants and the Institutional Grants Scheme) to universities, and is not an input to the processes of the ARC and NHMRC in assessing individual research proposals.

The Australian Academy of Science has consistently argued that block funding schemes should reward research quality, research outcomes (including long-term outcomes) and the impact of that research. The Academy has welcomed the commitment to distribute all the Institutional Grants Scheme (IGS) funds and at least half of the Research Training Scheme (RTS) funds under a framework that recognises research quality – especially if additional monies are made available when central agencies, and the community more broadly, better understand the value of investment in research.[25]

The Academy of Science, together with other pre-eminent international scientific organisations, considers that the impact of research is attested by citations of the work in scientific literature and in patent applications, and by scientific standing of the journals in which the research is published. While this is not an exclusive definition of 'impact', it is disconcerting to find that the RQF impact working group specifically excludes any bibliometric measures of impact from its considerations.

The Academy reminds the RQF Development Advisory Group (DAG) that the funds available under the RQF were intended to provide the higher education sector with the critical infrastructure funds that underpin nationally competitive research grants. The Academy is concerned that in an attempt to assess 'impact' in terms of universities' engagement with business, professions, governments and regional communities – all activities that are to be applauded – then the quality of research may well be eroded if research infrastructure funds are redirected into these enterprises. Engagement with the community ought to be core business for any university.

The RQF DAG is well-advised to reconsider what seems to be turning into an increasingly complex assessment exercise that invites inefficient and expensive game-playing. One cost-effective means of distributing RQF funds is to base it almost entirely on the value of national competitive research grants awarded to universities. The national competitive research grants reflect both the quality of the proposed research and past research (track-record) that in turn reflect quality and quantity of research training and the research environment, all of which are given rigorous assessment through peer review. That is, success in gaining national research competitive grants is an appropriate proxy and surrogate for research quality.

The RQF has already resulted in significant researcher mobility and assessment of discipline priorities that have increased diversity among Australian universities. The amount of money associated with the RQF should be such as to more than compensate universities for the time and resources related to research quality assessment.

25 Australian Academy of Science, 3 July 2006. *Research Quality Framework: The impact working group*. A submission to the Australian Government Department of Education, Science and Training. www.science.org.au/reports/3july06.htm

Higher education

Recommendation 5

That Australia continues to invest in the future by building on the Higher Education Endowment Fund (HEEF) for capital works and research infrastructure in universities.

A strong university sector is at the core of Australia's capacity to maintain and develop the level of education among the population appropriate to a first-world country, including the skills base necessary to address the needs of industry and the many environmental issues that remain unresolved.

The Academy notes the modest increases in operating grants funding under the Commonwealth Grants Scheme, and is aware that the total funding per Commonwealth-funded student place increases significantly towards 2008, with the increased upper limit on student charges providing most of the increase. However, the Academy also notes the concern expressed by the Australian Vice-Chancellors' Committee that the value of this funding will decrease in future years unless it is indexed at a higher rate than currently applies. A recent discussion paper[26] prepared by the Group of Eight Universities makes the cogent case that Australia's higher education system remains under-resourced, over-regulated and under-planned. This must change.

The Academy welcomes the announcement[27] of $5 billion (now $6 billion) in a perpetual Higher Education Endowment Fund (HEEF) for capital works and research infrastructure. But future HEEF funds should not be drawn from existing initiatives and programs that already provide capital works for universities and for national research infrastructure more broadly.

The Academy notes that a significant fraction of the increased funding available to universities derives from the income from full-fee paying students, either domestic or from overseas. While the generation of external income is to be applauded, the Academy is concerned to ensure that the process is fully costed, so that the excellence of the research and teaching base on which the international competitiveness of the institution relies is maintained. In this context, it should be noted that countries such as Singapore and China, from whence many international full-fee paying students originate, are rapidly building up their own national university capacity, and will thus become more competitive in terms of attracting their own students, or even competing for international students from the region. It is probably safe to assume that the respective governments will set the cost of admission to their universities to be competitive in that international market.

In Australia, there is no indication that any 'profit' from these external revenue generating activities finds its way into supporting the core science and research programs of the universities. The Academy remains very concerned that there does not appear to have been any progress on problems previously identified. Thus the student to staff ratio continues its inexorable rise: this issue must be addressed if Australian universities are to maintain their current international standing for educational excellence, let alone improve their position.

The deteriorating situation regarding the lack of graduates in the science and engineering fields has been clear for years. The latest OECD data[28] show that Australia is very near the bottom in the percentage of university students in engineering, physics and mathematics. A large turn-around is necessary if Australia is to compete internationally in knowledge-based industries, as well as maintain an internationally competitive research capability, both in universities, and publicly-funded research organisations.

While the figures vary somewhat in successive data sets, OECD data show that Australia ranks about seventh with the number of researchers per thousand of the labour force at 7.2, but the number employed in industry is only 1.7 per thousand of the overall labour force, which ranks Australia at a position of about rank 19 among other OECD countries.[29]

[26] Group of Eight, 6 June 2007. *Seizing the opportunities: Designing new policy architecture for higher education and university research.* www.go8.edu.au/policy/papers/2007/Go8%20paper%20on%20higher%20education%20and%20university%20research%2006.06.07.pdf

[27] The Hon. Julie Bishop media release, 8 May 2007.

[28] OECD. *Science, Technology and Industry Scoreboard 2003 – Towards a Knowledge-based economy*. www.oecd.org/publications

[29] OECD *Science, Technology and Industry Scoreboard 2003.*

The reasons for the drop-off in enrolments in general science degrees and consequent poor engagement with science appear to be related to a number of factors:

- the very large number of subjects available at years 11 and 12
- the perception that high tertiary entrance scores are paramount, so students opt out of 'difficult' subjects like maths, physics and chemistry in years 11 and 12 , to find that science degrees at university are no longer open to them
- parents and students have little idea of what jobs are open to scientists, so that career options available to science graduates are not obvious
- teaching of science in schools is no longer very hands-on, due to lack of funding and OH&S regulations. Consequently there is little opportunity for science teachers to 'excite' students or for students to get their hands dirty and discover science and investigation via experimentation
- science teaching is often carried out by education graduates, with limited science backgrounds, rather than by scientists with teaching qualifications. This reduces the visibility of a career in science to high school students.

An additional factor leading to poor university enrolments is the strong job market, so that school leavers can obtain employment immediately without a degree. Emphasis on trades has siphoned off some students to TAFE. The issue of identifiable and financially-rewarding careers appears to be particularly important to parents and it will be crucial to promote the diverse array of opportunities that are available to holders of science degrees and to show that not all scientists conform to a negative stereotype.

Named or 'boutique' degrees do not seem to be suffering the same decline in enrolments as general science degrees. These are often seen as addressing new opportunities, even though this novelty is transitory (even based on fashion) and actual job opportunities are not by any means guaranteed. Indeed a generalist science degree may offer much improved flexibility and diversity of employment. Further, the Academy recognises that data management expertise becomes a core skill for researchers, including graduate and postgraduate science students across all disciplines, and recommends that they receive data management training as part of their education.[30]

The appreciation of the crucial roles to be played by scientists and by scientific thinking in Australia's future can be at least partially increased by ensuring that school and university students study in an environment where science is enthusiastically embraced. At university this should be in an environment of excellent research. In schools there should be an environment of enquiry and evidence-based evaluation of information.

University degrees modelled after the Bologna Process have the potential to educate students in the fundamental skill of transforming information into knowledge. The Bologna Process recommends consolidated generic courses, in contrast to 'boutique courses' such as forensic science or nutrition, or highly vocational undergraduate courses. Specialisation, including vocational training, would occur at the post-graduate stage through an additional Graduate Diploma or Masters degree. In the Australian context, these must be Higher Education Contribution Scheme (HECS) funded places. Graduates today are highly likely to end up in careers far removed from their higher education course of study. This makes the need for young people with solid skills in a range of areas and a high degree of flexibility particularly important for Australia's future.

There is a perception that 'the best and brightest' Australian graduates tend to head overseas. The question of the supposed 'brain drain' has been a somewhat vexed issue over many years. Some studies based on data obtained from immigration information provided by travellers in and out of Australia suggest that there is in fact, a net 'brain gain' but there is much anecdotal evidence to suggest that there is a real issue of quality not resolved in such analyses.

The weakness in R&D employment in the private sector, in engineering particularly, is compounded by the process of privatisation of public enterprises that had previously provided a large employment and training base for graduates, and served an important role as part of the supply chain of experienced engineers for industry. The conclusion is that the Australian university system is struggling to provide the throughput of numbers, and the quality of graduates required to service our public sector research capability, or a growing knowledge-based industry, and that current measures are not providing a speedy solution to the problem.

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[30] Australian Academy of Science media release, 27 March 2007. *Saving the fundamentals of science*. www.science.org.au/media/27march07.htm

Publicly funded research organisations

> **Recommendation 6**
>
> *That Australia provides support for publicly funded research organisations sufficient to enable them to maintain their core capabilities, on which their competitiveness as world-class research providers depends.*

The Academy maintains its conviction that the publicly funded research organisations – including AIMS, ANSTO, BoM, CSIRO, DSTO and GA – comprise an important part of Australia's research and innovation system. The role of these organisations is different from, but complements that of, universities. They have a clear responsibility to maintain core competencies in strategic research relevant to Australia's economic, environmental and industry priorities.

The Academy's National Committee for Earth Sciences has conducted a strategic review of research in geosciences in Australia and has clearly identified where the role of Geoscience Australia in long-term, visionary research complements university research. Publicly funded research organisations must be able to invest in long-term research that is not readily supported by short-term competitive research grants from funding agencies.

The Academy welcomes the announcement in the May 2007 federal budget[31] that CSIRO:

'…will receive $2.8 billion including $244.5 million for new measures over the next four years that include: $174 million to support an expansion of the Flagships programme; $51.7 million to support construction of the Australian Square Kilometre Array Pathfinder; $16.8 million for the Australian Animal Health Laboratory to improve diagnostic testing of new and emerging diseases; and $2 million to develop a *Wellbeing Plan for Children*.'

The Academy notes that funding includes expansion of the CSIRO National Research Flagships initiative to further develop research into challenges Australia is facing in climate and energy. This means that CSIRO has received a noteworthy increase of 19.5% compared to the previous four year period.

This should reduce concern that servicing too high a level of external research contracts could have the effect of drawing down the intellectual capital of the organisation, thus weakening its capacity to service such activity in the long term.

The structure of research, particularly innovative basic and applied research, has changed in ways that should be recognised both by the knowledge sector (universities, institutes, government agencies and CSIRO, and DSTO) and by the government as a facilitating and funding body. The divisions between disciplines (such as chemistry, physics, engineering, psychology and medicine) and between structures (such as universities, CSIRO and institutes) are no longer appropriate; indeed, they often stand in the way of necessary interactions and collaborations. It is important that government funding mechanisms should not be divided by traditional silo mentalities, and that the universities and CSIRO, in particular, should welcome attempts to break down barriers between disciplines and institutions. It does not make sense in 2007 that many of our best scientists and engineers do not participate in university teaching and research because they are technically in CSIRO or another government agency. Attention should also be given to the related issue of 'whole of government' approaches at federal level, where research expenditure on defence, CSIRO, universities and the health sector needs to be integrated to achieve maximum impact, rather than balkanised. It is also important to ensure that federal and state expenditure on research, particularly but not exclusively in the health sector, should be harmonised.

Many creative research staff, both at senior and more junior levels, comment that they now spend a great deal of time on compliance, health and safety, human research ethics, genetic regulations, animal research ethics and many other issues, even though there is a strong sentiment that these requirements are applied with little regard as to whether they are relevant to, or meet any needs of, the Australian community. The government should be committed to ensure that regulatory interventions should only be applied when they are necessary, and not in a bureaucratic and speculative fashion.

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[31] Department of Education, Science and Training. *Budget information 2007 – at a glance*. www.dest.gov.au/portfolio_department/dest_information/publications_resources/resources/budget_information/budget_2007_2008/at_a_glance.htm

Research Centres, Programs and Fellowship Awards

Recommendation 7

That Australia increases its level of support for existing research centre schemes and develops new 'International Research Centres', and that the research fellowship awards be substantially expanded, particularly for early- and mid-career researchers.

The Academy has previously expressed its strong support for the CRC program, considering that it remains a world leader in fostering collaboration between research providers and research users in both the private and the public sector. In addition, the Academy strongly supports the Special Research Centre and Centre of Excellence programs offered by the Australian Research Council (ARC). These schemes offer extremely good value for money in terms of supporting long-term fundamental and strategic research[32] and provide mechanisms for rapid introduction of research into emerging science areas. They also often attract strong interest and 'leverage support' from industry. While the latter does not invest directly in the ARC funded research, it frequently takes a strong interest in possible research outcomes, girding these centres with direct research investment, often through ARC Linkage scheme grants.

The Academy considers that the centre and fellowship programs are uniquely linked, with the capacity (see recommendation 9) to have additional fellowships linked to industry. While the present Australian fellowship programs have real merit, there are valuable lessons to be learnt from the Canada Chairs program[33], in terms of scope, as well as university, industry and government involvement.

As already mentioned, the Academy recognises that Australia accounts for approximately 2% of the world's research publications. The country certainly 'punches above its weight'. However, for Australia to be placed at the cutting edge of a specific number of research fields that will underpin our future industries, almost daily interaction between the world's best research teams is essential. This requires the formation of a number of (10 to 15) 'Special International Research Centres'. These will perform research 'at the edge' and should be structured so as to ensure a constant flow of students and staff between the Australian headquarters and the key overseas nodes. The Academy notes the highly successful Marie and Pierre Curie Fellowship and excellent Human Capital and Mobility Research Programs in the EU[34] which have transformed the research landscape in Europe.

The Academy welcomed the announcement in the first *Backing Australia's Ability* (BAA) package that the funding level for the CRC program would, by year five, '…be increased by 80%', but is disappointed to now find that the actual funding profile rises to a level of only 65% above pre-BAA levels in 2005–2006, and falls to essentially the pre-BAA level in 2010–2011. The most recent review of the CRC program was generally supportive of it, but made a number of recommendations that resulted in a major revision of the guidelines and selection criteria. The most significant of these changes was the removal of the option for public good outcomes as the main objective of a CRC, and a requirement that there be at least one commercial entity among the core participants in a CRC.

The Academy endorses the findings of the Productivity Commission's report in stating that:

'Collaboration can generate significant benefits. The CRC program is, however, only suited to longer-term arrangements. There are complementary options for business collaboration with public sector research agencies and universities that could provide more nimble, less management-intensive, arrangements.'

According to the Productivity Commission[35], the CRC program could be improved in two ways:

- the original objectives of the program – the translation of research outputs into economic, social and environmental benefits – should be reinstated. This is likely to produce greater

[32] ARC *Discovery Magazine*, Spring and Summer 2005–06.

[33] Canada Research Chairs. www.chairs.gc.ca/web/home_e.asp

[34] European Union Delegation of the European Commission to the USA. *Science and technology/research*. www.eurunion.org/policyareas/science.htm

[35] Productivity Commission, 9 March 2007.

- community benefits than focusing public support on the commercialisation of industrial research
- the share of public funding should be aligned to the level of induced social benefits provided by each CRC, thereby reducing some of the large rates of subsidy to business collaborators.

The Academy recognises the importance of encouraging the commercialisation and utilisation of CRC research outputs, but is concerned that these changes may result in a focus on short-term commercial outcomes at the expense of long-term strategic research objectives. Commercial or other outcomes are generally achieved outside the CRC framework itself; that is, by the users of the research taking up the research outputs of the CRC. The government is urged to limit its expectations of short-term commercial outcomes to be achieved by CRCs themselves.

In this context, the Academy is disappointed at the exclusion of public good outcomes as the main focus of a CRC. The Academy sees the CRC program as an effective mechanism to maximise the national benefit from research in both the public and private sectors. Enhanced environmental and social outcomes have long-term economic benefits, and the Academy urges the government to review its position on this restriction.

Another pressure on the CRC program arises from the increased financial pressure on universities and publicly funded research organisations that result in a decreasing flexibility in their ability to allocate resources to CRCs. This financial pressure exacerbates legal and other factors that add complexities to participation in CRCs. The Academy is concerned that the combination of these factors does not erode the effectiveness of the core concept of the CRC program that can be summarised as 'enabling the participants to achieve their objectives more effectively than working alone, or in one-on-one relationships.'[36]

National research infrastructure

Recommendation 8

That Australia makes a long-term commitment to maintaining first class national research infrastructure facilities and promotes Australian access to international facilities.

The Academy welcomes the announcement on 28 February 2006, by the Minister for Education, Science and Training, The Hon Julie Bishop regarding the release of the National Collaborative Research Infrastructure Strategy (NCRIS) Roadmap, which identifies areas in which Australia should aim to develop, or further develop, research capability through significant infrastructure investment.[37]

'Through NCRIS, the government is providing $542 million over 2005–2011 to provide researchers with major research facilities, supporting infrastructure and networks necessary for world-class research.'[38]

The first nine capabilities are: evolving biomolecular platforms and informatics; integrated biological systems; characterisation; fabrication; biotechnology products; networked biosecurity framework; optical and radio astronomy; integrated marine observing system and; structure and evolution of the Australian continent.[39]

Among the successful projects there are programs that will:

- establish a national network of medical imaging facilities across Australia
- provide facilities to support gene discovery and genome analysis in universities and specialist centres around Australia
- establish a comprehensive fabrication capability for Australia's emerging nanotechnology industry
- develop a networked biosecurity framework to improve collaboration between the existing agencies and institutions involved in biosecurity research, to help prevent the entry into Australia of new diseases and pathogens.

[36] A paraphrase of a statement by Professor Peter Robinson, then Deputy Vice-Chancellor, University of Wollongong, CRC Association Conference, Brisbane, May 1998.

[37] Department of Education, Science and Training (DEST). *National Collaborative Research Infrastructure Strategy*. www.ncris.dest.gov.au

[38] DEST. *National Collaborative Research Infrastructure Strategy*.

[39] DEST. *National Collaborative Research Infrastructure Strategy.*

It is critical that ARC or NHMRC research grants that require access to a particular National Collaborating Research Infrastructure include a line item to cover the cost of that access. In the longer term, it is important to note that to maintain world-class research facilities, the cost of infrastructure rises faster than the Consumer Price Index, and that the level of funding of infrastructure support remains under review to ensure that the overall infrastructure inventory remains world-class and able to leverage international collaboration, both in terms of overseas participation in Australian facilities and Australian access to international facilities.

An important component of these international linkages are those arrangements that provide access for Australian scientists to major international research facilities, such as the European Organisation for Nuclear Research (CERN), the Gemini telescope, the synchrotron light sources in Tsukuba, Japan, and Argonne in the USA; and the Global Biodiversity Information Facility. Some of these arrangements (Gemini, Tsukuba, Argonne) are funded through the current Major National Research Facilities program. It will be important to continue and expand these arrangements to include facilities such as the International Ocean Drilling Program. It is also important that resources are available to provide for local and reciprocal international access to major Australian facilities, such as the Australia Telescope National Facility, the OPAL research reactor, and the Australian Synchrotron.

Early Career Researchers

Recommendation 9

That Australia gives urgent attention to nurturing rewarding and secure career paths for talented early-career researchers.

The Academy agrees with the Productivity Commission's finding that career structures for Australia's early- to mid-career researchers require urgent attention. The lack of suitable, secure positions, with remuneration, research funding and the expectation of employment on a par with that overseas, is attracting and keeping our best talent off-shore. This creates a cycle of fewer people wishing to study the core science subjects, find a career in research, or become science and mathematics teachers to train and inspire the next generation. The solution is to invest in the nation's R&D base in universities, research organisations and small-to-medium sized enterprises (SMEs). In universities and research institutes a suitable approach is to create schemes to offer security and pay parity for scientists who have completed one or two post-doctoral fellowships. There is an urgent need for more mid-career fellowships, especially from the ARC. Career structure is a large issue, especially for young post-doctoral researchers. The academic world can be seen as a pyramid, where there are numerous places available on the lower rungs, but where higher positions are scarce.

The UK model of Royal Society or UK Research Council University Research Fellowships which pay academic-scale salaries and provide substantial research support funds is an attractive one. Host universities are required to offer such fellows a continuing appointment after a five to eight year fellowship. In industry a large fraction of scientists is now being attracted to employment in SMEs. A similar career path may be envisaged through engagement with SMEs by providing funds to promote collaboration and potential recruitment of early- and mid-career researchers. Enabling a broad and high quality research base in which success is measured by outcome will do much to contribute to wealth creation through innovation in the 21st century.

The Academy is concerned about the related issue of Australia permanently losing many valuable post-doctoral scientists overseas and has suggested a 'boomerang scheme' to tempt Australians back to the country before they become too settled overseas. The scheme would involve substantial start-up funds, a salary equivalent to Australian peers and job security.

Maximising the benefits from Australia's formal linkages to global scientific activities

Recommendation 10

That Australia recognises the importance of engagement with the international scientific community and uses science more effectively as a tool in foreign policy.

The knowledge-based economy of the 21st century will be even more dependent on scientific knowledge as global competition increases the pace of change. Capacity building in developing countries is important so that these countries can make their own decisions and avoid the past mistakes of the now developed world. This is particularly important in the link between industrial development and climate change. While continued climatic change now seems inevitable, the Academy acknowledges that it is important to reduce the pace of that change as much as possible, to give extra time for societies and ecosystems to adapt as smoothly as possible. In response to this challenge, the Academy increased its activity in the InterAcademy Panel (IAP) and in the Federation of Asian Academies and Societies and will host the Executive Committee of IAP in Canberra in 2007.[40]

With respect to global engagement in science and technology, a recent report to the Prime Minister's Science, Engineering and Innovation Council (PMSEIC)[41] chaired by the President of the Academy, Professor Kurt Lambeck, recommends:

- establishing a process that prioritises Australian participation in specific large scale international science projects and international infrastructure development
- establishing a funding instrument to enhance Australia's capacity to engage in international projects in a timely and flexible manner. The instrument should include support for Australian scientists to participate and take leadership roles in international projects.

With respect to people, the report recommends:

- addressing barriers to international scientists moving to and from Australia using a coordinated approach across relevant departments
- identifying further opportunities within existing programs of relevant funding agencies to facilitate engagement with the international science community and placing particular emphasis on opportunities for early and mid-career researchers.

With regard to partnerships, the report recommends:

- extending Australia's joint bilateral science funding program beyond the existing relationships with China, India and France, to include more traditional science and technology partners (for example the US, the UK, Canada, Germany, Japan and the EU through their Framework Programme), as well as exploring opportunities for such partnerships with developing nations in our region
- engaging with peak industry bodies to identify further ways to promote links between international companies and Australia's academic and industrial research sectors to leverage international opportunities that maximise the value of Australian technologies.

With regard to promotion, the report recommends:

- expanding the current ways in which Australia's science and technology strengths are promoted and showcased on a global scale through relevant agencies and industry peak bodies. This should include consideration of increased Australian science and technology representation in major overseas capitals with a focus on identifying areas for bilateral and regional cooperation with research and industrial agencies
- canvassing relevant agencies to expand the ways in which international science and technology opportunities can be promoted within the Australian research and business communities.

In this era of globalisation, the internationalisation of science assumes an increased importance. As is well understood, Australia, with its indigenous capacity at about 2% of the global scientific effort, relies heavily on its linkages with the global community to ensure access to the other 98% of the world's scientific developments. The Academy plays a key role in this process, as it provides the formal link with the corresponding academies around the world. It also provides the formal link between international scientific unions and their national discipline-based committees.

The Academy elects Corresponding Members, eminent scientists residing overseas who have developed links with scientific institutes in Australia and maintain strong ties with Australian scientists. The list of 27 Corresponding Members is listed on the Academy's web site.[42]

A report by the Academy[43] maps the extent of Australian involvement in international collaborative scientific activities, and the benefits that flow from that involvement. The report also provides an inventory of opportunities to enhance the scope and effectiveness of that involvement. Approximately

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40 Awards and admission of New Fellows, 3 May 2007. *President's address*. Australian Academy of Science. www.science.org.au/sats2007/presidentsaddress.htm

41 *Australia's Science and Technology Priorities for Global Engagement – A report of the PMSEIC working group*. December 2006.

42 Australian Academy of Science. *Corresponding Members*. www.science.org.au/academy/fellows/corresp.htm

43 Australian Academy of Science, April 2005 *Maximising the benefits from Australia's formal linkages to global scientific activities*. www.science.org.au/reports/linkages.htm

100 major global scientific organisations are identified, as well as many more significant activities and organisations that fall under these major organisations, with which Australia is formally engaged.

In addition to benefits that directly increase Australia's scientific capacity through these international arrangements, other benefits include the fact that there is a relatively large number of Australians in leadership roles in global scientific organisations, and Australia has hosted a large number of major international scientific conferences, including the general assemblies of almost all of the International Council of Science (ICSU) member unions.

Australia's research community is highly respected internationally, and our scientists (both as individuals and as Fellows of the Australian Academy of Science) are in demand as officers and spokespersons for international scientific forums such as the WHO, UNESCO, UNIDO and OECD. The Academy considers that the federal government should welcome these roles and facilitate them, in the national interest. The Academy also notes that such roles help our scientists obtain international recognition and funding for research.

Another benefit from these formal arrangements that has the potential to become very significant is that academies in other countries often have strong links with industry in that country. In the case of China, for instance, its academy of science is the major operator of national research organisations, which, in turn, are affiliated with major industrial enterprises.

Increasingly, the Academy has been using its international contacts to foster science–industry partnerships.

For instance, the Academy organised a joint scientific and industrial mission to China in October 2005 that involved several companies in the biotechnology and nanotechnology area. This model holds great promise for developing international industrial linkages, particularly in scientifically intensive industries. In addition to scientific and industrial links, international science relations should be seen as an important part of Australia's international and trade relations generally. Scientific issues are increasingly influential in matters of national security; for instance, studying bio-terrorism, infectious diseases and military technologies.

The third Australia–China Symposium was held on the topic of energy in Sydney in November 2006, while the fourth annual bilateral symposium was held in Beijing in August 2007 on the topic of global sustainable ecosystems.

The Academy considers that Australia could achieve far greater benefits than is currently the case with an increased use of the opportunities available through the international scientific linkages that exist. These opportunities are ripe for development. The Academy has looked at working with the Department of Foreign Affairs and Trade to develop further the framework for these activities.

Science plays a key role in the consideration of a range of economically important issues, including trade in genetically modified foods and products, international telecommunications, and microelectronics, to name a few. Science is critical to national credibility on a range of global environmental issues, including climate change and the protection of biodiversity.

Conclusion

The Australian Academy of Science contends that the nation's future socioeconomic and environmental prosperity will be underpinned by science, technology and innovation. The Academy has brought together ten recommendations aimed at increasing the chances of the nation realising its potential as a major contributor to a global, knowledge-based economy. Without urgent attention to education, research and innovation policies, Australia may find its current competitive advantages in the international market-place rapidly eroded. Alternatively, strategic investment in science, technology and innovation will open up new and exciting opportunities to strengthen the quality of life for all Australians.

List of abbreviations and acronyms

ABS	Australian Bureau of Statistics
AIMS	Australian Institute of Marine Science
ANSTO	Australian Nuclear Science and Technology Organisation
ARC	Australian Research Council
BAA	*Backing Australia's Ability*
BERD	Business Expenditure on R&D
BoM	Bureau of Meteorology
CPI	Consumer Price Index
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAG	Development Advisory Group
DEST	Department of Education, Science and Training
DSTO	Defence Science and Technology Organisation
EU	European Union
GA	Geoscience Australia
GDP	Gross Domestic Product
GERD	Gross Expenditure on R&D - national
HECS	Higher Education Contribution Scheme
HEEF	Higher Education Endowment Fund
IAP	Inter-Academy Panel
ICSU	International Council for Science
IGS	Institutional Grants Scheme
NCRIS	National Collaborative Research Infrastructure Strategy
NHMRC	National Health and Medical Research Council
OECD	Organisation for Economic Cooperation and Development
PMSEIC	Prime Minister's Science, Engineering and Innovation Council
R&D	Research and Development
RQF	Research Quality Framework
RTS	Research Training Scheme
SET	Science, engineering and technology
SMEs	Small-to-Medium Sized Enterprises
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
WHO	World Health Organization

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ISBN 0 85847 242 2