must have reduced the capacity of the Executive Committee to act enthusiastically. As it was, it did more that some rank and file members were prepared to permit, and the inevitable resignations followed. The Staff Association could no longer represent a consensus view for such a view no longer existed.

In an ironical postcript to the affair and as if to prove to the rest of Australia that the University of Queensland was truly part of the Queensland Wonderland and fully integrated, the Senate would subsequently appoint a committee of its own members to enquire into the cause and course of the protests at the degree ceremony of 10 May, 1985. Alice herself would have found the perverse logic of having such an inquiry conducted by Senate members entirely consistent with the tea parties, games, and trials that were going on around her.

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Government funding of scientific research

The Hon. Barry O. Jones
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Minister assisting the Minister for Industry, Technology and Commerce
Parliament of Australia

The subject which was proposed to me: 'Government Funding of Scientific Research', and the series of talks the University's Chemical Society has organised on the topic, indicate a growing interest and participation of the scientific community in Australia's political life.[1]

One obvious result of this higher profile of the scientific community was an improvement in the performance of science in this year's Federal Budget. Science fared relatively well in the Budget, considering the government's over-riding concern to reduce the deficit. Science ranked 14th out of 28 departments in terms of the increase in funding allocated in the 1985/86 Budget, compared with 26th in the 1984-85 Budget. It ranks 11th in total Budget outlays, behind such crowd pleasers as Social Security, Defence, Education and Community Welfare. As I said at the National Science Forum in August, 'I can say with confidence that science is no longer in political Death Valley'.

But the heightened public and political awareness about science and technology (S&T), and the heightened scientific awareness of public and political affairs, have broader and more important implications. The journal *Nature*, in its recent survey of science in Australia, observed that S&T are now issues ordinary people take seriously. 'Nowhere else, except possibly in India now and the Soviet Union in the 1930s, has the exploitation of S&T been as proper a subject of polite conversation as it has become in Australia', *Nature* said. I am not convinced that this is quite the case — but there has certainly been a dramatic shift towards the integration of S&T into Australia's social, economic and political cultures.

One measure of this is the greater media interest in the subject. Earlier this year only one metropolitan paper, *The Australian*, had a full-time science reporter. Now *The Sydney Morning Herald* and *The Age* have specialist science writers and *The Australian Financial Review*, which strongly reflected the business sector's derisory ignorance of S&T, will soon launch a weekly science section.

The past several years have been unsettled and unsettling in this field: government criticised scientists and industry over the state of Australian technology; scientists attacked industry and government; and industry blamed government and scientists. Now, however, we are moving towards — dare I say — accord and consensus on the subject.

Australian science could be poised at the brink of the most important and most productive period in its history. The major one is that industry, especially manufacturing industry, has not yet demonstrated any real commitment to increasing its research and development (R&D) effort. I was appalled to read the other week the results of a survey commissioned by P A Technology which showed that the majority of Australian senior executives in manufacturing industry saw little need to do more than a minimal amount of R&D.

If this is the case, then it reveals in Australian business a level of ignorance, shortsightedness, and complacency that is almost beyond belief. Of course there are many exceptions; the problem is that they are just that — exceptions. As the Prime Minister said in his opening speech to the National Technology Conference in 1983, the task before us is to make S&T work for Australia.

It is clear that as the links between science, technology and economic growth become closer and more inextricable, and competition between nations more intense, all industrial countries are moving to ensure the national benefits of the science they perform. This is nowhere clearer than in the United States, the world's leading scientific nation, where there has been growing concern in recent years about the flow of scientific and technical information and know-how to the USSR and to Japan, the concern being on strategic grounds in the former case and economic in the latter.

The simnple truth of the matter is that Australia can no longer afford a situation where, in the words of the historian Hugh Stretton, 'Australian science finds its practical application in Australian agriculture, but in British, American or Japanese industry'.

Science, I regret to say, is not part of our political culture and in some ways its sheer complexity repels politicians, bureaucrats, journalists, and businessmen. It has been a hard slog to raise consciousness in areas like biotechnology, advanced materials, microelectronics and similar areas, with little effective support, it must be said, from the academic community.

In their Report on Australian Science Policies, the OECD Examiners (April 1985) noted (para 10-13) 'the intense discussion in Australia of the role of technology in national life' since the Hawke Government assumed office and the need to continue it.

The Examiners commented:

We were struck by what seemed to be a widespread Australian view of technology as in some sense external to national life. This is in part, no doubt, a consequence of Australia's historical idiosyncracies. A high proportion of the techniques used in Australian industry (although not in agriculture) are indeed imported from overseas, mostly by foreign-owned companies. Australia has a tradition of importing technical and professional workers, rather than (or as well as) educating them from childhood. The country's institutions for labour/management relations are such that new technical procedures are frequently seen as being imposed "from outside" on local factories or offices, often with minimal consultation . . .

The process of technological development . . . is seen as discontinuous: the transition from research to design of a product or service, or from design to sale, seems sometimes to involve the collision of mutually uncomprehending cultures . . .

The somewhat remote Australian attitude to technology seemed to us to lead to a consistent undervaluation (and to some extent also a misinterpretation) of national technological achievements and possibilities.

The Examiners' Report was valuable, but it has been inadequately discussed and some of its recommendations have already been ignored.

But if the broad function of science in Australia is to work for Australia, not all research has the same precise function. Let me turn now to the different types of scientific research, why they are carried out, and the parts played by the three key groups in the process of research: the scientific community, industry and government.

The objectives of science

Australia's overall level of funding and performance of basic and applied research, and the level of R&D performance and funded by the public sector, are broadly similar to those of other middle-ranked OECD countries. In contrast, the level of experimental development, and the level of R&D which is funded by the private sector is very low in comparison to these countries.

Many of the problems concerning the perceived relevance and effectiveness of public investment in R&D are the result of the general lack of technological orientation, and of R&D capability, in Australian industry. A major objective of research policy for Australia over the next ten years should be to increase the level of support and performance of R&D by indigenous industry.

The disinterested pursuit of truth is an **end in itself** (a social and cultural value) and also a **means** to the achievement of socially desired ends (e.g. economic development or military capability). A vital and dynamic capability in basic research is needed to provide the reservoir of knowledge and skills to underpin applied research and experimental development.

The rationale underlying public investment in R&D in Australia is that such investment is needed:

- to identify, understand, and transfer technology from overseas; and
- to undertake research and develop new technologies in response to domestic economic and social needs.

All major industrialised nations accept the need for a R&D capability. There are three broad objectives behind this involvement; economic, social and cultural. All are important, but the first is the most discussed, reflecting a general belief that the level of R&D significantly influences the national economy and that its absence leads to economic stagnation.

National economic goals include the generation of wealth and employment. This is achieved through using resources more efficiently, increasing export earnings and replacing imports while using less protection than at present. These goals can only be achieved with a satisfactory level of technological innovation and performance, and research is an essential basis for innovation.

While industry has the main responsibility for carrying out this research, there is a general acceptance amongst industrial nations that some government involvement is also necessary because of the tendency of industry to invest in R&D at a level below that considered to be in the best national interest.

Longer term research, especially, is often beyond the role and capacity of the private sector. The benefits cannot easily be captured by individual companies because of the non-proprietary nature of the research. The time-frames are often too long and the risks too high, while the fragmented structure of many industries means individual companies have neither the resources nor the expertise to carry out research themselves. Furthermore, this research caters for the future, addressing industries and markets which do not yet exist.

The national responsibility and interest is perhaps more clear-cut with the second objective I mentioned: the social objective. Here research is an essential element of government responsibilities to the community in areas such as public health, protection of the environment and so on.

The third objective is cultural, where a nation justifies research on intellectual grounds. It contributes to the country's international status and is important in the education and training of scientists. In the long term, the results of this research may contribute to more direct social and economic benefits.

Of course, not all research programs will fit neatly into one or other of these categories. Research into climate and weather, or soil and water degradation, for example, will have both economic and social objectives.

Scientific research is also categorised according to its objectives in another way: that is fundamental, strategic and tactical. Fundamental research is directed primarily towards adding to the pool of human knowledge rather than to particular applications. It is concerned with the inner logic of science or 'science for science sake' and corresponds with the cultural objective in the above classification.

Strategic research is mission — or applications — oriented, with a long timescale and a broad application.

Tactical research is problem-oriented, involving the application of established scientific knowledge and methods to the solution of practical problems. Both the strategic and tactical categories of research can be applied to economic or social objectives.

Fundamental and strategic research are often grouped into the one category of basic research and called pure basic and strategic basic research. This has led to a misconception amongst some commentators in the recent debate about S&T based on equating all basic research with pure or fundamental research.

The process of innovation

It is widely accepted that basic research plays a vital role in the process of technological innovation. According to the so-called *linear model* of innovation the development of a commercial product or process is a alinear sequence of events, starting with basic research and continuing through applied research to experimental development and finally marketing. This has fostered the 'science push' model of innovation which claims that pumping resources into basic research inexorably leads to innovation and commercial development.

It is now accepted that this rather simplistic view of innovation is not supported by the evidence. Australia, like the UK, is a strong performer of basic research, but disappointing in the industrial sector. Japan, in contrast, is less impressive in basic research; its industrial performance however is well-known. (The Japanese recently boasted that the majority of their products were based on technology invented in the UK: this is flattering perhaps to UK scientists, but not to UK industrialists.)

The linear model has credibility only on a **global** scale. As Jan Kolm has said, 'isolated research findings in small nations do not coalesce into technologies, but feed the international science pool on which the major international companies draw'. Australia's science feeds world science from which international technology grows and from which Australia then imports know-how and products.

Many research scientists believe that government has no legitimate policy role to direct expenditure on basic research. (Professor Bede Morris of the ANU said on a recent Science Show that the appropriate function of granting bodies is to hand over funds to the best researchers, and tell them to enjoy themselves.) A small country such as Australia simply cannot afford to place all its emphasis on this serendipity approach to research.

It is generally the proponents of the serendipity approach who claim that the level of funding for basic research is far too low. In fact higher education research expenditure has expanded significantly during the last decade, increasing by 20% in real terms over the period 1976-81. The level of expenditure per effective full-time academic researcher showed a modest increase in real terms from $54,800 to $62,000 (constant 1979-80 prices) (Johnston 1985: 'Why Scientists Don't Get More Money'). If we add together the Special Research Centres and Key Centres for Teaching and Research, all provided through CTEC, the total amount allocated has increased from $29 million in 1977 to $79 million proposed for 1985. This is an increase of 40% in real terms. Over the same period, the general recurrent funds provided to universities and colleges have remained approximately constant in real terms.

In addition new granting schemes have been initiated — for example NERDDC (National Energy Research Development and Demonstration Council) Grants and Marine Research Grants — and the funds available to others boosted — for example NH&MRC (National Health & Medical Research Council).

Since 1976, a black year for research funding, there has been a substantial decline in the proportion of research expenditure provided by 'free funds' to researchers through ARGS, though even that scheme has increased substantially — 20% in real terms — during the period 1984-86. Programs such as the National Research Fellowships and Biotechnology Fellowships have been developed to try to direct the national research effort more effectively to secure social and economic objectives. The National Research Fellowships Scheme will provide an extra fifty fellowships in 1986, bringing the total to 150, 40% of which are for fundamental research. These increases demonstrate the government's wish to foster research of the highest quality both in basic research, supported through ARGS and the Special Research Centres, and in research which is oriented to specific social and economic objectives.

However scientists need to realise that the 'science push' arguments which have featured centrally in the debatae about research expenditure are no longer accepted without question. As Professor Ron Johnston has said:

They [scientists] will need to accept the importance of demand policies, and seek to assist and shape them in a way which does not stifle creativity, but allows research to be shaped more by the context of opportunities and needs. And they will need to take highly visible steps to increase the level of accountability and value of their own research. (Johnston 1985).

Science in Australia

I believe the public and political debate about S&T in Australia has also been clouded by several other, related misconceptions:

- some government economists tend to lump together all research with economic objectives under the general label of 'industrial R&D'
- related to this, the suggestion that government performs and funds research as a 'second-best' substitute for private sector R&D
- alternatively, a view that CSIRO's role, and to a lesser extent that of the universities, is to provide a free problem-solving service for individual firms — a tax-paid 'dial-a-boffin' service, if you like.

These difficulties of the debate have been compounded by the fact that there are no objective measures for determining either the optimum total level of R&D that a country should perform, or the optimum level of government contribution to R&D, or the optimum ratio of fundamental to strategic to tactical research.

International comparisons do provide some measure of a country's relative commitment to R&D, but have to be treated cautiously because of differing economic, social and cultural conditions. This is clearly shown by the differing approaches being taken by particular countries to strengthen their R&D effort. Thus the United States, Sweden and Japan, which have a very strong industrial R&D base, are moving government support towards fundamental research, leaving strategic and applied to industry.

Canada, the UK and the Netherlands, on the other hand, are shifting in the opposite direction, with government providing increasing support for research with more immediate, tactical objectives.

Nevertheless, there are a number of clear observations that can be made from a comparison between Australia and other developed nations:

- Australia's total R&D effort is low and falling, while that of the industrial front-runners is high and rising.
- Australian government support for R&D is broadly comparable with that of other medium-sized developed countries, but business support for R&D is amongst the lowest of all industrial countries.
- Related to this, the quality and quantity of Australian research is high, but its performance in applying this research in industry is dreadful.

Australia has a long tradition of 'truncated development' in technologically based industries, a superficial form of industrialisation where foreign factors of production (capital, technology and management) largely substitute for local ones. The very high degree of foreign ownership in industry constitutes a formidable disincentive to developing indigenous applied research or design skills. Both are seen as strategic activities, carried out at the place ;where strategy is determined — head office. Subsidiaries generally do not carry out all the functions from original research to developing an international marketing strategy. (ICI and Philips stand out as exceptions.) Many smaller firms prefer acquiring an exclusive domestic franchise in mature products developed overseas: as the licensor updates, so does the licensee. The need for local thinking is sharply reduced.

The philosophy of 'truncuated development', promoted by Sir Robert Menzies and Sir John McEwen, but not under that name, was politically popular and enjoyed bipartisan support. It actually worked very well for us in the 1950s and 1960s when we sold our staples at high prices and bought back technology. Since the 1970s, with dramatic changes in the balance of world trade, 'truncated development' has been disastrous for Australia. Our proportion of world trade in ETMS ('elaborately transformed manufactures') actually fell between 1978 and 1982. Of the 24 OECD nations, we rank 21st in the per capita value of technologically based exports, a mere one-seventh of the OECD average, and only one-thirtysecond of the leader (Switzerland). The only good news is that we still outrank Greece, Iceland and Turkey. The fact that we are failing in the fastest growing area of world trade should occasion no surprise: we have actually programmed ourselves not to succeed.

Let me illustrate the point. The raw materials in my Japanese digital watch (bought in 1978) are almost certainly Australian — iron ore, silica and silicon, lead, copper and other traces. Their value is hard to calculate exactly, but certainly less than 10 cents. The watch was worth almost a thousand times the value of the raw materials.

Volvo, Saab-Scania, SKF, L.M. Ericsson, Hasselblad, Atlas Copco, and Electrolux are all household names in Australia, originating in a country 15,000 kilometres away with barely half our population. It cannot be said that Hills Hoists, Violet Crumbles, Vegemite or the Holden have made a comparable impact in Sweden. In October the Royal Swedish Academy of Engineering was holding a series of seminars in Melbourne and Sydney to tell us how to do it: I imagine it will be some time before our Institute of Engineers is in a position to reciprocate.

The P A Technology survey asserts that the Australian average level of private applied research, expressed as a percentage of revenue, is only 60% of the average expenditure of the other countries surveyed.

Partly as a result of the debate over the past few years, and in particular the past year, there is an emerging consensus on what Australia should be doing in the area of S&T to improve its economic competitiveness and its standard of living. There is widespread, or at least growing, agreement between the scientific community, government and industry on the following points:

- Australia needs to at least maintain its government-funded R&D and substantially increase industry R&D. The draft National Technology Strategy suggests increasing private sector Gross Expenditure on R&D from the present level of 0.2% to 1% of Gross Domestic Product.
- Australia needs to increase the benefits from the research dollar by improving the quality and application of research. This will mean improved management of staff and resources, and more effective communications, liaison and collaboration between the performers of research, especially the universities, CSIRO and manufacturing industry: that is my definition of 'relevance'.
- Universities will do the bulk of fundamental research but their expertise would be made more available to help industry with its problems. Their research would be done more effectively, both in terms of its internal organisation and its closer links, through collaboration, to the strategic research of CSIRO and the tactical research of industry.
- Industry should substantially increase its R&D base, in order to reap the benefits of both its own research. Industry research will primarily be tactical, but it will also contribute funding to the research in CSIRO and universities.

Public sector science

The public sector performs about 80% of Australia's R&D. Research in Australia's 19 universities accounts for about 30% of the total R&D effort. About 70% of this research is carried out in the natural sciences, 30% in the social sciences and humanities.

The broad role of universities is the acquisition, preservation and transmission of knowledge. More specifically their tasks include:

- the advancement of knowledge for its own sake, with the freedom of choice to pursue questions which may be unfashionable or out of favour with government or community opinions at the time
- the training of the next generation of researchers whose skills will be required in both strategic and tactical, as well as future fundamental, research. Obviously if a university system loses its best people, national impact could be felt for generations.

To take the first point — the universities' fundamental research role. Academics have become very concerned recently over what they see as pressure by the government to do work of more relevance to industry, and hence a threat to their tradition of free enquriy. They viewed as ominous a statement by the Minister for Industry, Technology and Commerce, Senator Button, to the National Meeting of Concern on S&T in Canberra in April:

- *I firmly believe that a country's scientific effort should include a proportion of basic research of the highest quality. To endorse basic research, however, is not necessarily to say that it has to be at the same level as at present, nor that every basic research endeavour or area presently in progress is unquestionable.*

Thus Professor Adrienne Clarke of the University of Melbourne in an address at ANZAAS in August:

If our strength in basic research were weakened, we would become severely undercapitalised with respect to fundamental knowledge, we would erode our position as a civilised nation and lose our membership of the club of nations who share knowledge and the capacity to access this knowledge. We would launch the next generation of Australians poorly equipped to deal with a world of rapidly changing values and technologies.

I do not disagree with what she says, except perhaps the implication that strategic research does not fulfil similar objectives. The difference between the two is often only apparent in the reasons for carrying out that research. But nor do I see any great discrepancy between Senator Button's position on university research and the view which Professor Clarke put in her paper, which generally speaking advocates stronger links between universities and CSIRO and business so that greater benefits can flow from Australia's fundamental research.

There are some semantic hang-ups to be unhooked in the debate on research. Some bureaucrats and politicians go white and rigid at the idea of 'curiosity led research' which they see as complete self-indulgence, following whims and will-o-the-wisps at public expense, whereas I see it as evidence of commendable determination to pursue knowledge of the universe as far as it can go. I take up the point made by John Gribbin in his *In Search of Schrodinger's Cat* (1984) that the branch of physics that has given us the transistor radio, the Sony Walkman, digital watches, pocket calculators, micro computers and programmable walshing machines has been based on what used to be regarded as the most esoteric and remote of intellectual pursuits — quantum mechanics.

My particular hang-up has been with the phrase 'relevant research'. Relevant to what? and in what time-frame? As I said in my tabling speech for CSIRO's 1983-84 Annual Report (9 May 1985, Hansard pp 1963-4):

It is often insisted that CSIRO's research must be relevant, but relevance has a disconcerting habit of changing from year to year. The priorities of 1980 may look absurd by 1985. The propositions that in 1985 we could carry out only research which could be applied to 1985's industries is a guarantee of failure. When do we begin thinking about 1990? Must we wait for another five years? If we do, we will be doomed. There was a telling illustration of this point on 6 March 1985 when Sir Roderick Carnegie assisted the Minister for Industry, Technology and Commerce (Senator Button) to launch SIROTECH Ltd, CSIRO's new technology transfer company. Rod Carnegie said that we must put more emphasis on relevant research, and the illustration he gave was biotechnology. But when did biotechnology jump the hurdle to become relevant? Very recently. Even two or three years ago biotechnology would have been regarded — although not by me — as a classic example of pure research, on the frontiers of knowledge. It is essential that industry lift its currently deplorable performance and make a serious effort in applied research.

It is important to note that much university research already has, and always had, an applied orientation, particularly in the engineering, agricultural and medical faculties. This is even the case with the Australian Research Grants Scheme, the premier body for funding basic research. The document, 'A Case for the ARGS for 1985', notes that 'it is in the very nature of basic research that an appreciable proportion of this research activity must be allowed to proceed without any constraints from "influences external to the inner logic of science itself" '. Yet later on, the document states that in 1981 40% of ARGS projects contributed 'directly to specific socio-economic objectives' and a further 25% had 'identifiable indirect but potential application to specifiable national objectives or national needs'.

In fact, there is nothing new about government concern to improve the coordination and priority-setting of university research in Australia. The creation of granting schemes for medical, energy and agricultural research are all examples of this trend towards more selective distribution of research funds.

Australia is not alone in this. The Netherlands recently introduced new measures to target university research funds more effectively,. As well as the traditional system, based on student numbers, the new system identifies research for special support according to the criteria of quality of research and, in some cases, the relevance of the research to national social and economic objectives. By 1987, half of all university research is expected to be funded in this way. So it would seem that 'relevance' — so long as it is relevance at a distance — is not as inimical to the universities' traditional role as some of the recent debate might suggest.

It is probably true that universities are already doing more with industry than the economic rationalists in Canberra are inclined to believe. Last year for example, industry and commerce gave over $14 million to universities for research, with almost $17 million more coming from non-government medical foundations, overseas bodies and grants from the general community. The universities' independent consulting companies earned about $7 million. But the figures are still very tiny, barely 2% of the total cost of running universities.

More developments in the field of university/industry collaboration are planned. The Australian Vice Chancellors' Committee and the Business Council of Australia have established a joint working party on university/business cooperation to consider such matters as:

- how to promote more effective consultation between the two groups, to improve a two-way flow of information between them on R&D requirements;
- the quality and quantity for graduates and the adequacy of degrees in preparing people for work in industry and commerce.

I understand options the joint working party are considering include: the appointment of business liaison officers at universities; reciprocal appointments to appropriate university committees and company boards; the retention of academic consultants by private corporations; and collaborative awards in science and engineering which will encourage post-graduate students to do industrial research under joint supervision.

I see the past trend towards universities doing more strategic research continuing. In essence the Federal Government is seeking to do no more than urge universities to be more effective at what they are already doing. Let them redouble their efforts.

Both the recent OECD Examiners' Report on Australian science and the draft National Technology Strategy place heavy emphasis on the need to upgrade educational standards, particularly in scientific and technological subjects.

Thus the draft National Technology Strategy concludes:

Participation rates in both secondary and tertiary education should be increased, particularly in technology related subjects and especially amongst women. The problem is as much one of low or uncertain demand for technology skills and unfavourable student perceptions as it is one of education supply. Education needs to be recurrent rather than front-ended, and industry needs to take greater responsibility for training and retraining.

The OECD report states:

Scientific discovery and public understanding of scientific issues are among the most important amenities that rich countries can afford. Technical understanding is critical to virtually every aspect of modern life. People need technical education as voters and as citizens. Many of the most important decisions made in democracies — about disarmament, for example, or about nuclear power — require technical understanding. People need technical education as consumers of modern goods and services. They need it as workers in the private and public sectors, and in order to be prepared for new kinds of work in the future.

Only about a third of our 17 year olds are still at school, compared with almost 90% of Japanese 17 year olds. The proportion of our labour force entrants with degrees or diplomas doubled to 7% between 1950 and 1980, but in Japan there was a 40-fold increase from 1% to 39%. The average skill base in Australia is thus growing only slowly, at a time when that of much of the world in general, and the Pacific rim in particular, is increasing rapidly. The participation in higher

education amongst 17 to 24 year olds is also low by international standards, and has declined since 1976. Total enrolments in bachelor courses in the natural and applied sciences, engineering and technology have fallen substantially relative to total bachelor enrolments.

The situation for women is particularly bleak. Only 4% of tertiary education students in engineering and technology are women in Australia. In Sweden, by contrast, some 15% of students in technical universities are women and at the Massachusetts Institute of Technology women account for 17% of engineering students. Clearly there is a need for students, especially women, to be better informed about career prospects in S&T and for curriculumns, especially in secondary school, to relate science to everyday life and work.

One feature of modern society, with its rapid rate of technological change, is the need for recurrent training. As the OECD report notes, the skills of a 30 year old electronics engineer, for example, probably become obsolete every four years or so. He or she will need to be retrained, either on the job or at university or technical college. A priority in the education field is for more active cooperation between the higher education sector, government laboratories such as CSIRO, and industry in the training and retraining of scientists, technologists and technical staff.

CSIRO, Australia's largest scientific research organisation, carries out about a quarter of the country's R&D, measured in terms of expenditure. It is the primary source of strategic research, to which it devotes about 60% of its effort. Tactical research makes up a further 30%, and fundamental 10%. The division of its research towards economic, social and cultural objectives is about 85: 10: 5.

As with the universities, I do not see any fundamental changes to CSIRO's role as necessary; rather what is needed is a concerted effort to increase its effectiveness in that role. While there has been a push to have it do more research of immediate relevance to industry, better-informed commentators recognise that CSIRO's strength is and should remain longer-term research broadly applicable to national needs and problems.

There will be, however, some shift towards doing more short-term tactical research for manufacturing industry, both to bridge the gap between the Organization's strategic research findings and the industry's own poor capacity to take up these findings and to make it more familiar with the industry's problems.

CSIRO is already doing this. The Organization has responded to the challenge it faces in offering manufacturing the same sort of contributions it has made to agriculture and mining. This year, and building on earlier initiatives such as changes to promotion guidelines which give greater recognition to contributions to industry and the community, we have seen:

- launching CSIRO's technology transfer and commercial assessment company, Sirotech Limited. Sirotech has already scored some notable successes, with several more in the offing;
- establishing a CSIRO Office of Space Science and Applications — COSSA — which has already coordinated a number of ventures bringing scientists and industry together in this field.
- introducing of a corporate planning system to decentralise research planning and to ensure that potential users are consulted in defining research objectives;
- appointing a director of information and public communication, the launch of a series of booklets on CSIRO's research, the issuing of new staff guidelines on public comment and other initiatives to improve communication with industry and the community;
- setting up a manufacturing industry collaborative research scheme to promote research carried out with manufacturing companies;
- creating a Division of Information Technology and an Organization-wide collaborative program to strength its work in computer-based information technologies.

Industry science

There is no doubt that industry is the weak link in the chain, the laggard. It performs less than 20% of Australia's R&D. Without its active and enthusiastic cooperation, all the initiatives of universities and CSIRO and other public research institutions will fall far short of achieving their intended objectives.

How far should manufacturing industry be blamed for its poor performance in R&D? The policy of industrial protection was appropriate for its time, but it long outlived its appropriateness. To a large extent, today's industry is a captive of its history, industrially and politically. Many of the industry's present chief executives climbed the corporate ladder during this era. Technological innovation and R&D are not part of their way of thinking. And, as Paul Keating put it with his customary acuteness, there is still a 'redneck' element in management.

Hugh Stretton puts the blame firmly on business and government. Industrial protection, he said, has been a good principle badly practised. In his contribution to *Australia: The Daedalus Symposium*, published in the US by the American Academy of Arts and Sciences (and here by Angus & Robertson), Stretton notes that Australia has produced respectable numbers of excellent painters, writers, musicians, scientists, scholars, doctors, lawyers, engineers, accountants and other professionals, and world champions at many sports and games. 'Only at two activities — business and government do Australians seem to be incurably mediocre', he says.

He notes that in their book *Elites in Australia*, John Higley and his associates classed as entrepreneurs only four of 81 board chairmen and chief executives of the 54 largest corporations in Australia. And of the 100 richest Australians with personal fortunes above $15 million listed by *Business Review Weekly* in its first survey (Nov. 12-18 1983), he says: 'Very few have invented anything or done much technical R&D; scarcely any have made significant use of Australian science. The brainiest one who showed the greatest technical ingenuity got rich by inventing a computerised betting system.' In fairness, it must be said that by the third (1985) survey, a significant proportion of the 253 individuals (200 entries) were at least investing in high technology.

Stretton continues that a more objective view of the contrast between Australians' excellence in arts and science with their mediocrity in business and government is apparent in the fact that Australians make up 0.3% of the world's population, write 2% of the world's scientific papers, win 1.3% of the postwar Nobel Prizes, make 0.7% of the world's patent applications, develop 0.2% of patents to production, and produce 0.1% of the world's high technology output.

'Many Australian business owners and managers', he says, 'are very ignorant and anti-intellectual, uneducated in anything except perhaps accounting. What stops them from understanding their scientific opportunities also stops them from knowing the above figures or understanding their implications. Many firmly believe and never tire of declaring that businessmen are Australia's dynamic and productive element while academics — at best cultural ornaments and at worst drones and parasites — are a luxury the country can ill afford. Accordingly, the conservative businessmen's government of 1975-83 began to reduce the universities' resources year by year, while in the name of supply-side economics increasing various business subsidies and tax exemptions. Australian business absorbed the aids and exemptions, and year by year continued to reduce its already small expenditure on R&D. Thus, the OECD country with the most extreme disparity between its academic and business performance is the least able to understand the facts or costs of that disparity, or to apply corrective policies.'

Stretton may be judging us too harshly. For example, some dispute that the treatment of universities was as bad as he indicates.

Yet the P A Technology survey I have already briefly mentioned does support the view that Australian business still holds to an alarming anachronistic view of S&T. It was their second survey of senior executives from manufacturing, engineering and processing companies in Australia, the United States, West Germany, Britain and Japan. Let me list some of their conclusions and findings:

- the 1985 survey does not seem to show any improvement on the 1984 survey which revealed Australian executives did not know how to apply technology to make their companies more competitive. Companies still grossly underestimate the strategic importance of technological investment and resources by comparison with their competitors overseas.
- 55% of Australian executives interviewed have an optimistic attitude to growth, to the markets and to technology, yet they expect this growth and optimism to continue with minimal input of financial and human resources into R&D.
- None of the Australian executives interviewed believed an increased expenditure on R&D was a strategic factor in pursuing growth through technology. In comparison, 27% of overseas executives interviewed indicated that boosted R&D expenditure was the primary response.

On a slightly more positive note, while Australian executives did not see R&D as a high priority in achieving overall growth, 50% did expect to spend more on R&D.

At least there is one promising sign there. And I believe there have been others recently, particularly in the opinions expressed and actions taken by business groups such as the Business Council of Australia and the Metal Trades Industries Association.

The Australian position stands in stark contrast to the US situation. *Business Week* reported in July that R&D expenditure by the 820 companies in its R&D scoreboard — which range, as it says, from 'the battered industrial giants of the Rust Bowl to the high tech darlings of Silicon Valley' — shot up by 14% last year, the biggest gain since R&D spending began a steady climb in the late 1970s.

The biggest spenders were IBM which boosted R&D spending by 25% to US$3.2 billion and General Motors, up 18% to $3.1 billion — about 10 times CSIRO's total budget. Other big spenders include AT&T ($2.4 billion), Ford Motors ($1.9 billion), DuPont ($1.1 billion) and General Electric ($1.0 billion).

The Government is doing all it can to establish the right policy environment, in terms of providing both a favourable general economic climate and an appropriate industry policy. In doing this we reject the ideological extremes of leaving everything to market forces, or of massive government intervention and direction.

One of the most challenging tasks we face is to achieve greater co-ordination between policy instruments available to government at all levels. State purchasing preference schemes, state offsets policies and a wide range of inconsistent regulations are among the problems. Even at the Federal Government level there is the difficulty of co-ordinating the direction and activities of an array of government departments and agencies which have an influence on industry policy development.

Of particular importance to science in Australia is the 150% tax deduction on R&D investment introduced this year. We are optimistic that this will not only reverse the decline in R&D performed by the private sector but also increase its funding of research in public sector research institutions.

But the tax incentive will not work if industry feels little need to spend on R&D. In the final analysis, we have to understand that the task is a shared one — between you, the scientists, we the government, and industry. We have to break down the cultural barriers and institutional rigidities that separate us, to free up the flow of ideas and people, particularly between research institutions and between them and industry.

As I said in my opening remarks, there is a growing recognition of this need and a willingness to do something about it. But it is still very slow. The sleepers are taking some time to wake. There remains the hard work of translating this recognition and willingness into concerted and concrete action, to make the most of the tremendous human and natural resources this country possesses.

Final words

I have discussed the role of science in terms of its economic, social and cultural objectives — mainly economic: that is, technological innovation and the generation of wealth. In these terms, the function of science is to do research and to educate and train others, towards these objectives. This has been my focus because it has been the focus of public debate and political decision making.

But science has another function, a moral one. That is to ensure that the community is made aware of the directions and the results of science: its promises and limitations, its benefits and risks. Scientists are by no means the only people qualified to comment on these matters, but their intimate involvement in scientific developments makes them well placed to consider the implications of those developments. CSIRO is to be commended for encouraging its staff, in its new guidelines on public comment, to talk not only about their work, but also to contribute to public debate on scientific and technological issues relevant to their expertise.

Professor Gerald Holton, of Harvard, discussed this issue in an article in the *Times Literary Supplement* 2 November 1984) headed 'Do scientists need a philosophy?' He noted that, at least amongst physical scientists, 'the immense forward thrust today is neither enlightened nor diverted by epistemological debates of the kind that engaged so much energy and attention in the past, through the first half of this century.'

While Einstein and his fellow students read Plato, Spinoza, Hume and Mill, the Nobel Prize winning physicist Sheldon Glashow and his fellow students read Velikovsky and L. Ron Hubbard. Holton suggests that today's scientists have redirected this 'energy of explicit philosophising' into another branch of philosophy, namely ethics.

'To a degree unimaginable a few decades ago,' he says, 'scientists are discovering that there is a morality which the enterprise of science demands of itself — even if such concerns are as yet expressed only by a small fraction of the total community. Indeed with about one-third of the world's scientists and engineers working directly or indirectly on military matters while the arms race proceeds unchecked, this transfer of attention from epistemological to ethical problems may be too little and too late. At this ominous junction of science and history, as we watch the growing reign of the irrational in world affairs, the debates of former times to give precision to scientific rationality seems curiously antiquated. Perhaps this redirection of philosophical concerns signals a growing awareness that the process of scientific innovation is not in danger — but that humanity is.'

Thus, in a very real way, the more effective harnessing of science to revitalise industry and generate wealth — the source of so much debate in Australia today — is only a start — and the easy part.

Notes

1. This paper is a slightly modified version of the 16th Lady Masson Memorial Lectureship delivered at the Chemistry School, the University of Melbourne on 1 October, 1985.

University fees

Senator C. J. Puplick

Liberal Senator for New South Wales
Parliament of Australia

The tertiary fees debate[1] continues to be an open-ended one shaped by requirements to balance the issues of social equity, individual capacity to pay, the desirability of widening access to tertiary education and the right of the public to expect their tax dollars to be properly spent.

The Whitlam Government abolished fees on 1 January 1974, at the time estimating that the cost would be in the order of $27m for university fees and $7m for technical college fees.[2] It is interesting to note that the total outlays by the Commonwealth on tertiary education in 1972-73 was $262.8m, but in 1973-74 tertiary education expenditure was $524.3m, an increase of some 100% over the previous year. This increase in direct Commonwealth expenditure was offset by an equivalent reduction in Commonwealth grants to the States in that year.

Let us compare those figures with the amount now spent on tertiary education by the Federal Government. The 1985-86 estimate is $2,517.2m. This represents an increase in money terms of some 380% over the past 12 years. However the real increase in tertiary education spending from 1975 to 1985 is negligible (6.3% increase in real terms over the period)[3].

As part of its attempts to wind back levels of Government expenditure, the Fraser Government attempted to re-introduce fees for second degrees, but the measure failed in the Senate in November 1981.

The report of the Committee of Review of Student Finances noted in March 1983:

The selective introduction of fees in this way ignores the need for a strengthening of research activities, and the need to encourage new skills and upgrading in a time of rapid technological and economic change. Fees would impose even greater hardship upon postgraduate students without awards and act as a further disincentive to disadvantaged groups.[4]

This view of course raises two quite distinct questions, the first related to postgraduate degrees, where I think the argument is well founded; and the second to the impact of fees on the socioeconomic mix of tertiary students, where I think the argument fails.

The history of fees is an interesting one from the Federal Government's perspective. The Commonwealth, prior to the Second World War, had no funding role in the university sector, however the wartime shortage of graduates led the Government to assume some financial support for the universities and some students. Living allowances and tuition fees were introduced in 1943.[5]

This arrangement continued until the introduction of means tested scholarships in 1951. This Commonwealth Scholarship scheme was expanded in 1966 and by 1973 40,760 university students and 10,567 CAE students were receiving scholarships.[6] There was, I believe, a general acceptance that the Commonwealth Scholarship Scheme worked in a very satisfactory fashion and indeed for most of its existence it was further complemented by a widespread existence of other scholarship schemes. One of the most regrettable consequences of the decision of the Whitlam Government to abolish fees was to provoke the collapse of other scholarship schemes such as those provided at Education Department Teachers' Colleges, or by other State Government Departments such as Agriculture, or by the private sector which offered various tied scholarships.

The economics of fees

Students on campuses around the country have expressed their opposition to the concept of the re-introduction of tuition fees.[7] This is not surprising as no-one likes the idea of paying for something that is presently "free". Some students have responded in surveys that the re-introduction of fees would cause many to postpone or cease their studies.[8] It was argued by Malcolm Fraser when the Whitlam Government abolished fees that the fees system encouraged students to work hard and pass examinations and that the abolition of fees would require the universities to scrutinize standards even more.[9] This argument has been counterbalanced by others claiming that it is the parents who would be paying the fees for a large proportion of students so there is little incentive for the students to perform except out of obligation.[10]

It is important to ask whether the abolition of fees in fact had any impact upon the socioeconomic mix of students in higher education and whether it in any way achieved its stated objective of benefiting the 'socially disadvantaged'. A survey undertaken by the University of Melbourne and published recently in *The Bulletin* seems to indicate that there has been very little change in the social composition of the students attending that university:

Taking figures for 1962, when tertiary fees were charged, the enrolment make-up comprised 58 percent of students from the high income bracket, 22 percent from the middle and 20 percent from the lower income area. The academic year following the removal of tertiary fees (1975) showed a student body composed of 55 percent from the upper income bracket, 18 percent from the middle income section and 27 percent from the lower income area. The 1980 survey showed that 55 percent of students were from the upper income area, 19 percent from the middle and 23 percent from the lower income bracket.[11]

This evidence shows that when compared with the distribution of the workforce as a whole, the children of upper income families have a much better chance of attending university than their counterparts in lower income families, regardless of whether fees were being charged or not.

There have been other studies on the consequences of the abolition or possible re-introduction of fees. D.S. Anderson *et al* produced a comprehensive report on the social composition of students since the abolition of fees. Their conclusion was that at best, the abolition of fees has had some effect on the accessibility of higher education, but at worst, it could be seen as a further benefit to the economically advantaged at the expense of the average taxpayer.[12]

More recently Anderson has claimed that his research has been misused and that the 'effect of the abolition of fees would take six or seven years to become clear'.[13] He believes that the work he did in 1979-80 had shown that there was some movement towards greater 'equity' in tertiary education.

Don Smart and others in a recent paper 'The Hawke Government and Education' have concluded that the essential return to 'pragmatic' education policies, including the possible re-introduction of fees along the lines suggested by Senator Walsh with