# Australian and New Zealand Science — Problems for Innovation

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I was asked by the New Zealand Association of Scientists (NZAS) if I would attend their Annual Conference and make some comparisons between New Zealand and Australian science, particularly in the light of the recent survey on how scientists in New Zealand are viewing their situation. I was happy to do that but, having been in Australia for only a year, I felt I could only offer a fairly superficial comparison, especially as there has been no recent workforce survey in Australia of the kind undertaken by the NZAS. Nevertheless, there are obvious differences in the way things are done.

Based on that talk I have prepared a paper that first, describes my understanding of the Australian science scene in terms of structures, funding and some aspects of policy. I then highlight some problems for the Australian scientific workforce as I see them and conclude with selected analyses of the NZAS workforce survey and some comments on those elusive qualities, creativity and innovation.

## Scientific Research Organisations in Australia

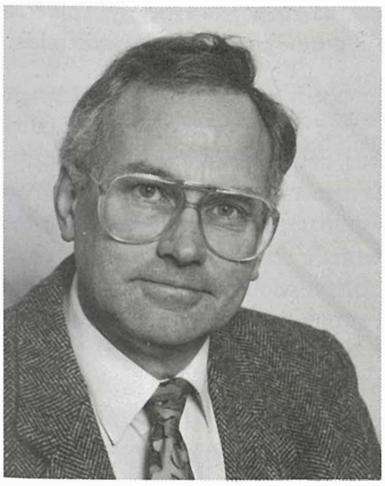
Australia has a more complex R&D structure compared with New Zealand, being a larger scientific community with various science and technology organisations being administered by both Federal (Commonwealth) and State governments with upper and lower houses. This complexity leads not only to a diversity of structures but also to differences in funding and how science policy evolves. The main channels for the distribution of Commonwealth funds for R&D are summarised in Table 1 and the mechanism for providing advice and policy formulation in Figure 1.

There are three Commonwealth research agencies established under their own statutes; the CSIRO, the single largest full-time scientific research organisation in Australia, the Australian Nuclear Science and Technology Organisation (ANSTO), and the Australian Institute of Marine Science (AIMS). In addition, there are a number of agencies established within Commonwealth departments. The Defence Science and Technology Organisation (DSTO) within the Department of Defence is second in size only to CSIRO in terms of staff and funding. The Department of Primary Industries and Energy has three in-house research agencies, the Australian Geological Survey Organisation (AGSO), concerned with national geoscientific mapping, the Bureau of Resource Sciences (BRS) which provides technical advice in the industries of agriculture, mineral, petroleum, forestry and fisheries, and the Australian Bureau of Agriculture and Resource Economics (ABARE) which undertakes policy research with relevance to the primary and energy industries. Attached to the Department of Industry, Science and Technology is the Bureau of Industry Economics (BIE) and Antarctic research is undertaken by the Department of Environment, Sport and Territories. Minor Commonwealth players are the Bureau of Meteorological Research, Alligator Rivers Research Institute, the Anglo-Australian Telescope, the Australian Institute of Health and the Nuclear Safety Bureau.

At the State level, there are many organisations such as departments of agriculture, and conservation and land management, that do operational scientific research in addition to their regulatory and advisory functions. They also have access to industry funds. Finally, there are a number of private research organisations.

The other major organisations where scientific research is carried out are, of course, the universities and hospitals.

One thing lacking is the equivalent of the Research Associations in the New Zealand sense, the rural sector having elected to fund the existing research organisations and not provide their own research infrastructure.



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## Funding

The sources of funding are almost as diverse as the organisations receiving funds (Table 2). Total R&D expenditure in Australia in 1990-91 was $5.16 billion and in that year 41% was spent in the business sector, 26% in university or higher education, 20% in Commonwealth research agencies, and 12% in the state government sector. The remaining 1% was spent in private non-profit organisations. There has not been a review since that time but using those figures and the estimated federal research expenditure for 1994-95 of $3.25 billion, the total R&D expenditure for this year could be in the region of $7 billion.

Of the Commonwealth research agencies, CSIRO receives approximately 50% of the funding and the 1994-95 budget is $467 M. The other major recipients are DSTO ($219 M), AGSO ($70 M), ANSTO ($66 M), Antarctic research ($59 M), and AIMS ($16 M). These funds are dispersed directly to the organisation as appropriation. However, the appropriation does not cover all costs and there are external earning targets imposed on some of the Commonwealth agencies. The targets for CSIRO, ANSTO and AIMS are reviewed from time to time by the Australian Science and Technology Council (ASTEC) which reports to the Prime Minister and Cabinet. It is currently 30% of total income for CSIRO and 30% of appropriation for the other two.

A major source of the external earnings is from the Research and Development Corporations and Councils (RDCs) of which there are 19, 16 being industry specific. In my area of work the main RDCs supporting research are the Australian Wool Research and Promotion Organisation (AWRAPO), Grains Research and Development Corporation (GRDC), and the Meat Research Corporation (MRC). In 1994-95 it is estimated that industry's contribution to research, through levies, will be just over $100 M and this is matched dollar for dollar by the Commonwealth government. In addition, various government departments and agencies such as BRS in DPIE and the Australian Nature Conservation Agency (ANCA) in the Department of Environment, Sport and Territories (DEST) offer research funds for specific purposes.

Research funding for universities comes from a range of sources. Through the operating grant to universities, $313 M has been notionally allocated for research training in the 1994-95 year and $210 M for the so-called Research Quantum which is the notional research component for staff research activity unrelated to teaching. These figures are calculated on the 1990 Relative Funding Model where the research training component is 7.6% of the operating grant and the Research Quantum is fixed at 6.2% of the 1990 operating grant. An obvious consequence of the latter policy is to erode the non-teaching research base. Also included in the calculation of Commonwealth support for university R&D is approximately one third of academic salaries. In addition, there are the competitive granting agencies, the Australian Research Council (ARC) and related grant schemes ($311 M) and the National Health and Medical Research Council (NH & MRC) ($126 M). The ARC and NH & MRC funds are not available to the Commonwealth research organisations except on a grant where a university staff member is the principal investigator. The Institute of Advanced Studies, at the Australian National University, is separately funded and will receive $130 M in 1994-95. This does not include the John Curtin School of Medical Research which is now funded through the Department of Human Services and Health ($17 M).

A relatively recent and unique source of funds on the Australian science scene is the Cooperative Research Centre (CRC) scheme. In the 1994-95 year there will be 61 CRCs consuming an estimated $113 M. This scheme, a legacy of the Hawke administration, is available to research consortia that must comprise at least one university partner. The term of these CRCs is seven years with a major review at year five. Not surprisingly, the CRC fund is fiercely contested and is, arguably, the most attractive source of research funds in Australia at the current time. The partners, to the centres, contribute in excess of two dollars to the government's one dollar in, in-kind contributions or cash.

For private industry there is $48 M for the Commercialisation and Technology Innovation Scheme, and $64 M for a technology transfer scheme. Other Commonwealth programs and grants to private industry bring the total to approximately $145 M. In addition is the 150% tax deductibility for research. This scheme is estimated to free-up $395 M to industry R&D in 1994-95.

## Policy

Figure 1 shows the structure used for determining science policy at the federal level. Three broad objectives have been set for R&D in Australia:

- to maintain a high quality science base within the universities and government research agencies;
- to maximise the practical applications of the science base to industry and the wider community;
- to encourage greater innovation by business, particularly through strengthening their research and development activity.

Some policies arising from the second objective are the external earnings requirement for some research organisations, the CRC scheme, the Commercialisation and Technology Innovation Scheme and the schemes in technology transfer.

To encourage greater innovation by business there is the 150% tax concession for R&D expenditure over $20,000. There is also a syndication scheme to encourage two or more R&D companies to get together to conduct research that would be too expensive for either alone. In reality not one syndicate has worked this way. What has happened is that a company, typically a finance company not in R&D, but with cash, has associated with an R&D company with tax losses. An amount of money is paid by the financier into the syndicate for the core technology and a further amount for R&D. The financier can claim the tax concession for their investment in R&D. The company gets the finance to develop the technology but forgoes the advantage of a tax loss. When the syndicate winds up the financier gets back the original core technology investment plus interest and the R&D company retains the intellectual property. If the technology is successful the partners in the syndicate share the income generated. Although not quite what was intended, the result is considered favourable for R&D. It has been estimated that for every one dollar spent on R&D without syndication, syndication induces expenditure of an additional $2.6 (Bureau of Industry Economics, 1994).

The States determine the priorities for their research agencies based on where they see their local problems but, as a proportion of their funding is determined by the Federal Government, it has some influence on the direction and amount that is dispersed for research. State agencies can apply to the Commonwealth funding agencies and so are in direct competition with the Commonwealth research agencies.

CSIRO sets its own research directions in a triennial policy setting exercise where senior research management and captains of industry provide their views on future trends. These views are converted to numerical scores using the criteria of feasibility of doing the work in Australia and attractiveness in terms of benefit to Australia. However, the CSIRO Board have the final say on how the funding is distributed using the priority setting process as only one input. The Board must also heed directives from the Minister of Science regarding government policy. A factor that has weakened the priority setting process is the external earnings requirement. As many of the agencies contracting CSIRO to do work for them will often only fund the marginal costs, a proportion of the appropriation meant for "public good" research as determined by the priority setting process is subsidising the external work.

Although there is a commitment to maintaining the science base, CSIRO has been receiving in real terms less of that cake in recent years and more is being diverted, directly or indirectly, through agencies who are setting their own research priorities. This underlies the external earnings policy. The effect is to steer CSIRO and other research providers toward the priorities of those industries that have the cash to afford it. The philosophy is that industry being the "engine" of economic recovery can direct the science community to where they perceive the important problems lie.

## Problems for Scientists in Australia

In my experience, the problems perceived by industry and government are usually little different from those perceived or acknowledged by scientists. The problems that need to be overcome to achieve the desired outcomes of healthier people, healthier livestock, clean air, clean water, biodiversity, better communications, efficient manufacturing etc are usually well understood and undisputed and the part science and technology must play in providing solutions to these problems is recognised on all sides. However, the biggest problem today is the clash of cultures in how scientists should be managed to achieve those ends.

Free-market economic philosophy, the push for innovation, customer focus and general short-termism has permeated science in Australia as surely as it has in New Zealand. The management of government science has been taken over by a commercial culture which is alien to the way such science has traditionally operated. Scientists, in government and universities, have been accustomed to considerable freedom in how they operate and are used to choosing the areas in which they work. They also tend to take a long term approach because they recognise that the most important problems are complex and one individual, or even a team of scientists, can usually expect to achieve only relatively small advances in time frames of three to five years. They often work on problems for which there are no easy solutions and are reluctant to draw conclusions without supporting data. Hunches, inspiration and luck play a part, but for their work to be accepted it must be scientifically sound and published to allow scrutiny by other scientists. In the commercial world, on the other hand, staff are used to much more direction from management and they tend to operate within much shorter time frames. Decision making is often done in a climate where very little information is available and deadlines are short. Results are measured in terms of profits and in many cases the means to profit are limited not by scientific validity but by legal requirements. My perception is that there is also a very high turn-over of staff at all levels, much more so than in science.

Combined with this clash with the commercial world has been the inexorable (and universal) increase in documented accountability over and above scientific papers and reports. This has reduced the time scientists spend doing research, and has not only put immense pressure on the scientists, but also on support staff. In Australia, the 30% external earnings requirement has caused severe problems for some sectors of government research, in particular the agricultural sector where short term gains are difficult to achieve. Redundancies and low staff morale are in danger of becoming chronic problems. In the universities, increased teaching loads and the shortage of money for long-term research are also sapping morale. There are now severe career uncertainties in science. In CSIRO the increasing emphasis on outside money has lead to an increase in research being done by staff on term appointments. The pressure to employ generalist managers to recruit the required specialist staff on short-term contracts is mounting. There seems very little incentive at the moment for science graduates to enter a career in research. The 10-15 year opportunity cost, high level of creativity and specialisation required, and the low pay in their early years as a scientist can no longer be traded off for career security. In fact, judging by the TER scores required for entry into science courses these decisions are being made at the school-leaver level.

In addition to the uncertainties imposed by funding restraints and accountability, three reviews of science and technology are in progress. A Senate inquiry has been set up to review the decision by the CSIRO Board to reduce rural industry research in the face of the priority setting process giving it a high rating. The second is an internal review, established by the CSIRO Board, to look at CSIRO structure and operation to see how it can improve its performance in delivering the outcomes expected by government. A third review, by the Industry Commission, is covering the entire gamut of R&D in Australia. The results of these reviews will not be known until the end of 1994 or early 1995 and could well set the agenda for major changes in science policy particularly for CSIRO. This is another source of uncertainty and anxiety amongst scientists and support staff.

## Some Results from the NZAS Survey

In the light of these problems, I was very interested to look at the NZAS survey and see how a broad group of scientists were viewing their situation in New Zealand. Apart from age structure, I cannot directly compare Australia with New Zealand. I did, however, look at the questions of job satisfaction, job security and freedom to choose their area of research. From my brief experience in CSIRO, these are declining commodities amongst Australian scientists. I recognise that we are looking at a selected group of scientists who chose to respond to the survey. Nevertheless, 30% of New Zealand's scientists responded which gives the survey considerable credibility.

A comparison of the age structure of respondents with research staff at CSIRO is shown in Figure 2. The age structures of CSIRO and the CRIs are very similar but quite different to that of the university respondents where 25% are in the 56-65 age group. For the CSIRO and the CRIs this probably reflects the redundancies that have occurred in these organisations over the last five years and beyond and the recruitment of young postdoctoral labour. For the CRIs, many of the redundancies occurred prior to the transition from government departments to CRIs. The universities have remained virtually untouched by redundancies.

There is also a stark contrast between universities and CRIs when comparing job security (Figure 3) and freedom of choice of project (Figure 4). The full time researchers are feeling far worse off and again this is not surprising given the changes that have occurred. It is interesting, however, that although university researchers feel secure in their jobs and 63% have a totally free choice of project they are only feeling marginally more satisfied in their jobs (Figure 5). My guess is that the administrative and teaching loads in the universities are taking their toll.

## Creativity and Innovation

Another reason that I chose these results is because of an interest in the concepts of creativity and innovation. The cry from governments for innovation (defined, in essence, as ideas that make money) in the quest for economic growth and wealth from their investment in science is very loud. Creativity in science does not automatically lead to economic growth but it is necessary for innovation. How then do you create an environment that nurtures creativity and innovation in science?

Innovation is an interest of governments on both sides of the Tasman and quite rightly so. Last year, officials from MoRST visited the University of Otago to explain the Ministry's role. A question was asked not about innovation but about careers. The response was that perhaps there was little point in offering careers to scientists when it was well known that their creativity declined rapidly once they are over the age of 40. It turned out that the source of this information was an article by a staff writer, Malcolm Gladwell, in the *Washington Post* (Gladwell, 1990). Mr Gladwell produced a series of graphs where he plotted "creativity" as measured by "outstanding contributions as judged by experts" against age of the contributor. In the case of physicists for instance there were 141 contributions by 90 physicists where the peak of "creativity" was age 35. In the case of 83 contributions by 63 astronomers the peak was age 45. Interestingly, at age 50, these scientists were still producing at 60% of their peak and their creativity began to rise again after the age of 65. Engineers and medical researchers, we are told, tend to peak later.

There are of course a number of reasonable explanations for the apparent decline in "outstanding contributions" other than a drop in creativity. Increased administrative responsibilities, tackling more difficult problems, a move into new areas of research and so on. Nevertheless, whether or not Mr Gladwell's study was valid (the methodology he used was not given) his theme was positive rather than negative. How is creativity enhanced if it really does fall with age? This theme has also been taken up by Ernest L Boyer of the Carnegie Foundation (Boyer, 1990) who quotes the *Washington Post* article and proposes a "creativity contract" for university professors whereby the university offer individual professors flexible career paths within the institution that takes account of changing interests and changing levels of productivity. In other words, enhancing careers rather than destroying them on the basis of perceived creativity.

A better researched study on scientific creativity was by Andrews (Andrews, 1975). He was interested in defining the factors that lead to a high level of creativity and innovation in research. He chose for his study a group of 115 medical sociologists who had each directed a project dealing with social psychological aspects of disease. These researchers held doctorates or masters degrees in psychology, sociology or medicine. At completion, the projects were submitted to a panel of experts in medical sociology who rated them on innovativeness, defined as the degree to which the research represented additions to knowledge or new theoretical statements. During the course of the project, each subject took a Remote Associates Test which is a measure of creativity. They also answered a series of questions on their working environment. The results were perhaps not surprising. The four social-psychological factors that facilitated the realisation of creative potential were: high responsibility for initiating new activities, high degree of power to hire research assistants, no interference from administrative superior, and high stability of employment. Others have come to similar conclusions (Burnside, 1990; Payne, 1990; Yong, 1994).

In Australia, as in New Zealand, the pressures of declining funding, the imposition of a commercial culture, increased accountability (much of it as a consequence of reduced funding and in the name of efficiency but also as a consequence of increased public scrutiny and distrust of science) and continual restructuring, are making it more and more difficult for scientists to sustain a line of work in their speciality and maintain a career. This is not the way to encourage creativity and innovation.

The solution, I believe, is for science policy makers to first recognise the major differences between scientific and commercial cultures when setting up links between the two and then establish workforce policies that give scientific staff greater career security, more freedom to choose their area of activity, and a substantial reduction in administrative load. In that way innovation will flow.

## Late Breaking News

Since giving my talk the findings of two of the reviews mentioned above have now been published.

The Industry Commission has produced a draft report (Industry Commission, 1994) and is calling for comments. The report covers the complete spectrum of Federal R&D and summarised below are some of the recommendations. It recommends CSIRO go back to what it has been traditionally good at doing; that is public good research. They do not preclude work for private firms but costs for any such work must be fully recoverable. They recommend that appropriation funding be reduced to 10-20% and that what research CSIRO does should be driven more directly by users of that research. They are seeking comments on three options for the distribution of the remainder. These are: distribution by the Department of Industry, Science and Technology; distribution by several portfolios covering science; and an equivalent to the Foundation for Research Science and Technology. They also recommend that those funds, over a phasing-in period, become broadly contestable by organisations outside CSIRO. These recommendations also apply to ANSTO, AIMS and AGSO. There are obviously problems for the scientific workforce here and consequent problems for innovation. They recommend that CSIRO not be spilt into separate and independent corporations. For the universities, they "see merit" in the transfer of the Research Quantum into the ARC. This would obviously reduce the universities' independence in research. For the rural industries, they recommend a reduction in government subsidy to one dollar for every four dollars raised by the industries.

The Senate inquiry report, entitled *CSIRO: the case for revitalisation*, (Senate Economics References Committee, 1994) has recommended that "... CSIRO re-instate the high priority ranking of rural research ...". Regarding the workforce, they believe "... that the claims made by scientists are genuine: that they are spending too much time on administrative matters and too little time on research". The Committee also "... believes that there are serious problems with employment security in CSIRO. In some areas this is hampering the efficiency of its research scientists and is a major cause of low morale among staff" and "... the Committee recommends that the CSIRO Board address the problems of employment insecurity, poor conditions of employment, low career status, excessive accountability, stresses of fund raising, ineffective industrial participation and low morale among its rural research staff as a matter of urgency." Under the section on external funding, the Committee recognises the negative aspects of the 30% external funding target and that in some case this has put scientist jobs at risk but not those of their managers. They recommend that the CSIRO Board try to resolve these issues.

## Acknowledgments

I would like to thank Professor Don MacGregor of the New Zealand Ministry of Research Science and Technology for supplying me with Boyer's article on creativity.

## Note Added in Proof

Since the submission of this paper, the Industry Commission has published its final report entitled *Research and Development*, Report No. 44, Australian Government Publishing Service, Canberra, May 1995.

Regarding CSIRO, no firm recommendation was made on structure but the Commission considered that: "... CSIRO's principle role is to undertake research which has direct value to industry and the community, but lacks sufficient prospective private returns for it to be performed or sponsored by firms ('public good' research). The results of such research should be widely disseminated." They also recommended that: "... an independent agency be designated to monitor and publicly report on CSIRO's performance against agreed priorities and perfomance indicators."

With the universities, they recommend amongst other things that the ARC be made responsible for determining the criteria for allocation of the Research Quantum and that responsibility for funding the John Curtin School of Medical Research be transferred to the NH & MRC. Under business R&D, it is recommended that the tax concession remain. The CSIRO has also reported some of the findings of its internal review and, although not yet public, greater flexibility in the way it operates appears to be a key theme.

The Australian science community now awaits a synthesis of all these reviews in the long awaited "Innovation Statement" that is to be announced by Senator Peter Cook, Minister of Science. The announcement was expected in September but has been delayed and is now expected in October. Only then will the future shape of Australian science become clear.

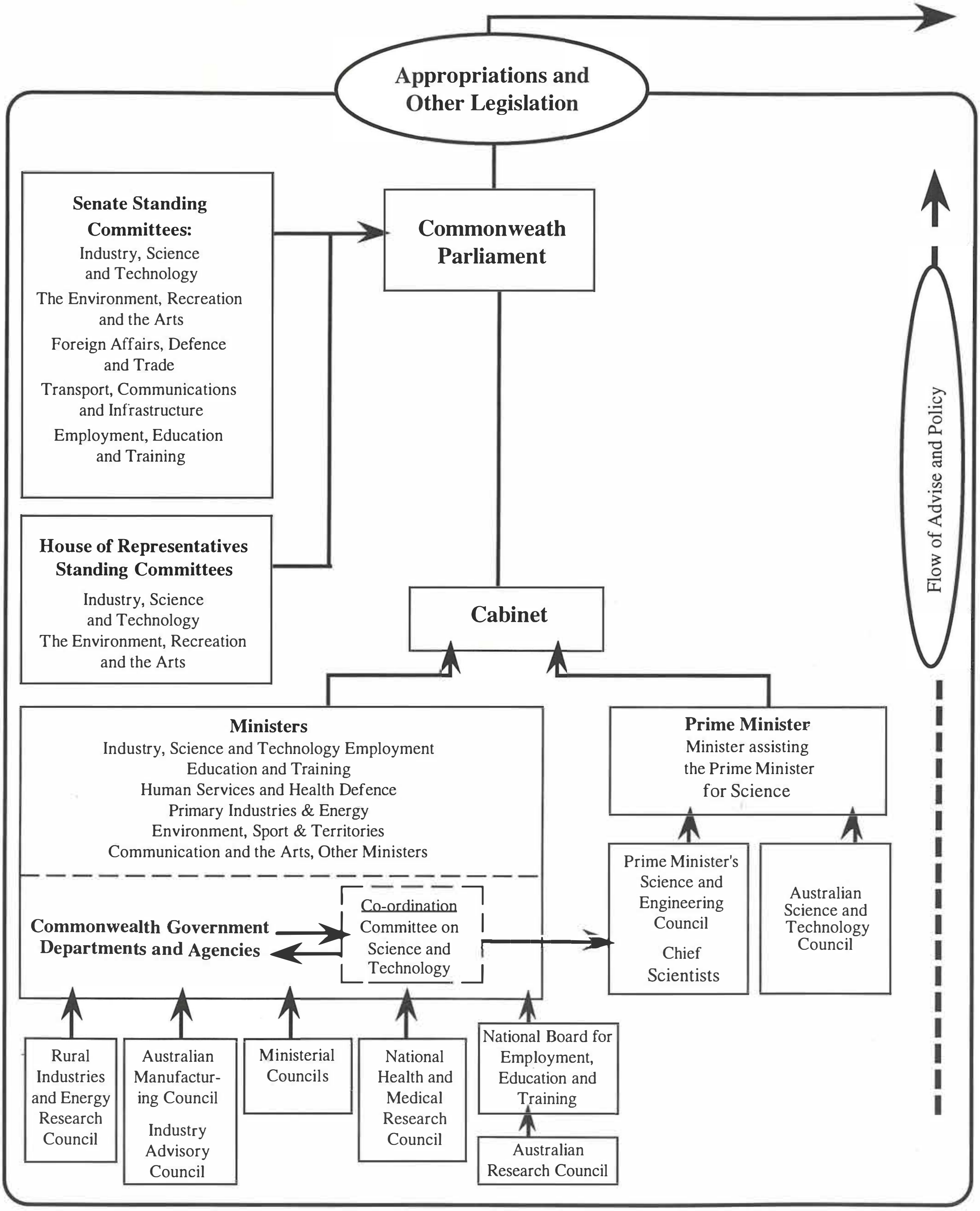


**Figure 1 Main Channels of Advice and Policy Formulation in Science and Technology**
Source: Dept of Industry Science and Technology, 1994. Commonwealth of Australia copyright reproduced by permission.

The figure is indicative of major bodies and principal channels for the flow of policy advice leading to Parliamentary and Cabinet decisions on science and technology issues. It does not purport to be other than illustrative. Of course, there are a host of influential forces, including professional organisation and other non-government groups, and there are many cross-links and productive interactions between them.

**Table: Commonweath Support for R&D (Estimated 1994-95)**

Source: Department of Industry Science and Technology, 1994.

| Agency | Funding | Agency | Funding |
|---|---|---|---|
| CSIRO | 467 | Higher Education | |
| DSTO | 219 | Proportion of Academic Salaries | 400 |
| CRCs | 113 | Research Training | 313 |
| AGSO | 70 | Research Quantum | 210 |
| ANSTO | 66 | ARC and related | 311 |
| Antarctic Research | 59 | NH & MRC | 126 |
| AIMS | 16 | IAS | 130 |
| | | JCSMR | 17 |
| Industry | | Subsidy for RDCs | 126 |
| Industry innnovation programmes | 145 | | |
| Tax concession | 395 | Other Support | 70 |

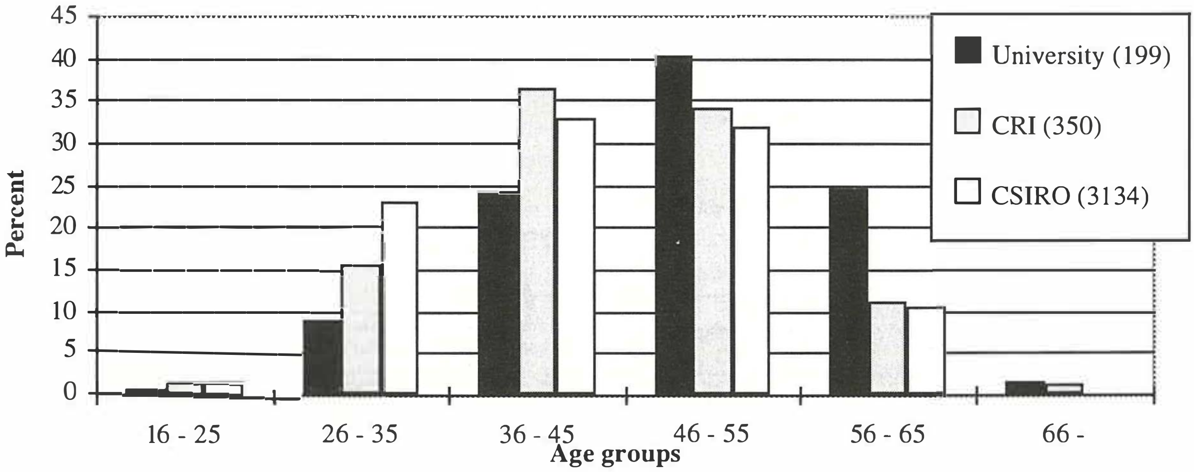


**Figure 2 Scientists — Age Structure Comparison**

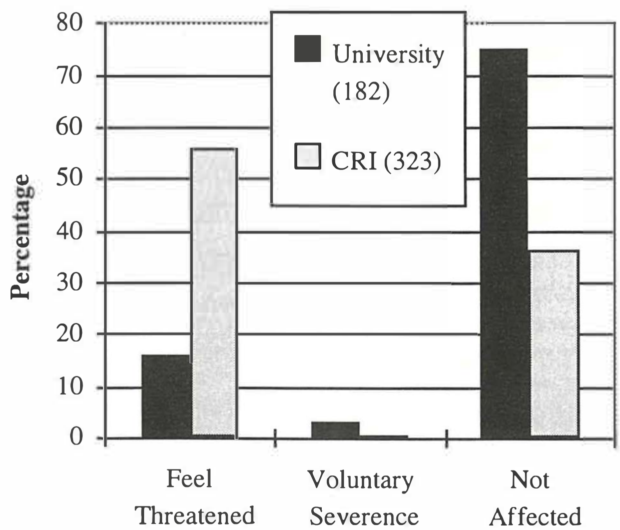


**Figure 3 Job Security**

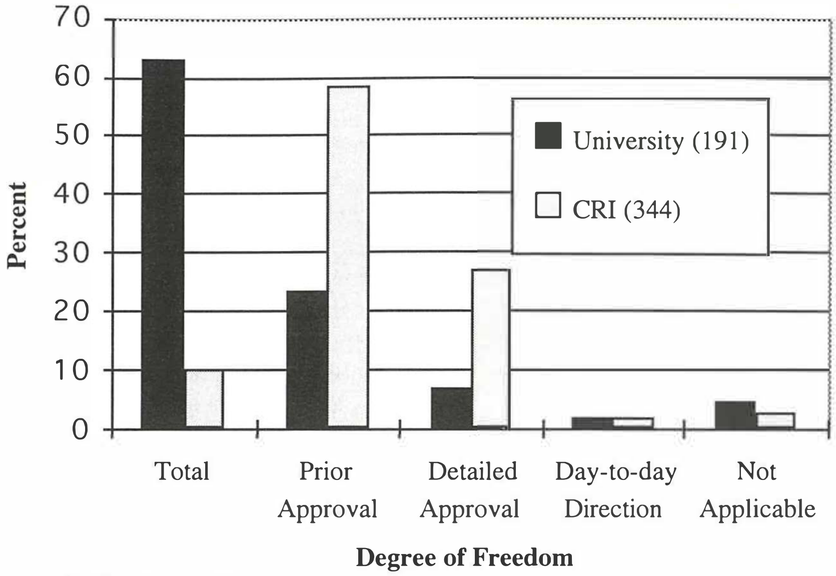


**Figure 4 Freedom of Choice of Project**

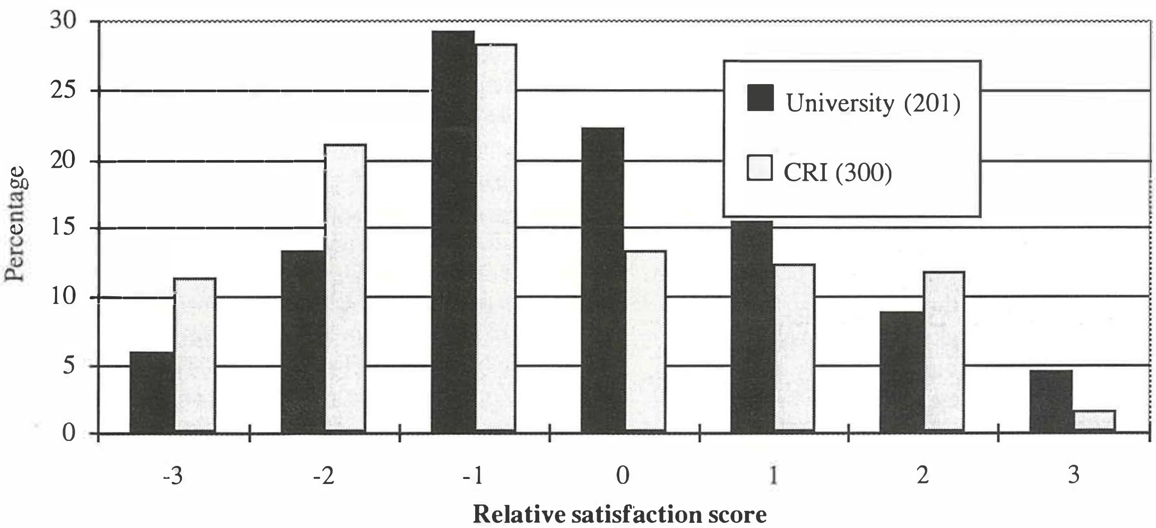


**Figure 5 Job Satisfaction**

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