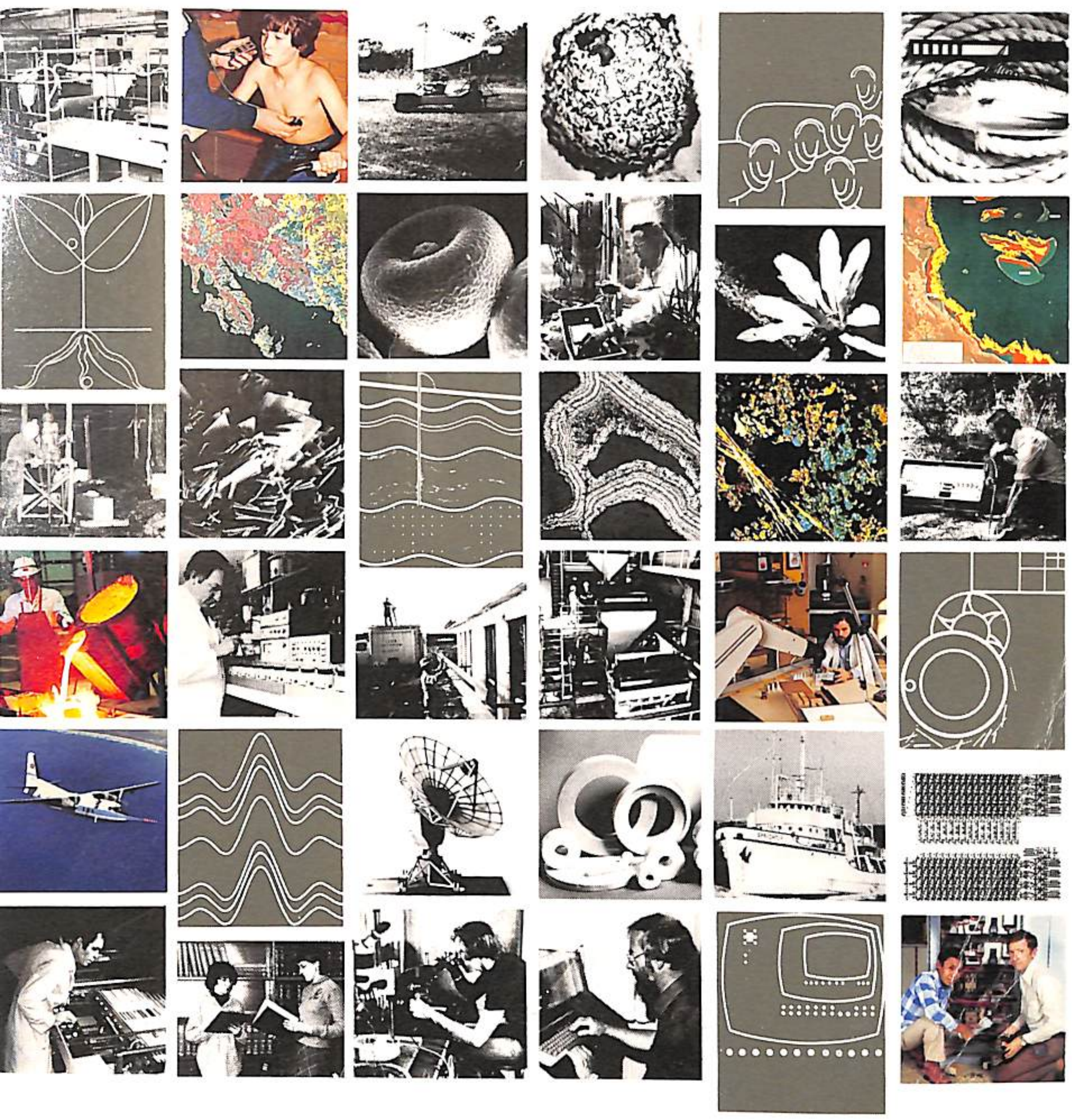
CSIRO ANNUAL REPORT 1982/83



Commonwealth Scientific and Industrial Research Organization

Commonwealth Scientific and Industrial Research Organization, Australia

CSIRO Annual Report 1982/83

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COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

The Honourable Barry O. Jones, M.P.,
Minister for Science and Technology,
Parliament House,
CANBERRA, A.C.T. 2600.

The Executive of CSIRO has pleasure in submitting to you, for presentation to Parliament, its thirty-fifth annual report, which covers the period 1 July 1982 to 30 June 1983. The report is submitted in accordance with section 57 of the Science and Industry Research Act 1949.

J.P. Wild (Chairman)
N.K. Boardman
D.P. Craig
H.M. Morgan
S.B. Myer
G.G. Spurling
G.H. Taylor
P.D.A. Wright

Role and Organization of CSIRO

CSIRO was established as an independent statutory corporation by the Science and Industry Research Act 1949. It succeeded the former Council for Scientific and Industrial Research established in 1926. The Act was substantially amended in 1978.

The main role of the Organization is to plan and execute a comprehensive program of general scientific research on behalf of the Commonwealth.

Research is carried out mainly in the physical and biological sciences, with the emphasis on strategic research. Strategic research is undertaken to achieve practical results and is characterized by its orientation towards the basic research end of the research and development spectrum.

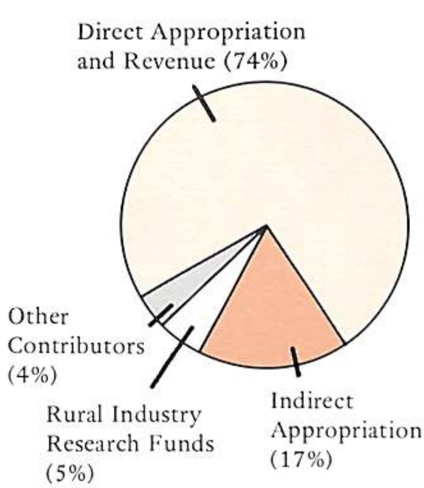
The transfer of research results into commercial use or other beneficial applications is a principal aim of CSIRO. Other activities are undertaken to the extent that they can be carried out conveniently in conjunction with the Organization's main research and technology transfer activities.

CSIRO's statutory functions, in summary form, are:

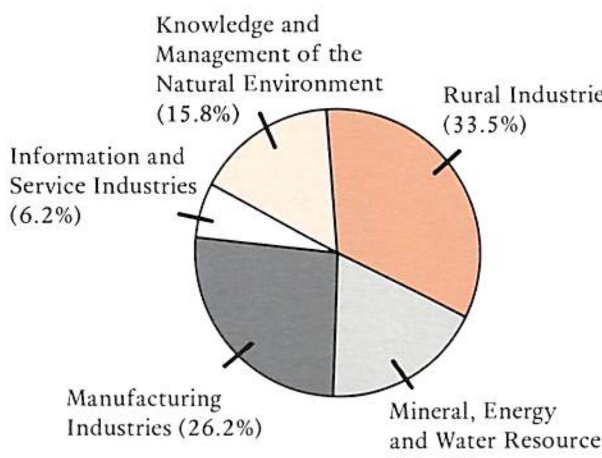
- to carry out scientific research relevant to Australian industry, the community, national objectives, national or international responsibilities, or for any other purpose determined by the Minister;
- to encourage and facilitate the application and utilization of research results;
- to liaise with other countries in matters of scientific research;
- to train research workers;
- to make grants and award fellowships and studentships relevant to the Organization's research;
- to recognize, cooperate with and make grants to industrial research associations;
- to establish and promote the use of, standards of measurement of physical quantities;
- to collect, interpret and disseminate scientific and technical information; and
- to publish scientific and technical reports, periodicals and papers.

The Organization is funded primarily by direct appropriations from the Commonwealth Parliament. Decisions on research priorities are made by CSIRO in the light of advice received from the CSIRO Advisory Council and other interested bodies. The following figures show the sources of CSIRO's funds and their allocation to categories of research objectives.

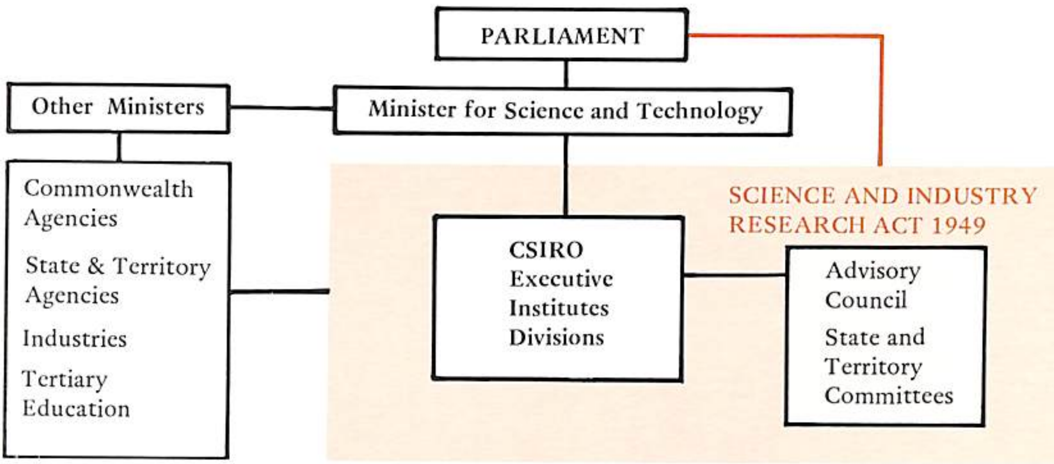
Sources of CSIRO Funds



Distribution of Research Effort



The figure below is a simplified representation of CSIRO's main relationships with the Commonwealth Parliament and other bodies.



CSIRO is governed by an Executive comprising three full-time members, one of whom is Chairman, and five part-time members. The Chairman is the chief executive of the Organization and is assisted in this role by the other two full-time members of the Executive.

The research work of the Organization is carried out in five Institutes, each headed by a Director. Institutes are groupings of Divisions and Units with related research interests. The latter are headed by Chiefs and Officers-in-Charge respectively. Divisions and Units are each responsible for coherent sets of research programs, with Units generally being responsible for narrower fields of research and having fewer staff than Divisions.

Support services are provide as follows:

- Planning and Evaluation Advisory Unit — Assistance in setting research priorities and allocating resources.
- Bureau of Scientific Services — Technology transfer, information services and international aid.
- Office of the Executive — Corporate policies, coordination and development.
- Finance and Administration — Budget, works, administrative services and systems.
- Personnel — Policy advice and operational assistance in all staff matters.

On 30 June 1983, CSIRO had a total staff of 7574 in more than 100 locations throughout Australia. About one-third of the staff were professional scientists, with the others providing technical, administrative or other support.

The CSIRO Advisory Council is supported by six State Committees and a Northern Territory Committee. The Council comprises the chairmen of its State and Territory Committees, senior representatives of Commonwealth agencies with interests in science and technology, and persons representing industry, tertiary education and community interests.

Further details on the names of senior members of the Organization and members of its advisory bodies are set out in Appendices I and II. Appendix III sets out the roles of the Institutes, Divisions and independent research Units of the Organization. An organization chart appears overleaf.

EXECUTIVE

Chairman
Dr J.P. Wild

Full-time Members
Dr N.K. Boardman
Dr G.H. Taylor

Part-time Members
Professor D.P. Craig
Mr G.G. Spurling
Mr H.M. Morgan
Mr S.B. Myer
Mr P.D.A. Wright

Chief Executive
Dr J. P. Wild

Executive Member
Dr N. K. Boardman

Executive Member
Dr G.H. Taylor

INSTITUTE OF ANIMAL AND FOOD SCIENCES

Director
Dr K.A. Ferguson

Divisions and Chiefs

Animal Health
Dr A.D. Donald (*Acting*)

Animal Production
Dr T.W. Scott

Fisheries Research
Dr S.W. Jeffrey (*Acting*)

Food Research
Dr J.H.B. Christian

Human Nutrition
Dr B.S. Hetzel

Tropical Animal Science
Dr D.F. Mahoney

Units and Officers-in-Charge

Project for Animal Research and Development
Dr J.L. Wheeler

Australian National Animal Health Laboratory
Mr W.A. Snowdon

Molecular and Cellular Biology
Dr G.W. Grigg

Wheat Research
Dr C.W. Wrigley

Office of the Executive

Executive Secretary – Mr L.G. Wilson

Finance and Administration
Secretary – Mr H.C. Crozier

Personnel
Secretary – Mr K.J. Thrift

Planning and Evaluation Advisory Unit

Director – Dr D.E. Weiss

Bureau of Scientific Services

Director – Mr S. Lattimore

INSTITUTE OF INDUSTRIAL TECHNOLOGY

Director
Dr W.I. Whitton

Divisions and Chiefs

Applied Organic Chemistry
Dr D.H. Solomon

Building Research
Dr F.A. Blakey

Chemical and Wood Technology
Dr W. Hewertson

Manufacturing Technology
Mr R.H. Brown

Protein Chemistry
Dr W.G. Crewther

Textile Industry
Dr D.S. Taylor

Textile Physics
Dr A.R. Haly

INSTITUTE OF BIOLOGICAL RESOURCES

Director
Mr M.V. Tracey

Divisions and Chiefs

Entomology
Dr M.J. Whitten

Forest Research
Dr J.J. Landsberg

Horticultural Research
Dr J.V. Possingham

Plant Industry
Dr W.J. Peacock

Soils
Dr D.E. Smiles

Tropical Crops and Pastures
Dr E.F. Henzell

Water and Land Resources
Dr R.J. Millington

Wildlife and Rangelands Research
Dr C.J. Krebs

Unit and Officer-in-Charge

Centre for Irrigation Research
Dr D.S. Mitchell

INSTITUTE OF PHYSICAL SCIENCES

Director
Dr N.H. Fletcher

Divisions and Chiefs

Applied Physics
Dr J.J. Lowke

Atmospheric Research
Dr G.B. Tucker

Chemical Physics
Dr L.T. Chadderton

Computing Research
Dr P.J. Claringbold

Environmental Mechanics
Dr J.R. Philip

Materials Science
Dr J.R. Anderson

Mathematics and Statistics
Dr T.P. Speed

Oceanography
Dr A.D. McEwan

Radiophysics
Dr R.H. Frater

Unit and Officer-in-Charge

Australian Numerical Meteorology Research Centre
Dr W.P. Bourke (*Acting*)

INSTITUTE OF ENERGY AND EARTH RESOURCES

Director
Mr I.E. Newnham

Divisions and Chiefs

Energy Chemistry
Dr P.G. Alfredson

Energy Technology
Dr D.C. Gibson

Fossil Fuels
Mr A.V. Bradshaw

Geomechanics
Dr B.H.G. Brady

Groundwater Research
Mr R.A. Perry

Mineral Chemistry
Dr D.F.A. Koch

Mineral Engineering
Dr A.F. Reid

Mineral Physics
Dr K.G. McCracken

Mineralogy
Mr A.J. Gaskin

Unit and Officer-in-Charge

Physical Technology
Dr E.G. Bendit

Organization Chart
The chart shows the structure of CSIRO as at 1 July 1983.

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Introduction

CSIRO is Australia's principal government research organization and its main role is to undertake strategic research on behalf of the people and industries of Australia. Our constant challenge is to sense what the nation will be requiring ten years hence, and yet be responsive to the pressures and policies of the present. The latter are constantly changing. Ten years ago a new emphasis was given to conservation of the environment; since then it has shifted to energy, especially alternative liquid fuels; to the seas and oceans that surround our continent; to fresh-water resources, the most precious of all our resources; to manufacturing technology and the support of existing industries; and now to high technology for the development of new industries. CSIRO has responded to the succession of high priorities over the years by expanding its work in these areas, usually at the expense of work in other areas. Political interest in such matters has recently been growing strongly, and we welcome the commitments to increase investment in Australian science and technology made in the policy platform of the present Government.

Flux at the margin attracts most political and public attention, but it is the less publicized bulk of long-term programs, continually under review and continually evolving, that contribute principally to our main purpose. Since 1978 we have instigated a formal planning system as well as more vigorous review procedures. Reviews of subjects or Divisions are conducted by expert committees, the majority of whose members come from outside CSIRO. No comment or criticism is more welcome and more to the point than that which we receive from these committees. We also receive valuable advice from the CSIRO Advisory Council, particularly from its five standing committees which look in detail at our industry and community activities, and from our State and Territory Committees. I would like to pay tribute to the people who give their time to serve on these committees and provide the Executive with feed-back on how we are doing in the cities and the far flung regions of this country.

CSIRO's Appropriation for 1982/3 was $265 million. This figure has grown steadily through the years, due partly to inflation, partly to 'fictitious' increases—i.e. book transfers from other listings of government expenditure of items such as industry, superannuation and building funds—and partly to new responsibilities imposed or agreed to by government. Meanwhile, funds for the bulk of the Organization's research have not kept pace with inflation. As a consequence, many Divisions have been compelled to reduce their staff year by year. The most devastating effects of this process are reduced flexibility and the lack of opportunity to appoint young scientists—the much-needed lifeblood of any research organization.

To suit the needs of changing circumstances, there is also a pressing need for greater flexibility in replacing staff. An urgent requirement is for government permission to institute voluntary retirement at 55 years or more. This move would have the overwhelming support of management and staff associations. World-wide experience in both public and private sectors shows that benefits far outweigh costs when even more flexible retirement arrangements with financial incentives are offered to those willing to retire early. We are looking into these possibilities.

Developments during 1982/83 form the substance of this report; I mention here a few:

- The Organization continues vigorously with its efforts to bridge the gap with manufacturing industry. The latest development is a proposal to initiate the formation of a company, 'SIROTECH', to assist in the two-way task of stimulating awareness of industry requirements in CSIRO Divisions and promoting CSIRO inventions and technology in industry.

- 'SIROMATH', also a joint company, was formed two years ago to provide high-level mathematical consultancy services to Australian industries. The company has been successful and has expanded very rapidly, financing this expansion from earnings.
- New criteria for the promotion of research staff have been issued, emphasizing the importance of industrial achievement and dispelling the mistaken notion of 'publish or perish'.
- A new scheme has been successfully launched for promoting collaboration between CSIRO and universities using shared funds. Initially the scheme is working with six universities.
- The Australian National Animal Health Laboratory at Geelong, ever in the news, is nearing completion. Probably the most complex building ever to be undertaken in this country, it has been designed and constructed with notable success in collaboration with the Department of Housing and Construction. Owing to the general controversy, the Executive decided it should not seek introduction of live foot and mouth disease virus to the Laboratory before the end of 1985 unless, of course, there is an outbreak of the disease. ASTEC came to a similar conclusion, but with a date towards the end of 1987. The Government's decision is awaited.
- Despite some opposition, the Executive terminated cloud-seeding research operations on the basis of lack of statistical evidence of increased rainfall.
- Research highlights came from areas such as: the new ceramic PSZ (partially-stabilized zirconia, popularly known as 'ceramic steel'); the VLSI (very large-scale integrated circuits) program, with the development of a multi-purpose chip; productivity gains for the sheep-meat, egg and cheese industries; and the development of sophisticated security systems for bank notes and credit cards to prevent counterfeiting.

CSIRO is something uniquely Australian and it is the responsibility of its Executive and staff to maintain its value to the nation and its standards of excellence, and with them the confidence and pride of the Australian people. Times and attitudes change. There was a time, or so it is now believed, when to criticize CSIRO was akin to criticizing the monarchy or motherhood. We were a sacred cow. Those days have gone and I bid them good riddance. It is altogether healthier to live in an era of debate, controversy and exchange of information, and it is our duty to respond to criticism, whether based on fact or myth, and explain what we are and what we do. In this respect I am sure we can do better.

Criticism comes from within as well as from without. Here, for example, are words written by a Chief of Division:

> 'There is a widespread feeling that things are not what they should be in CSIRO. Many people have mentioned their misgivings to me, including old and tried members of the staff, whose loyalty and good will are beyond question. They feel that we are getting off the track and are losing the high reputation that we had.
>
> If these misgivings are justified it is very disturbing and the causes must be found before there can be any chance of retrieving the position.
>
> The commonest cause advanced by our own people, as well as by outsiders, is that the Organization has become too big and impersonal and, consequently, has lost its old spirit of zeal and unity.'

Those words were written at the start of the 1950s, the decade when Clunies Ross was in the chair, God was in His heaven, and all was well with the world—now thought of as our golden age.

The concerns about the size of CSIRO expressed by that Chief illustrate a dilemma facing policy makers. Sheer size is often seized upon as the culprit when the going gets tough in any enterprise. Certainly bigness brings its problems but they tend to be at least manageable while the components remain together. The alternative is fragmentation, and then the problem is transformed into something much worse, compartmentalization and inflexibility to change.

The formation of Institutes within CSIRO and the devolution of responsibility to those closer to the work-face are the main weapons we use against the problems that come with being large. Meanwhile, we take advantage of the strengths inherent in our size, diversity and unity by continually reshaping our forces in response to emerging national needs. While this is not always accomplished entirely without tears, it is done in a way that preserves as far as possible the environment necessary for creative and productive research and minimizes the losses that can occur when shifts are made arbitrarily or too suddenly. Our success in this is critically dependent on our ability to perceive and act upon trends in national requirements and in science well ahead of time. This is the greatest challenge facing the management of CSIRO but, with the goodwill and cooperation of our many advisers and customers in industry and the community, I am sure we shall continue to meet the challenge.

J.P. Wild
Chairman

Research Policies and Administration

This section covers developments in policies for the Organization's research, financial matters, and other matters of a general policy or administrative nature, including those required to be reported under the Science and Industry Research Act 1949. CSIRO's statutory and other reporting obligations are set out in Appendix V.

1. Determining research priorities

The main mechanisms for deciding on and implementing desirable changes in the Organization's overall research effort are:

- planning studies, reviews of specific research subjects, and reviews of the research Divisions and Units of the Organization;
- identification at Executive, Institute and Divisional levels of research topics to be terminated or reduced to free resources for redeployment;
- procedures at all levels for allocation of redeployed resources to areas identified for expansion; and
- approaches to government for additional resources to facilitate expansions of research effort in areas which accord with government policy and in which the Executive sees a need for a greater or more rapid expansion than that feasible through redeployment.

Planning studies have been described in a number of recent annual reports. They involve comprehensive examinations of the Organization's research activities, grouped into broad sub-sectors. These studies are well advanced and will be completed within the next two years. A formal evaluation of the distribution of the Organization's research effort between these sub-sectors should then be feasible. In the meantime the Executive, with advice from the CSIRO Advisory Council and other external sources, keeps the overall distribution of its research effort under constant review.

In combination, these mechanisms lead to changes at many levels in the Organization's research. Some changes are broad, such as increases in research on energy, manufacturing technology and water resources. Others are very specific, such as the initiations and cessations which are reported in Table 3 of Chapter 2, and the even more numerous changes that happen all the time within research programs. The mechanisms also complement each other; for example, both internal redeployment and approaches to government have in recent years taken place in connection with research concerning biotechnology, information technology, energy and water resources.

A feature of some recent proposals made from outside the Organization for the reallocation of CSIRO's broad research priorities is a reliance on generalized economic data, such as the absolute or comparative size of the industry in question. Economic parameters and trends are relevant to decisions on the balance of research effort but numerous other factors need to be given adequate weight. Some of these are described in a following section. A good account of the general position was contained in the 1977 report to the then Government by the Independent Inquiry into CSIRO, which stated that:

> '. . . there are specific reasons why Government in general, and CSIRO in particular, should undertake research supportive of particular industry sectors. These . . . include: the extent of fragmentation of the industry, the extent to which problems or opportunities peculiar to Australia exist, the extent to which long-term research can contribute to industries' needs and realisation of capabilities, and the extent to which public benefits (as distinct from benefits to individual firms) derive from research supportive of such sectors. . . .
>
> We considered various quantifiable parameters, for example export earnings, proportions of Gross Domestic Product (GDP) or employment, which might be used to provide a basis for deciding on the extent of CSIRO activities in support of various industry sectors, or for judging the appropriateness of its current division of effort. The Committee concluded that no automatic quantifiable measure can be used as a basis for such decisions. Judgement must be made from time to time in the light of prevailing circumstances.'

The Executive fully endorses the conclusions of the Independent Inquiry and believes that its concise statement on this matter should be given greater recognition.

The Committee of Inquiry went on to recommend various consultative and planning processes which CSIRO should expand or introduce to improve the quality of its decisions on the broad allocation of research resources and the visibility of its decision-making processes. All of these measures have been adopted over the past five years, and the Executive has publicly stated its concurrence with the Inquiry's proposals and recognized the improvements in the quality of the inputs to its decision-making that have resulted. In particular, there has been a much needed improvement in the economic information available to influence decisions, going far beyond the general statistics referred to earlier.

It is important that comprehensive and widely respected mechanisms for research planning should be adopted and continually improved. The nature and quality of these mechanisms are as much subject to review as are their outputs. Professor A.J. Birch has recently examined CSIRO's response to decisions arising from the Committee of Inquiry which he chaired, and his comments and advice to the Minister responsible for CSIRO will be carefully considered when they become available. Also, the Executive will shortly be commissioning a comprehensive review of the Organization's strategic research planning process.

Suggested Shifts in the Balance of Research Effort

The processes of examination and redeployment just described cause steady evolution in the distribution of CSIRO's research effort but some commentators believe that more radical changes are necessary. Most of these suggestions originate from groups representative of particular segments of industrial activity or community need, or from parts of the science policy community that have concentrated their studies on a particular sector or area. It is proper for interest groups to urge that additional resources be devoted to their areas of interest, particularly when cases can be supported with quantified data. However, the data presented often take the form of bare statistics about the industry which do not adequately support the representations being made. A sample of these representations follows.

It has been urged that CSIRO's research effort should be shifted in favour of:

- increased *manufacturing* industry research effort, because of:
  - (i) the high proportion of gross domestic product contributed by this sector, and its potential to generate new employment opportunities commensurate with the skills and availability of labour in the Australian workforce,
  - (ii) the oftentimes lower demands for capital investment for each job created in this sector relative to the mining sector and its potential, particularly in the case of high-technology industries, to grow quickly,
  - (iii) the backwardness of many Australian manufacturing technologies in comparison with best practice overseas and the consequent unfavourable balance of trade in high-technology products and licences, and
  - (iv) the low numbers of public sector research and extension workers supporting this sector in comparison to the rural sector;
- increased *rural* industry research effort, because of:
  - (i) the high national economic returns from such research relative to research in support of sectors having lower levels of comparative advantage,
  - (ii) the high proportion of export earnings generated by rural exports, and the high potential for 'downstream' processing of rural products,
  - (iii) the relatively low level of general government assistance to the rural industry compared to levels of assistance granted to the manufacturing sector (primarily in the form of tariffs, which also add to the costs to rural producers), and
  - (iv) the high degree of Australian ownership in this sector compared to the manufacturing and mining sectors;

- increased *construction* industry research effort, because of:
  - (i) the size of the construction sector in the national economy, and its impact on the economic performance of other sectors, and
  - (ii) the scope for saving energy by introducing new designs for buildings;
- increased *'information* sector' research effort, because of:
  - (i) the high and increasing proportion of the working population whose activities can best be described as generating, transmitting or interpreting information, and
  - (ii) the special relevance to Australia's requirements of some of the new information technologies;
- increased *transport* research, because of:
  - (i) the high level of economic activity in the transport sector, and
  - (ii) the great dependence of other sectors on transport as part of their competitiveness; and
- increased *environmental* research, because of:
  - (i) the urgency of certain problems, such as soil erosion, and
  - (ii) the increasing importance of protection of the natural environment with the growth of leisure industries.

Factors Influencing the Distribution of Research Effort

The considerations which the Executive takes into account in determining the distribution of the Organization's research resources between broad sectors of the economy, and between these and other national needs of a social nature, include:

- the need for research on behalf of community interests which is not provided by the ordinary operations of free market forces: for example, research into environmental issues;
- prospects for industry utilization of research results (often described as industry 'needs'): there are well established links and proven customers for the Organization's rural, mining, energy, environment and building research, for example, and for those parts of the manufacturing sector concerned with processing of primary products such as wool, food, forest products and minerals;
- opportunities for scientific advances and contributions from the natural sciences: there is a vast range in the potential for science to contribute to various sectors of economic activity, and at different times there are different prospects for advances in individual fields of science. For example, exceptionally rapid advances are now being made in the biological sciences, giving rise to opportunities for significant contributions to the rural and manufacturing sectors and to important aspects of environmental protection and conservation;
- prospects for the development of new industries: these prospects are based partly on scientific potential and partly on perceptions of the likelihood of an economic environment being created which will stimulate the establishment and growth of new high technology firms. A significant improvement in the latter area has become apparent over the last year or so and it now seems likely that positive incentives, such as improved access to venture capital, will be provided to these firms. These considerations, combined with scientific opportunities, have influenced the Executive to nominate for expansion research on advanced materials, biotechnology, information technology and a new set of technologies with broad applicability in manufacturing; and
- Government policies, and conclusions and recommendations of bodies external to CSIRO which form part of the research planning system: for example, the Executive has taken close note of IAC conclusions (1977), ASTEC conclusions (1979) and conclusions of the Senate Committee on National Resources (1982) that the Organization should maintain its level of rural research effort; conclusions of NEAC and NERDDC (1979) and ASTEC (1977) in relation to increased levels of energy research effort; a conclusion of the AWRC in 1982 relating to increased water research requirements; and conclusions of ASTEC (1981) and the

Senate Committee on Science and the Environment (1979) that the urgent need in the manufacturing sector was for industry to increase its level of R&D activity, rather than for an increase in the performance of such research by the public sector; on the other hand, note was also taken of the conclusion of the Institution of Engineers Australia (1980) that more emphasis should be given to government sponsored mission oriented work for the benefit of manufacturing industry.

High Technology Industries

Much attention has been focused on high technology elements of the manufacturing sector in recent years. These elements present particular difficulties because:

- competition between firms is largely based on rival technologies, with consequent constraints on the free flow of information about underlying technological problems which may benefit from CSIRO-style strategic research;
- many of the firms involved are controlled from overseas and limitations are often imposed on local performance of research, product development and sales to export markets;
- the expertise and the will to evaluate new technologies generated within Australia are often lacking; and
- there is an apparent shortage of reliable and well-informed sources of venture capital.

In spite of these difficulties the Executive has instituted a number of measures to assist new high technology industries. The establishment of a Very Large Scale Integration (VLSI) Unit of the Division of Computing Research and a new Division of Manufacturing Technology constituted major commitments of resources to these areas. Also, a substantial shift is being made within the Division of Applied Physics to place more emphasis on applying modern physics to the problems of industry and for creating new industries. These initiatives have been undertaken by redeploying existing resources.

International Comparisons

The optimal distribution of a nation's research effort between sections of the economy is dictated by the size and maturity of that economy, the nation's endowment of human and natural resources, and many other factors such as distance from markets and economic ties with other nations. Australia's characteristics, seen from these perspectives, differ markedly from those of other developed nations. Comparisons of sectoral distributions of research between Australia and other nations must therefore be interpreted cautiously.

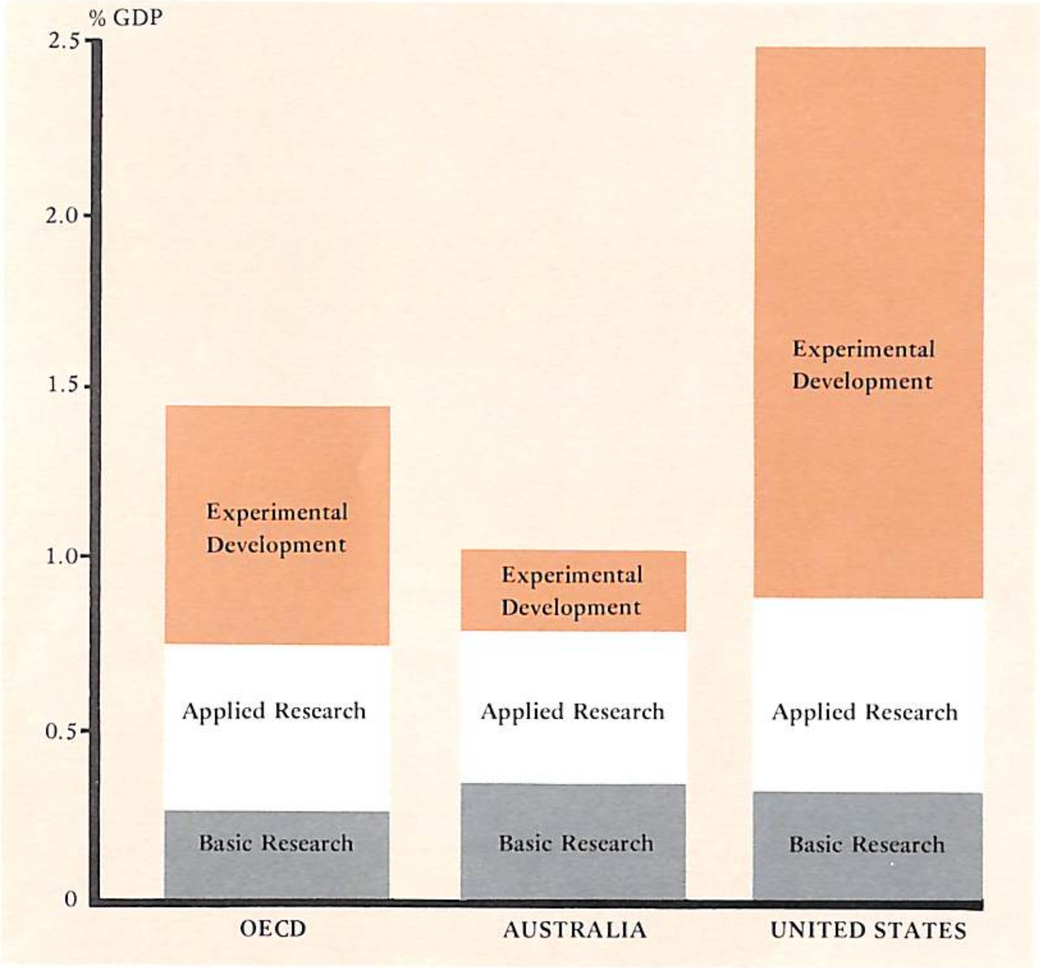
In one particular aspect international comparisons may be revealing. Amongst nations with mature economies it is possible to discern a pattern in the proportions of effort put into basic research, applied research and experimental development. The figure opposite shows these proportions for Australia, the United States and a representative set of OECD nations. There is a striking uniformity in the proportions devoted to basic research and to applied research in the three examples. There is an equally striking *dissimilarity* in the proportions devoted to experimental development. It seems likely that Australia is severely under-investing in the latter category, which covers principally commercialization—the conversion of research results into marketable processes and products or other direct commercial uses.

This conclusion is supported by another statistic. The Australian private sector contributes a low proportion of effort to research and development compared with the average amongst OECD nations (0.2% of Gross Domestic Product, or GDP, in 1979, compared with the OECD average of 0.7%). By contrast, the level of effort contributed by governments in Australia is almost the same as the average contributed by governments in the OECD (0.8% of GDP for Australia, 0.7% of GDP for the 'average' OECD nation).

On the basis of these figures, Australia does *not* appear to be over-investing in basic research, as is sometimes claimed. Rather, we have been under-investing in experimental development which, by its nature, is ordinarily the responsibility of private industry. In general, it is the low level of funding by Australian industry that accounts for our proportional differences from other nations.

Proportion of Effort Devoted to Basic Research, Applied Research and Experimental Development*

The OECD figures are based on a representative set of OECD nations.



*Source: OECD publications.

2. Distribution of research effort

This chapter sets out the current distribution of CSIRO's research effort and lists research topics designated for expansion or reduction. It forms part of the Organization's response to its statutory reporting obligations. The latter are discussed in detail in Appendix V.

Table 1 shows the distribution of resources to research areas as at 30 June 1983, according to the classification being used by CSIRO for strategic planning. In recognition of the increasing national importance of information-based industries the CSIRO Classification of Research has been amended to include a new sector named 'Information and Service Industries'. In consequence, the previous sector of the Classification named 'Community Interests' has been omitted, and another new sector named 'Knowledge and Management of the Natural Environment' created to encompass the residue of programs from the old sector. Each of the new sectors has been divided into sub-sectors as shown in Table 1.

A version of Table 1 has appeared in each CSIRO annual report since the reporting year 1978/79. Subject to the following qualifications, it is intended that year-to-year comparisons of Table 1 figures should provide an indication of shifts in the allocation of CSIRO's research resources between broad sets of national objectives. Table 1 contains figures for both professional staff and expenditure. The figures for professional staff are a better guide to research policies because they do not suffer as much from coincidental factors, such as the acquisition in one year of a major item of equipment intended for use over many years. However, caution is still required with staff figures because it can often take many months to recruit suitable staff to new programs or to replace those who leave. Two further factors need to be kept in mind when making year-to-year comparisons. First, the nature of research means that a program may benefit a number of diverse industries and provide other community benefits as well. In Table 1 each research program is assigned to the single research category to which the current work is primarily relevant. A comparatively small shift in the balance within a research program can therefore cause a reclassification of the whole program from one research area to another. Second, variations arise from changes to the Classification itself. Apart from the variations mentioned above, the only significant changes to the Classification during the reporting year were: separation of 'marine biology' into 'fisheries biology' and other 'marine biology'; and integration of 'computing' and 'information services' into a broader research area 'information, communications and computing services'.

Table 2 shows the allocation of financial and manpower resources to the Divisions and independent research Units which make up the Institutes of CSIRO. This information is displayed in further detail in the chart enclosed at the back of this report. The chart also partially reflects the distribution shown in Table 1 through the use of coloured dots to depict the relevance of research programs to sectors of the Classification. Table 2 and the chart are intended to be read in conjunction with Appendix III, which sets out the research objectives of the Institutes, Divisions and independent research Units of CSIRO.

Table 3 shows individual research programs (and in some cases, sub-programs or projects) that have been expanded or reduced by two or more professional staff during the reporting year, in pursuance of the Executive's policy of selective concentration.

The aims of this policy are to:

- ensure that adequate resources are available for high priority areas and programs;
- achieve a greater selectivity and concentration of research effort; and
- ensure that programs with an inadequate level of resources do not continue.

Research programs and sub-programs commonly fluctuate by one or two professional staff below their approved levels due to natural turnover of staff. Meaningful reductions need to be distinguished from random fluctuations, and it has therefore been necessary to select as a cut-off point a change of at least two professional staff for Table 3. The resources for significant expansions of effort have, in the main, come from reductions falling below the selected level of significance. These factors lead to differences in the statistical make-up of figures for expansions and reductions, and cause the former to outnumber the latter, even though the level of CSIRO's total resources for the period remained relatively constant.

Areas of High Priority for Expansion

CSIRO periodically establishes research areas of high priority for expansion. These broad areas do not necessarily coincide with the research areas specified in Table 1.

For 1982/83 the six areas identified for expansion were:

. energy
. manufacturing industry
. biotechnology
. plant pathology
. water and soils
. oceanography

Areas nominated for expansion in 1983/84 are:

. biotechnology
. advanced materials
. generic manufacturing technologies
. information technologies
. water and soils
. plant pathology, and
. oceanography

Significant expansion of energy research has taken place in recent years and, while research in this area remains of high importance, the Executive believes that adequate resources are now being devoted to this area. Details of the expansion of energy research during the past year are recorded in the following section.

Another change is the replacement of the broad area 'manufacturing industry' with the more specific areas 'advanced materials' and 'generic manufacturing technologies'. As described in Chapter 4, the Executive's planning activities for the manufacturing sector are nearing completion and further refinement of priorities in this area is expected.

The remaining change is the inclusion of the new area 'information technologies' in recognition of its growing importance and the contribution that new scientific knowledge can make to its development.

Significant Changes Within 1982/83 Priority Areas

Energy research expanded and underwent a redefinition of objectives during 1982/83. The Divisions of Energy Chemistry and Energy Technology, established in 1981/82, are now working with newly defined research programs. A number of new energy projects have begun in these and other Divisions of the Institute of Energy and Earth Resources and many involve collaboration with outside bodies.

Coal research expanded significantly, particularly in the field of coal preparation where increased emphasis was placed on studies of the surface areas of coal, coal cleaning by flotation and dewatering. Other coal research to increase included on-line analyses and quality control, pumping of coal and the use of decrepitating ultra-low volatile coal. In the area of substitute liquid and gaseous fuels there was increased research on oil shale conversion through flash retorting and fluidized-bed processing, and on coal conversion through flash pyrolysis and gasification by means of an iron-bath reactor. The carbon monoxide-steam reaction also received increased study. In renewable energy research, more attention was given to research on high temperature solar selective surfaces while energy conservation studies concentrated more on natural convection and augmented heat transfer, energy conservation and control, and the simulation and control of power station boilers. Environmental aspects of energy use gave more study to trace elements in coal and the disposal of fly ash from power stations.

In the area of *manufacturing industry* there has been a major shift of emphasis particularly to the technology intensive industries. The Division of Applied Physics has redeployed resources from its traditional research on standards of measurement and calibration services to industrial measurement in the fields of instrument technology, laser spectroscopy, ultrasonic and electromagnetic non-destructive testing, optical fibre instrumentation and electronic distance measurement. The very large scale integrated circuit (VLSI) program in the Division of Computing Research has also been expanded and extended by one year. In the area of advanced materials, emphasis increased on glassy metals and very high temperature properties of solids. New polymer development is also being expanded and there is increased effort on industrial physics and on integrated engineering manufacture including automation in the area of materials fabrication.

Resource-based manufacturing research is also undergoing changes. A new Division of Chemical and Wood Technology was formed during 1982/83 (see Chapter 10) from the Division of Chemical Technology and the Agricultural Engineering Group. Research in the Division is concentrating more on converting lignocellulosic material to high value chemicals and products (also applicable to the areas of *energy* and *biotechnology*), the commercial development of the SIROPULPER explosion process for the recovery of fibres from wastes and SCRIMBER reconsolidated wood. In the area of basic metal products there is increased effort on the direct smelting of iron ore with coal, *in situ* leaching and the use of mixed solvents in hydrometallurgy. Other changes have occurred in the area of textiles where more emphasis is now placed on pre-mill procedures. Building and construction has been reorganized following a review in 1981/82 and research emphasis is now placed on multidisciplinary approaches to building systems research.

Biotechnology related research continued to expand in 1982/83 as staff were appointed to positions previously allocated. This was most evident in the Molecular and Cellular Biology Unit which increased research on the accuracy of DNA copying and post replication modification, DNA breakage and repair, derivation of antimutagens and antirecombinogens, control of animal cell growth and function, monoclonal antibodies and genetic engineering in animals and animal cells. In the Division of Plant Industry, research on the molecular basis of plant improvement has increased especially on the organization and expression of plant genes, the molecular biology of photosynthesis, gene transfer in plants, tissue culture and somatic cell genetics. Amino acid sequencing of plant proteins of interest in these studies has been increased in the Division of Protein Chemistry. The Division of Animal Production has completely reorganized its research program structure and has increased research on the genetic and physiological bases of productive characteristics in animals. Developments in the Division of Chemical and Wood Technology have been mentioned under *manufacturing industry*.

A review of *plant pathology* research in Australia was completed in February 1983 and is expected to have a major influence on CSIRO's research effort in this field. In the area of soils and plant nutrition there was an increase in research on soil problems in plant production including root biology and the root/soil interface. Studies on crop and pasture pests and diseases have expanded in the fields of insect behaviour, biochemistry and ecology; C_4 herbicides and on the genetics of rust diseases. (These programs are also relevant to the area '*biotechnology*'). Research on forest diseases has increased and is giving more emphasis to diseases of radiata pine. There has also been a change of emphasis of research on the fungi *Phytophthora cinnamomi*; on dieback of native forest species and on the impact of insects on regeneration of eucalypts in pastoral areas.

Water and *Soils* research was more clearly defined and expanded in several areas in 1982/83. The Centre for Irrigation Research was formed from the Division of Irrigation Research to facilitate cooperation with research groups in several fields of water research. The centre has increased its research effort on water resource management especially that related to water quality. A new program, SIRAGCROP, for the optimal management of irrigated crops in South-eastern Australia involving collaboration with the Divisions of Plant Industry and Soils and the NSW Department of Agriculture has also begun. The Divisions of Water and Land Resources and Groundwater Research, which were established in 1981/82, have now finalized their research program structures. The Division of Water and Land Resources is increasing research on catchment hydrology and has reorganized this research into the fields of physical hydrology, regional hydrology and water quality, and sedimentation and erosion so that an integrated water/land approach to these problems is maintained. The Division of Groundwater Research has expanded research on hydrological processes and placed emphasis on groundwater as a resource. Several staff have also been transferred to the Division of Forest Research to study soils, nutrition and hydrology related to forestry. Research in the Division of Soils has been restructured to give more emphasis to the geochemistry, mineralogy and micromorphology of Australian soils.

In the area of *oceanography* transfer of the Division of Oceanography from Cronulla to the Marine Laboratories began in January 1983. Research on physical oceanography has expanded in the fields of mesoscale and continental shelf oceanography, small scale ocean processes, large scale ocean dynamics and climate, and ocean remote sensing. Further expansion of oceanographic research is expected to take place.

TABLE 1	% of Total Research Expenditure		% of Total Direct Professional Research Staff	
Rural industries				
Agriculture				
Plant improvement	2.4		2.2	
Plant physiology and biochemistry	2.4		2.5	
Soils and plant nutrition	2.9		3.0	
Crop and pasture pests and diseases	3.9		3.5	
Livestock production	5.8		4.9	
Livestock health	6.6		4.2	
Agricultural systems	2.9		2.4	
		26.9		22.7
Forestry				
Forest science	3.5		3.4	
		3.5		3.4
Fishing				
Fisheries biology	2.1		1.8	
Marine biology	1.0		0.8	
		3.1		2.6
Total – Rural industries		33.5		28.7
Mineral, energy and water resources				
Mineral resources				
Exploration	3.1		3.5	
Mining and beneficiation	2.9		3.5	
Environment	0.1		0.2	
		6.1		7.2
Energy				
Coal	2.7		2.5	
Petroleum, gas and oil shale	0.5		0.5	
Substitute liquid and gaseous fuels	4.5		5.2	
Renewable energy	0.8		0.9	
Energy storage	0.3		0.3	
Energy conservation	1.1		1.3	
		9.9		10.7
Water resources				
Water management	1.9		2.2	
Water technology	0.4		0.5	
		2.3		2.7
Total – Mineral, energy and water resources		18.3		20.6

TABLE 1 continued	% of Total Research Expenditure		% of Total Direct Professional Research Staff	
Manufacturing industries				
Resource-based manufacturing industries				
Food processing	4.8		6.0	
Textiles	5.3		4.3	
Hides and leather	0.4		0.4	
Cellulose and forest products	1.4		1.7	
Basic metal products	1.1		1.3	
		13.0		13.7
Technology-intensive industries				
Instruments and electronic equipment	3.5		4.0	
Advanced materials	2.3		2.8	
Specialty polymers	0.4		0.5	
Agricultural chemicals, pharmaceuticals and veterinary products	2.1		2.3	
Materials fabrication	2.5		2.7	
		10.8		12.3
Standards				
Standards of measurement	2.4		1.7	
		2.4		1.7
Total – Manufacturing industries		26.2		27.7
Knowledge and management of the natural environment				
Biosphere				
Fauna	2.4		2.4	
Flora	0.5		0.4	
Land	4.2		5.1	
Oceans	3.4		0.8	
		10.5		8.7
Atmosphere				
Atmospheric science	1.9		1.9	
Environmental protection	1.2		1.4	
		3.1		3.3
Extra-terrestrial				
Astronomy	2.2		1.9	
		2.2		1.9
Total – Knowledge and management of the natural environment		15.8		13.9

TABLE 1 continued	% of Total Research Expenditure		% of Total Direct Professional Research Staff	
Information and service industries				
Information services and technologies				
Mathematics and statistics	1.5		3.1	
Information, communications and computing services*	0.9		1.4	
		2.4		4.5
Service industries				
Building and construction	2.6		3.1	
Public health	1.2		1.5	
		3.8		4.6
Total – Information and service industries		6.2		9.1
CSIRO – Research total		100.0		100.0

*Does not include CSIRONET component of Division of Computing Research previously included in Table 1.

TABLE 2	% of Total Research Expenditure		% of Total Direct Professional Research Staff	
Institute of Animal and Food Sciences				
Animal Health	4.3		2.7	
Animal Production	4.6		4.1	
Fisheries Research	3.0		2.6	
Food Research	4.6		5.7	
Human Nutrition	1.2		1.5	
Tropical Animal Science	2.4		1.5	
Molecular and Cellular Biology	1.1		1.3	
Project for Animal Research and Development	0.7		0.4	
Wheat Research	0.3		0.4	
	——	22.2	——	20.2
Institute of Biological Resources				
Entomology	4.5		3.9	
Forest Research	3.3		3.2	
Horticultural Research	1.0		1.3	
Plant Industry	5.3		5.3	
Soils	2.8		3.6	
Tropical Crops and Pastures	3.6		2.5	
Water and Land Resources	2.1		2.6	
Wildlife and Rangelands Research	2.7		2.6	
Centre for Irrigation Research	0.9		1.0	
	——	26.2	——	26.0
Institute of Energy and Earth Resources				
Geomechanics	1.4		1.2	
Energy Chemistry	1.7		1.3	
Energy Technology	1.4		1.4	
Fossil Fuels	2.5		2.8	
Groundwater Research	1.1		1.0	
Mineral Chemistry	2.1		2.7	
Mineral Engineering	1.6		2.1	
Mineral Physics	2.2		2.8	
Mineralogy	1.8		2.1	
Physical Technology	0.4		0.5	
	——	16.2	——	17.9
Institute of Industrial Technology				
Applied Organic Chemistry	1.7		2.0	
Building Research	2.6		3.0	
Chemical and Wood Technology	2.8		3.3	
Manufacturing Technology	1.5		1.6	
Protein Chemistry	1.9		1.8	
Textile Industry	2.8		1.9	
Textile Physics	1.7		1.6	
	——	15.0	——	15.2

TABLE 2 continued	% of Total Research Expenditure		% of Total Direct Professional Research Staff	
Institute of Physical Sciences				
Applied Physics	5.4		5.4	
Atmospheric Research	2.1		2.1	
Chemical Physics	1.9		2.4	
Computing Research*	1.2		1.6	
Environmental Mechanics	0.5		0.5	
Materials Science	1.3		1.7	
Mathematics and Statistics	1.5		3.1	
Oceanography	3.4		0.9	
Radiophysics	2.9		2.7	
Australian Numerical Meteorology Research Centre	0.2		0.3	
		20.4		20.7
TOTAL		100.0		100.0

* Does not include CSIRONET component of Division of Computing Research previously included in Table 2.

TABLE 3

Variations in Professional Staff Deployment in Programs and subprograms [1,2]

(E = expanded, R = reduced, and T = terminated programs and subprograms)

Research area	Program/subprogram
RURAL INDUSTRIES	
Agriculture	
Plant improvement	Molecular basis of plant improvement (E)
Plant physiology and biochemistry	–
Soil and plant nutrition	Crop and pasture problems of acid soils (R)
Crop and pasture pests and diseases	Biological control of aphids (R)
	Development of herbicides specific to C_4 plants (E)
Livestock production[3]	Animal nutrition (tropics) (E)
Livestock health	Australian National Animal Health Laboratory (E)
	Molecular genetics of insects (affecting livestock) (E)
Agricultural systems	Integrated control and management of irrigated crops–SIRAGCROP (E)
Forestry	
Forest Science[3]	–
Fishing	
Fisheries biology	–
Marine biology	–
MINERAL, ENERGY AND WATER RESOURCES	
Mineral resources	
Exploration	Geochemical methods (R)
	Geophysical methods (E)
Mining and beneficiation[3]	Mineral beneficiation (E)
	Industrial minerals processing (E)
Environment	–
Energy resources	
Coal	Coal preparation (E)
	New uses for coal (E)
Petroleum, gas and oil shale	Deposit characteristics (R)
Substitute liquid and gaseous fuels	Coal conversion (E)
	Oil shale conversion (E)
Renewable energy	Solar energy systems (E)
Energy storage	–
Energy conservation	Energy conservation and control (E)

TABLE 3 continued

Research area	Program/subprogram
Water resources	
Water management	Hydrological processes (E)
	Applied hydrology (R)
	Water resource management (E)
	Catchment hydrology (E)
Water technology	–
MANUFACTURING INDUSTRIES	
Resource-based manufacturing industries	
Food processing	–
Textiles	Mechanical and physical properties (E)
	Premill procedures (E)
	Wool properties (R)
	Spinning and yarn faults (R)
	Dimensional stability (R)
	Colouration–jet printing (T)
Hides and leather	–
Cellulose and forest products[3]	–
Basic metal products	Metalliferous minerals processing (E)
Technology-intensive industries	
Instruments and electronic equipment	Instrument technology (E)
	Investigation of gas-discharge dynamics (E)
	VLSI (E)
	Electronics (E)
	Signal processing (E)
	Mass spectroscopy (R)
	Solid state and surface science (R)
	Computing systems in radiophysics (R)
	Dynamic measurement in industrial environments (E)
	Ultrasonic non-destructive testing (E)
Advanced materials	Radiation effects in solids (E)
Specialty polymers	–
Agricultural chemicals, pharmaceuticals and veterinary products	DNA breakage and repair (E)
	Control of animal cell growth and function (E)
	Monoclonal antibodies development (E)
	Genetic engineering in animals and animal cells (E)
Materials fabrication	Electrical discharge in gases (E)
	MM wave technology and microlithography (E)
	Integrated engineering manufacture (automation) (E)
Standards	Statutory standards of measurement and calibration services (R)
	Fundamental standards research (absolute determination of the volt) (T)

TABLE 3 continued

Research area	Program/subprogram
INFORMATION AND SERVICE INDUSTRIES	
Information services and technologies	
Mathematics and statistics[3]	–
Information, communications and computing services[4]	–
Service industries	
Building and construction[3]	–
Public health	–
KNOWLEDGE AND MANAGEMENT OF THE NATURAL ENVIRONMENT	
Biosphere	
Fauna[3]	–
Flora	–
Land	Geochemistry, mineralogy and micromorphology of Australian soils (E)
Oceans	Physical oceanography (E)
Atmosphere	
Atmospheric science[3]	–
Environmental protection	–
Extraterrestrial	
Astronomy	Australia telescope (E)

1 Program or subprogram is listed if change during year was equal to or greater than two professional staff.
2 The Divisions of Animal Production, Forest Research, Geomechanics, Mathematics and Statistics, Building Research, Chemical and Wood Technology, Atmospheric Research and Wildlife and Rangelands Research have completely reorganized or are reorganizing their program structures and are not included in the Table.
3 Programs in major contributing Division have been or are being restructured.
4 Division of Computing Research is under review and is not included in the Table.

3. Minerals research

Introduction

CSIRO's minerals research is directed towards better exploration, utilization and management of Australia's mineral resources. This statement applies to minerals other than fossil fuels, which include coal, oil-shale and petroleum. The latter were included in the statement of the Organization's energy research in the 1980/81 annual report.

CSIRO maintains a core program of strategic research on minerals in accord with its charter to conduct such research on behalf of the industry and the community with funds provided by government. In addition, to ensure relevance of the core program to the current and future needs of the industry, the Executive actively encourages projects which are directed to specific problems, including those funded wholly or partly by the industry.

Close attention has been given to relevant government policies and to views expressed by both industry and interested community groups in the development of the following statement. Government policies of particular relevance are that secondary processing of minerals and research in geoscience should be promoted, and that new mining projects and related developments should be environmentally sound. CSIRO research for the minerals industry is consistent with these policies and covers the full range of activities from exploration and extraction to processing, with significant resources being devoted to safety and environmental aspects. In relation to exploration research, agreement on the respective roles of CSIRO and the Bureau of Mineral Resources, Geology and Geophysics (BMR) was reached in 1982 and recorded in the Organization's annual report for 1981/82.

The minerals industry, unlike the agricultural and manufacturing industries, is dominated by a few large enterprises, some having access to research resources of parent organizations overseas. CSIRO carries out research for the benefit of this industry in collaboration with it, notably through the agency of the Australian Mineral Industries Research Association Ltd (AMIRA). Recent years have seen a sharp increase in CSIRO research sponsored by industry through AMIRA. A CSIRO Executive seminar on minerals research conducted during 1981/82 and attended by a wide range of industry representatives provided a significant input to the development of the policy reported here.

Research Objectives

CSIRO research is directed towards better exploration, utilization and management of Australia's mineral resources. In developing objectives for CSIRO's minerals research in these fields, the Executive took into account:

. the specific roles and activities of other Federal Government agencies with responsibilities in the minerals area;
. the specific responsibilities and roles of the States of Australia;
. the economic, social and political aspects of Australia's role as a supplier of minerals and processed forms derived therefrom to other countries;
. the role of industry in conducting research and applying the results to its commercial operations, and the supporting role of academic institutions;
. the roles appropriate to the AMIRA and local consultant and contract research organizations such as the Australian Mineral Development Laboratories (AMDEL) in meeting the needs of industry;

- the opportunities for, and the need to develop further, collaboration with appropriate research groups overseas.

Minerals research in Australia needs to take account of unique features of Australian mineral deposits and of the structure of the Australian minerals industry. Particular features which impinge on the selection of research objectives include:

- the geological settings in which Australia's mineral resources are located;
- the general remoteness of operations from markets and support services;
- the capital intensive nature, and sensitivity to the economics of large-scale output, of much of the industry's operations; and
- the growing importance of small-volume, high-value minerals.

Taking these factors into account the Executive has agreed that the broad objective of CSIRO minerals research should be:

To contribute to the locating, extracting and processing of minerals through development of procedures which are efficient, economic, involve safe working practices and do not impose irreparable damage on the environment.

Research Policy

In general, CSIRO concentrates its efforts on the research phase of the research, development and demonstration spectrum and does not play a leading part in the operation of pilot and demonstration facilities. The latter often involve multi-million dollar capital and operating investments. However, the Organization has a consultative role to play in development of such facilities and it aims to provide adequate resources to fulfil this role when called upon.

The nature of minerals research requires a multi-disciplinary attack on the problems to be solved, and a recognition of the interrelationships between, and interdependence of, the separate parts of the minerals industry. These factors exercise a continuing influence on the organization of CSIRO's minerals research and on the way research activities in the Divisions of the Institute of Energy and Earth Resources are managed.

The Executive requires that the results of the Organization's minerals research are transferred in an effective and timely manner to those responsible for commercial operations and the management of Australia's mineral resources. Arrangements for consultation in formulating broad research priorities and for subsequent involvement in promoting utilization of research results are therefore actively pursued.

In summary, it is Executive policy that:

- CSIRO minerals research projects will be directed towards solving problems or advancing scientific or technological knowledge in areas that are of direct significance to Australia;
- collaborative programs with other workers, both in Australia and overseas, will be undertaken as appropriate;
- after due regard to patenting and licensing considerations, the results of the research will be made available to interested parties with minimal delay;
- in the development or demonstration phases of particular projects, special expertise may be sought to supplement the Organization's research effort and, if appropriate, CSIRO will play a supporting role to another party.

Research Areas

In accord with the broad objectives determined for CSIRO mineral's research, studies are undertaken in the areas of exploration, mining, mineral processing and extractive metallurgy and of environmental impacts of all these stages of minerals activity. Brief statements of the nature of CSIRO research in each of these areas follow.

Exploration
Locating and delineating the extent and grade of Australian mineral resources are of high priority to the nation. Accordingly, CSIRO conducts research into the initiation and development of concepts and techniques, both geochemical and geophysical, to assist the exploration industry in its search for ore deposits. Recognizing the broadened role of the BMR in complementary studies in this area, CSIRO and the Bureau reached agreement in 1982 on measures to avoid any unnecessary duplication of research effort and to promote collaborative work. (As noted previously, these arrangements were presented in the Organization's annual report for 1981/82.)

The Executive has recently set in train a joint review of its Divisions of Mineral Physics and Mineralogy which together conduct most of CSIRO's research relating to minerals exploration (see Chapter 6). The outcome of this review will be reported when the Executive has considered the findings and recommendations of the review committee, which on present plans should happen during 1983/84.

Mining
Mining is capital-intensive and an arduous and hazardous occupation. Industry is anxious to improve the safety of its workings, particularly underground, and to increase productivity. CSIRO is undertaking research in selected areas, aimed at making significant contributions to these objectives. However, the nature of the problems to be solved, and the environment in which they are to be found, militate against quick solutions, and a continuing research effort is needed.

The present Government's policy platform encourages CSIRO to undertake appropriate safety research. The Organization's research directed towards safety in mining operations is an important element of CSIRO's effort in this field.

Mineral Processing and Extractive Metallurgy
The processes for preparing ore prior to extraction of the metals it contains, and for extracting the metal, are capital intensive. The wide variability of composition of the materials handled exacerbates the difficulties of maintaining close levels of control over the complex reaction sequences involved in attaining optimum output. The uniqueness of the composition of many Australian minerals means that the results of overseas research are often not applicable, and special analytical and processing techniques need to be developed to ensure that the cost structure and quality of the processes are commercially competitive.

Because of the significant effect of capital charges on operating costs and the risks associated with introducing entirely new processing techniques, industry is rightly cautious about accepting new concepts and introducing new techniques. Accordingly, CSIRO recognizes that it may be many years before there is significant industrial acceptance of research results which would entail major changes in industry practice. Before embarking on projects directed to such aims, CSIRO therefore assesses carefully the long-term prospects of success and potential economic and commercial impacts, particularly if a substantial allocation of resources is required for prosecution of the research.

Environmental Impact
The mining and processing of minerals, by their very nature, have an impact on the environment. In undertaking research into some of these environmental problems, CSIRO is mindful of the role of other Commonwealth and State organizations with responsibilities in this area. In addition, the environmental impacts that would be associated with proposed process changes and modifications of plant are an integral part of such research projects, recognizing that belated recognition of environmental aspects can militate against either their proper consideration or prospects for industry and community acceptance of proposed new techniques.

Minerals Research Goals, Objectives and Time Periods

The broad research goals and more detailed objectives of CSIRO's minerals research are set out in Table 4 overleaf. Two of the long-term research goals are not being supported at present; one of the effects of current limitations on resources is that research effort must be concentrated only on topics of highest priority, leaving considerable important work undone.

Future Research Directions

CSIRO is aware of its responsibility to ensure that the nature of its minerals research is in accord with the concepts of the mineral industry. It acknowledges the part that both AMIRA and individual companies have played in contributing to the continuing process of formulating mineral research policy. Interaction with the industry and relevant Commonwealth and State Government agencies will continue to be important in formulating future research directions. In addition to the broad strategic planning by the Executive of sectors and sub-sectors of the Organization's research activities, reviews of individual Divisions engaged in aspects of minerals research will continue to play an important part in determining more specific priorities for future research. The reviews in recent years of the Divisions of Mineral Engineering, Geomechanics and Fossil Fuels and the current reviews of the Divisions of Mineralogy and Mineral Physics drew extensively on the views of both industry and the scientific community in formulating future research directions and provided a mechanism for examining the effectiveness of each Division's work as a whole and of its on-going interactions with industry and the community.

Table 4

Mineral Research Goals and Objectives

*Near-term Goals (in use within 10 years)	Research Objectives
To improve conceptual and instrumental methods for locating and delineating economic mineral deposits.	Development of geochemical and geophysical exploration methods.
To improve safety and productivity of current methods of mining.	Elucidation of the geomechanical parameters that control mining excavations and development of methods of mine design and control.
To improve productivity of current methods of processing ores to marketable products (including metals).	Development of methods for analysis, design, control and optimization of processing systems.
To overcome undesirable effects of mining and processing minerals on the environment.	Containment of direct and indirect plant effluents.
Mid-term Goals (in use between 10-20 years)	**Research Objectives**
To develop approaches to exploration for blind ore-bodies.	Identification and development of new exploration methods and techniques.
To develop new technologies for recovery and processing of minerals.	Identification and development of new methods of mining ore bodies and of processing complex ores not amenable to current practices.
To develop new methods for the extraction of metals from ores.	Development of liquid metal bath processes.
Long-term Goals (in use beyond 20 years)	**Research Objectives**
To develop methods for the economic recovery of currently sub-marginal mineral resources.	Identification and development of technologies for *in situ* processing of minerals.
To develop methods for mining in hostile or fragile environments.	Development of safe, economic and socially and environmentally acceptable mining methods in highly stressed areas.
To develop processing methods which reduce current dependency on scarce resources—water and energy.	Currently inoperative.
To develop methods for recovery and processing of offshore minerals.	Currently inoperative.

*The time period does not imply termination of the work at the end of the period but refers to the expected time lapse between initiation of the research and achievement of broad industrial acceptance of successful results of the research.

4. Manufacturing industry research

Planning and Policy Development

Over the past few years the Organization has placed a high priority on improving its interaction with the manufacturing sector of Australian industry and examining the research it performs on behalf of this sector. These emphases were described in Chapter 4 of the CSIRO Annual Report 1980/81.

Late in 1982, the CSIRO Planning and Evaluation Advisory Unit's (PEAU) manufacturing industry research planning document was completed. This provides a detailed analysis of the technological needs of the various sub-sectors of manufacturing industry and of research opportunities for the Organization. It was prepared in consultation with representatives of a broad range of industrial companies, CSIRO scientists and bodies such as the Bureau of Industry Economics and the Manufacturing Industry Standing Committee of the CSIRO Advisory Council.

In parallel with this planning study, the Executive endorsed in principle a statement of policy on research for manufacturing industry. This statement includes criteria for selecting broad lines of research of relevance to manufacturing industry that are appropriate for CSIRO, and for determining priorities within these broad areas. The criteria take into account both the likelihood that the productivity and efficiency of Australian manufacturing industry will be significantly improved by technological innovation resulting from the research proposed and the appropriateness of that research to CSIRO's role, skills and resources.

The Organization is now applying these criteria to the many research opportunities identified in PEAU's planning document. The priorities thus identified will be considered by the Executive early in the reporting year 1983/84 and will form the basis of CSIRO's research for manufacturing industry for the next few years. They will be reported in next year's annual report.

Key Manufacturing Technologies

Although the identification of priorities for research in manufacturing industry is not yet complete, the following four groups of technologies have already been identified for increased attention by CSIRO:

- generic manufacturing technologies
- advanced materials
- biotechnology
- information technology.

These technologies are fundamental to many manufacturing sub-sectors and are widely acknowledged as corner-stones for industrial development; in some cases they have the potential to serve as a basis for the establishment of new manufacturing industries. They incorporate a number of the widely discussed 'sunrise' technologies. Biotechnology and information technology have potential for application in sectors of industry other than manufacturing. Approaches have been made to government for additional resources to enable a sustained expansion of research effort.

Generic Manufacturing Technologies

Generic Manufacturing Technologies include a group of electronics-based manufacturing technologies that are crucial for improving the productivity and efficiency of most manufacturing activities, and necessary for addressing the needs of a number of Australian manufacturing industries for example, the need for better quality control and for more flexible manufacturing processes.

The Division of Manufacturing Technology is developing high level skills in these technologies, which include robotics, machine tool control systems, computer-aided design and manufacture (CAD/CAM) and microelectronics applications in sensing. Industry is exhibiting considerable interest in, and support for, the development of these technologies.

Advanced Materials

Advanced Materials has been identified as a research area with marked potential to increase Australia's industrial competitiveness and to capitalize on resource advantages. Various research opportunities have been identified, notably an extension of the work done to date on the industrial ceramic 'partially stabilized zirconia' (PSZ). Commercialization of this material by an Australian company, under licence to CSIRO, is proceeding but expansion of the Organization's research is necessary to protect Australia's present technology lead.

Further studies, including a forthcoming subject review of materials science research, will determine which other advanced materials research opportunities will receive increased attention from CSIRO. Possibilities include the use of inorganic fibres to reinforce metals, especially aluminium; the use of cellulosic fibres to reinforce plastics and cement board; the development of sintered products and ceramics other than PSZ; the development of glassy metals and other amorphous materials; and the development of polymers for application in many industries.

Biotechnology

Biotechnology, although not applicable exclusively to manufacturing industry, has been identified as having high potential to contribute to improving manufacturing industry's productivity and efficiency, and to assist in the establishment of new industries.

As well as genetic manipulation of cells to produce new strains of plants or animals, biotechnology encompasses a range of industrial processes based on biological systems involving naturally occurring micro-organisms, micro-organisms that have been modified by genetic engineering, or isolated cells of plants or animals. Areas of biotechnology with prospects for the development of new manufacturing processes include:

- conversion of raw materials such as starch or lignocellulose to high value products;
- production of methanol from natural gas;
- production of vaccines, growth factors and hormones through genetic engineering processes;
- treatment of industrial wastes, including waste water. Examples are anaerobic filtration of high biochemical oxygen demand (BOD) wastes, and the microbial degradation of recalcitrant organic molecules; and
- conversion of raw materials, including conversions of sugars from cane, beet and sweet sorghum; starches from cereal grains, cassava and potatoes; usable substrates from lignocellulosic material; and methanol as a raw material for biotechnological production of a wide range of high value chemical including methane, ethanol and volatile fatty acids. Lignocellulosic and carbohydrate materials are also potential sources for substitute fuels and feed stock chemicals.

Information Technology

Information is recognized as a resource essential to the effective operation of a nation's or an enterprise's economy. Research related to information technology is conducted already in several CSIRO Divisions including Computing Research, Radiophysics and Manufacturing Technology. The Organization is currently examining areas appropriate for extending and consolidating this research effort, with particular attention being paid to technologies and processes applicable to the needs of Australian industry, including mining, medicine and commerce, as well as manufacturing.

Industrial Application of CSIRO Research Results

In recent years the Organization has increased its interactions with manufacturing industry, both through joint committees with various industry bodies and through specific events such as the CSIRO Executive seminar on 'CSIRO and Australian Manufacturing Industry' held in June 1983. Such interaction will help to improve CSIRO's identification of research needs, industrial awareness and technology transfer processes.

The Organization has given particular attention to ways of improving its technology transfer and technology development activities. In April 1982 a review committee was established to examine CSIRO's commercial activities (see chapter 10).

In parallel with this examination of technology transfer and technology development needs, the Executive decided to establish a body, to be known as SIROTECH, to aid in the development and commercialization of CSIRO's research results. The structure and detailed operating arrangements for SIROTECH, which will be established early in 1983/84, are being finalized. SIROTECH's operations will include the contracting to industry of further development of CSIRO research results, entering into collaborative arrangements with industry for this purpose, and providing advice to CSIRO about Australian industrial scientific and technological requirements and markets. SIROTECH will complement both industry's own activities and Government support for industry that may result from proposals currently being considered in the venture capital area. These concentrate on later phases of the commercialization process.

5. Agriculture

Research Priorities

The outcome of a strategic research planning study of Australian agricultural research needs was described in the CSIRO Annual Report 1981/82. This included a statement of policies and priorities for future research in support of agriculture and a list of research topics which will be accorded priority.

An examination of the Organization's current work in relation to these policies, priorities and topics is under way. The balance between work in support of animal industries and plant industries will be reviewed as part of this examination.

Research for Western Australia

The statement of policies and priorities for agricultural research drew attention to the need to maintain an appropriate regional balance. The nature and extent of the Organization's research effort applicable to the mediterranean climatic regions of Australia, particularly in Western Australia where soil characteristics pose special problems, were to be examined further. At that time the Organization had already established a CSIRO Laboratory for Rural Research (Perth) to focus better its existing rural research effort in Western Australia.

Following completion of this examination, which involved consultations with the Western Australian Department of Agriculture, the University of Western Australia, the Western Australian State Committee and the Advisory Council, the Executive decided to establish a new research group in Western Australia to strengthen its work on long-term implications of cropping practices on soil fertility and soil stability. In particular, research will be directed to studies of water and nutrient movement and root growth in relation to profile characteristics of sand plain and duplex soils; processes of soil nutrient availability; and soil management in relation to these. The projects of the group will be integrated with those existing in the Divisions of Plant Industry and Soils, and the leader of the group will be responsible to the Chiefs of those Divisions.

The group will develop collaborative projects with other CSIRO groups in Western Australia on the relationship between crop and animal research, particularly the role of pasture phase in cropping systems. The group forms part of the CSIRO Laboratory for Rural Research (Perth) referred to above.

Importation of Viruses

The Australian National Animal Health Laboratory (ANAHL), which is nearing completion at Geelong, Victoria, is designed to handle exotic livestock pathogens. The CSIRO Annual Report 1981/82 recorded the Executive's decision to recommend to the Government that live foot and mouth disease (FMD) virus be imported for work at ANAHL prior to an outbreak, once the microbiological security of the laboratory had been proved. It was also decided that producer groups should be consulted prior to importation.

CSIRO assisted the National Farmers' Federation (NFF) to conduct a forum at Geelong in August 1982 to debate issues involved in the importation of live viruses.

In November 1982 the Executive decided that it should seek approval to introduce a number of exotic viruses other than FMD virus immediately following the establishment of the microbiological security of ANAHL.

Work on these viruses would continue for at least one year before the introduction of live FMD virus would be proposed to the Government. CSIRO would therefore not seek permission from Government to introduce FMD virus into ANAHL until at least the latter part of 1985. Even then, a firm decision by the Executive to seek importation would be made in the light of scientific and technical developments at that time, and proceeded with only if necessary for the work of the laboratory.

It was also decided that a number of ANAHL scientists would undertake diagnostic, research and vaccine production training with FMD virus at overseas institutions to improve preparedness for an FMD outbreak prior to any work on the virus at ANAHL.

In December 1982, ASTEC reported to the Government on ANAHL and the importation of exotic animal pathogens. The report was tabled in Parliament in May 1983. It made the following recommendations:

(i) . For each exotic pathogen which is proposed for importation to ANAHL, CSIRO prepare a brief summary of the reasons why importation is sought, as a basis for consultation and discussions;

. the ANAHL Consultative Committee be given the responsibility of providing formal notice of proposed importations of exotic animal pathogens to the National Farmers' Federation, the Australian Veterinary Association and other organizations that it considers appropriate, with a view to obtaining their advice and comments prior to completion of its own deliberations; and

. the advice and comments received by the ANAHL Consultative Committee be transmitted to the Minister for Health as well as to the Executive of CSIRO so that they may be taken into consideration when the Minister's approval is sought for the introduction of exotic animal pathogens.

(ii) Each case proposed by CSIRO for the importation of an exotic animal pathogen should include details of:

. potential benefits for diagnostic preparedness, the procedures accepted internationally for identification of the pathogen, the opportunities for developing new or improved procedures using inactivated reagents, low-virulence strains and nonpathogenic virus models, and the risks associated with manipulation of the pathogen in diagnostic procedures:

. potential benefits for veterinary training, and the additional risks and costs associated with inoculation of cattle, sheep or pigs, the limitations for such training and the availability of other methods of training including attendance at courses and disease outbreaks overseas;

. potential benefits and risks of manufacture and testing of vaccines, including the availability of supplies overseas and potential developments in genetically engineered vaccines and in techniques for testing potency and safety which do not require live pathogens; and

. potential benefits for research, including a broad description of the planned research programs and their objectives, and the associated risks.

(iii) CSIRO nominate exotic pathogens, other than foot and mouth disease virus, considered to be of high priority for early importation to ANAHL following acceptance of its microbiological security, and proceed as soon as practical to prepare individual cases with a view to initiating consultation on the proposals through the ANAHL Consultative Committee and with the Australian Agricultural Council and its committees.

(iv) . Live foot and mouth disease virus not be imported for use at ANAHL for a period of five years, that is, until the end of 1987;

. the research programs of ANAHL give priority to the development of new or improved procedures for the identification of foot and mouth disease virus which do not require access to the live virus;

. as a matter of urgency, CSIRO initiate discussions with appropriate authorities with a view to locating for an agreed period, and with appropriate costs borne by Australia, a small ANAHL research group within an overseas animal health laboratory which has access to live foot and mouth disease virus;

- when this overseas group is established its main responsibility to be assist in the ANAHL research program, specifically by checking the efficacy of both standard and newly developed procedures and materials in use in Australia using the live virus where appropriate, and by preparing inactivated reagents for use at ANAHL; and
- this arrangement be entered into as soon as possible for an initial period ending three years after completion of the setting-to-work program at ANAHL, and the question of importing the live virus into Australia be re-examined before the end of that period.

In January 1983, the NFF advised the Government that most producer organizations opposed the importation of live FMD virus before an accidental outbreak. The NFF also communicated its support for the general concept of ANAHL and its belief that exotic animal diseases other than FMD virus should be imported for work at ANAHL only after consultation with livestock industries.

The Government's decisions on the ASTEC report are awaited.

Biological Control

A program to control the declared noxious weed Paterson's curse (*Echium plantagineum*, which is also known by the common name Salvation Jane in South Australia) was approved by the Australian Agricultural Council in 1979. CSIRO began experimental field releases of a potential control agent, a moth imported from the mediterranean homeland of the weed, in 1980. It appears that none of these releases led to the establishment of surviving populations of the insect. Shortly after the program was begun four plaintiffs, two beekeepers and two graziers, succeeded in obtaining from the High Court an interim injunction preventing CSIRO from continuing with the program.

After protracted legal negotiations, the proceedings were settled before the Supreme Court of South Australia in June 1983. Under the settlement, CSIRO submitted to a permanent injunction restraining it from continuing with the program, but with liberty to apply back to the court. The latter provision was intended to cover the situation if subsequent legislation were to come into force positively authorizing the program.

The outcome of this case has serious implications for biological control programs generally. It disclosed that in certain situations programs can be stopped by persons whose property interests may be adversely affected, notwithstanding that the program is likely to be of great national benefit. The Australian Agricultural Council, at its meeting in February 1983, established a working party to examine the need for legislation to make it possible for biological control programs to proceed in such instances. The Council expects to consider the report of its working party at its meeting in August 1983.

6. Research planning and reviews

Strategic planning studies, subject reviews and Divisional reviews together provide the main mechanisms for determining CSIRO's research priorities. In addition, Divisional reviews evaluate research that has been carried out over a period, usually five to seven years, and the management performance of the Chief or Officer-in-Charge. These reviews are timed to fall towards the end of the term of appointment of the Chief or Officer-in-Charge so that, where necessary, management arrangements can be readily revised. This chapter describes some general matters regarding these studies and reviews, and records specific activities that took place during the reporting year.

Planning Studies

Following decisions by the Government in 1977 on the report of the Independent Inquiry into CSIRO, formal strategic planning procedures were introduced. These procedures were described in detail in the 1979/80 and 1980/81 annual reports. Briefly, they involve a progressive examination of national research needs in sub-sectors of the Classification of CSIRO Research and the matching of these needs to scientific opportunities. The latter are the opportunities to contribute to the solution of identified national problems or areas of potential industrial growth or community welfare through the generation of new scientific knowledge.

Using these procedures, the sub-sectors of energy, water resources and agriculture have been studied. In addition, a study on manufacturing industry is well advanced and work has begun on all other sub-sectors of the Classification. It is expected that all of these studies will have been completed by mid-1984.

The Executive also expects to commission a review of its total planning procedures late in 1983.

Subject and Divisional Reviews

Subject reviews complement strategic planning studies by concentrating on more specific areas of national need or scientific opportunity. Divisional reviews include examinations of both Divisions and independent research Units. Table 5 shows the subject and Divisional reviews that have taken place since the passage of the Science and Industry Research Amendment Act in 1978.

A feature of recent reviews has been the high proportions of people from outside CSIRO on committees. Table 5 shows the subject and Divisional reviews that have taken place since 1978, and Table 6 shows the affiliations of members of the committees established to conduct these reviews. Over this period the proportions of members of review committees that came from outside CSIRO were 75% and 65% for subject and Divisional reviews respectively. In addition, half the chairmen of subject reviews came from outside CSIRO.

The following sections describe the outcomes of the research reviews considered during the reporting year and note other current research reviews.

Table 5 Subject and Divisional Reviews*

Completed Subject Reviews

Atmospheric Sciences
Biotechnology
Forest and Forest-products problems
Agricultural Engineering
Ocean Sciences
Arid and Semi-arid lands (rangelands) research
Plant Pathology is the subject of a current review.

Completed Divisional Reviews

Animal Health
Animal Production
Australian Numerical Meteorology Research Centre
Applied Geomechanics/Mineral Engineering
Applied Physics (National Measurement Laboratory)
Building Research
Chemical Technology/Wood Science
Cloud Physics
Mechanical Engineering
Entomology
Dairy Research Laboratory
Food Research
Irrigation Research
Mathematics and Statistics
Radiophysics
Soils
Textile Industry
Wheat Research
Wildlife Research
Fossil Fuels
Land Resources Management/Land Use Research

Current Reviews of Divisions and Units

Computing Research
Materials Science
Molecular and Cellular Biology/Protein Chemistry
Mineralogy/Mineral Physics
Textile Physics
Human Nutrition

* The review of arid and semi-arid (rangelands) research, reported later in this chapter, is not included because it did not form part of the Executive's normal review processes. It was carried out by an internal working group as a supplement to the reviews of Land Resources Management and Land Use Research.

Table 6 Numbers and Affiliations of Members of Review Committees

	Subject	Divisional	Total
CSIRO	7 (25%)	45 (35%)	52 (33%)
Non-CSIRO			
Advisory Council/State Committee	—	6 (5%)	6 (4%)
Australian University	7 (25%)	30 (23%)	37 (24%)
Overseas	6 (22%)	18 (14%)	24 (15%)
Industry	4 (14%)	17 (13%)	21 (13%)
Government	4 (14%)	13 (10%)	17 (11%)
Non-CSIRO Total	21 (75%)	84 (65%)	105 (67%)
Total Membership	28	129	157

Completed Subject Reviews

Atmospheric Science

Following consideration of the report of the reviewing committee the Division of Cloud Physics (see the CSIRO Annual Report 1980/81), the Executive decided to defer a decision on the future of the Division pending a wide-ranging review of atmospheric science research in CSIRO. Two additional significant elements in the Executive's decision to establish this review were:

- the agreement between CSIRO and the Department of Science and Technology to rationalize meteorological research in CSIRO and the Bureau of Meteorology; and
- the foreshadowed closure (by 1985) of the Australian Numerical Meteorology Research Centre (ANMRC) as a consequence of a recommendation of the Review of Commonwealth Functions.

Amongst its tasks, the committee reviewing atmospheric science was asked to examine the present objectives of the Division of Atmospheric Physics, the extent to which they were being achieved, the quality of the Division's research and other activities, and its relations with other bodies. It was also asked to advise on the appropriate role for CSIRO in atmospheric science, taking into account the activities of other bodies, and to advise on the optimal distribution of resources devoted to CSIRO's atmospheric science research and the appropriate organizational arrangements for this research.

The review committee, in its report, emphasized the strong scientific and practical considerations which indicated an extensive and high quality Australian involvement in atmospheric science.

Weather and climate affect almost all aspects of national and personal life, for instance transport, exploitation of resources, design of buildings and public works, energy production and needs, air quality and pollution control, tourism, and personal health and comfort. Agricultural and pastoral production, major elements in the national economy, are especially vulnerable to extremes of climate and weather, particularly drought and flood.

In addition to these national considerations, Australia, as one of the major developed and politically stable countries in the southern hemisphere, has responsibilities to the world community for undertaking weather and climate research.

Against this background, the committee saw CSIRO as having a major and continuing role in atmospheric research. The Executive affirmed CSIRO's role in the following terms:

> 'CSIRO's primary role in atmospheric sciences will be to carry out research into physical and chemical aspects of atmospheric processes and phenomena, especially basic aspects and those related to environmental and industrial problems and community needs.'

The Executive adopted the committee's major organizational recommendation of an amalgamation of the Division of Atmospheric Physics and Cloud Physics and the CSIRO component of ANMRC into a new Division of Atmospheric Research to be based at Aspendale, Victoria. The Divisions of Atmospheric Physics and Cloud Physics have been amalgamated already, and elements of the ANMRC will be incorporated on the formation of the Bureau of Meteorology Research Centre.

The new Division will undertake research into dynamics, radiation, cloud physics (including cloud dynamics), air/sea interaction, climate, atmospheric chemistry and transport, and applied meteorology. Work will be directed to investigating a few selected topics in depth, and will not range broadly across the whole field encompassed by each of the foregoing areas.

The Executive has further decided that the new Division should:

- Recognize the role of the Bureau of Meteorology and cooperate with the Bureau. Accordingly, the current involvement of CSIRO scientists in numerical weather predictions directed to operational forecasting will cease on the disbandment of the ANMRC. Also, climate research in the new Division will be directed towards elucidating physical and dynamical processes and mechanisms.

- Actively involve the Division of Fossil Fuels in chemical aspects of any work on urban pollution.
- Actively involve the Division of Environmental Mechanics in any work on boundary-layer processes, noting that research on micrometeorology and agrometeorology should remain concentrated in that Division. However, the Division of Atmospheric Research should maintain some expertise in this area to support planetary boundary-layer modelling and air/sea interaction work.

It was decided that the solar radiometric standard and the radiometer calibration service should be maintained until transfer to a more appropriate body within Australia.

Following the review, further agreements were reached between CSIRO and the Department of Science and Technology on detailed arrangements for the closure of the ANMRC and the division of its resources between CSIRO and the Bureau of Meteorology. It was also agreed that the ozone monitoring network should be transferred to the Bureau.

Arid and Semi-arid Lands (Rangelands) Research

The arid and semi-arid lands in Australia cover the extensive, sparsely populated centre of the country, encompassing much of the land in five States. CSIRO's role is to provide State and private agencies with the knowledge of how arid and semi-arid lands function, the principles for their management and the methods and techniques that may be applied in that management. CSIRO also has an obligation to initiate original research where new scientific progress can be made and to undertake research on the more complex land management problems. As reported in the CSIRO Annual Report 1981/82, the emphasis of the Organization's arid and semi-arid lands research and the location of the Rangelands Research Unit was investigated as part of the review of the then Division of Land Resources Management, in which the Unit was located.

An internal working group was established to review the Organization's rangelands research. It reported to the Executive in March 1982, and presented a supplementary report in July 1982. In its consideration of these reports, the Executive related the recommendations to the need identified in the Review of the Division of Wildlife Research for means of strengthening botanical work to support adequately the animal research of the Division.

In December 1982, the Executive decided to amalgamate the Rangelands Research Unit and the Division of Wildlife Research to form a Division of Wildlife and Rangelands Research. The amalgamation brings together the complementary skills in the former Division and Unit, thus strengthening CSIRO's overall research ability in the management of wildlife and rangelands.

The new Division's objective is to understand the nature of ecological systems in relation to the management and conservation of Australia's wildlife and land resources. The general aim of the Division's research is to study the ecology of animal and plant populations and to provide information concerning the processes controlling their stability, diversity, productivity and value to Australia. Specific areas of concern are the management of pests and the management of rangelands for sustained productivity.

The Organization assigns a high priority to arid and semi-arid lands research and will strengthen this research within the new Division. The objective of the rangelands research program is to develop methods and establish principles for using and managing arid and semi-arid lands in ways which will maintain their productive potential, stability and value to society. The research will be concentrated on establishing the ecological principles applying to the management of the land, developing methods for monitoring the stability of this land, and identifying the socio-economic factors that influence land management.

Arid and semi-arid lands research is to be based at two locations, one with emphasis on the ecological communities of the south and the other on those of the north. These locations should facilitate access to field sites throughout the arid and semi-arid lands. For the present, however, work will continue to be conducted from Deniliquin, NSW, the site of the former Rangelands Research Centre, but it is planned to relocate this work in Adelaide when suitable facilities are available. Rangelands research work will continue to be conducted from its current location at Alice Springs.

Agricultural Engineering

Over the past 50 years major scientific advances have taken place in Australian agriculture. For the most part these have not been matched by technological changes based on Australian research which would have enabled these advances to be fully implemented. Australia is heavily dependent on imports of agricultural machinery from Europe, and local industry is dominated by overseas-controlled companies. However, Australia is a dry country with fragile soils, and practices and equipment which have been evolved for northern hemisphere countries are rarely appropriate here. Consequently, research into several fields of agricultural engineering is needed to ensure that our level of agricultural production can be sustained.

The Organization receives many requests for assistance across the whole range of diverse problems which may be included in the term 'agricultural engineering'.

The Organization's Agricultural Engineering Group, which previously formed part of the Division of Mechanical Engineering, was transferred after the review of that Division to the Division of Chemical and Wood Technology, where the Executive decided that it should remain as a separately identified group.

In order to consider how the Organization's resources could most profitably be utilized in this area, an internal review was commissioned to advise the Executive on the future of agricultural engineering research and development with CSIRO, and to identify uniquely Australian problems that present strategic research opportunities suitable for CSIRO.

The Executive decided that:

- CSIRO should continue to undertake research in agricultural engineering;
- priority areas in agricultural engineering research for CSIRO were to be in the general field of soil/plant/water interactions, the development of soil manipulative systems suited to Australian conditions, and grain storage;
- the Agricultural Engineering Group should remain intact within the Institute of Industrial Technology and should form a separate Section in the Division of Chemical and Wood Technology;
- current projects on crop preservation, as well as future projects that may be funded by the Wheat Industry Research Council, should be continued, and developed in conjunction with the Division of Entomology; and
- the present externally-funded project on forestry engineering by the Agricultural Engineering Section should be continued until completed.

Completed Reviews of Divisions and Units

Division of Animal Health

The Division of Animal Health's primary role is the development of more cost-effective and less hazardous ways of controlling the major diseases that afflict the livestock industry, particularly in non-tropical Australia. The work entails detailed studies of the causal organisms and their epidemiology and interactions with the host, which may lead to recommendations for modifications in farm practices (for example, to reduce parasite burdens), the development of new or better vaccines, or other novel approaches to disease control.

The Division has also developed more precise tests for diagnosing bovine pleuropneumonia, tuberculosis and brucellosis, which have been of vital importance to the national campaigns to eradicate these diseases (successfully completed in the case of pleuropneumonia and in progress for the other two).

The application of the Division's research results helps to maintain the efficiency and competitiveness of Australia's livestock industries, which generate about a quarter of Australia's export income as well as providing employment, food and fibre locally. The successful eradication of some animal diseases is necessary for maintaining access to certain overseas markets.

A special area of activity in the Division was the development of the Australian National Animal Health Laboratory (ANAHL), a maximum security laboratory built to handle exotic animal pathogens as part of Australia's preparation for exotic disease emergencies.

As recorded in the CSIRO Annual Report 1981/82, a review of the Division of Animal Health was begun in April 1982. The review committee submitted its report in November 1982. Its recommendations can be grouped into two parts—those related to ANAHL and the import of live exotic animal disease viruses for use at the Laboratory, and those concerned with the remaining programs of the Division.

In March 1983 the Executive took decisions on the majority of the committee's recommendations but deferred consideration of all but one of the recommendations concerning ANAHL and the import of live exotic viruses. This action was taken pending development by the Government of its views on the live virus import issue and the provision of resources for the operation of the Laboratory.

The Executive's main decisions, based on the review committee's recommendations, were:

- that the Division of Animal Health should remain a Division within the Institute of Animal and Food Sciences. The Division is to concentrate its research on the major diseases of sheep and cattle (that is, sheep blowfly strike, worms and ovine footrot) and pig and poultry diseases, with emphasis on an immunological approach;
- that it would be desirable for the new Chief of the Division of Animal Health to have a background in parasitology or immunology. In consultation with the new Chief, consideration was to be given to relocating the Division's Headquarters at the McMaster Laboratory, Sydney,
- that ANAHL should be separated from the Division of Animal Health and should become an independent Laboratory within the Institute of Animal and Food Sciences. It also decided that the present Officer-in-Charge should be appointed Officer-in-Charge of the Laboratory until the completion of his present term of office in November 1984.

Division of Fossil Fuels and Fossil Fuels Research

As recorded in the CSIRO Annual Report 1981/82, a review was undertaken of the Division of Fossil Fuels in advance of the expiry of the seven-year term of appointment of the Chief. The review also encompassed fossil fuels research in CSIRO, which embraced research carried out by all Divisions in the Institute of Energy and Earth Resources, in particular the Divisions of Fossil Fuels, Energy Chemistry, Mineralogy, and Mineral Chemistry, and the Physical Technology Unit, by the Division of Materials Science in the Institute of Physical Sciences, and by the Division of Applied Organic Chemistry in the Institute of Industrial Technology.

The Executive agreed with the review committee's assessed need for better coordination of fossil fuels research. It decided that the Division of Fossil Fuels and the Physical Technology Unit should be amalgamated from 1 January 1984, and that the Director of the Institute of Energy and Earth Resources should establish, under his chairmanship, a Fossil Fuels Research Coordinating Committee. The Committee should be responsible for:

- reviewing regularly fossil fuels research programs on an Institute basis;
- ensuring that related fossil fuels research in a number of Divisions of the Institute is complementary and properly coordinated;
- advising where necessary, on the appropriate location and Divisional affiliations of aspects of fossil fuels research; and
- establishing where appropriate, task forces under a leader with responsibility and authority to

direct the research effort on a particular topic in two or more Divisions.

The Executive noted suggestions that the main thrust of the research in the Division of Fossil Fuels should be in establishing fundamental principles. It decided that the respective roles of CSIRO and industry in fossil fuels research should be that CSIRO would concentrate on strategic research investigating fundamental scientific problems, with industry largely responsible for the associated tactical research and development. Industry organizations exist to carry out these latter activities.

The Executive's decisions on the review committee's main recommendations were:

- first priority in the Division of Fossil Fuels should be given to ensuring the continuity of work in the coals characterization section;
- to establish a strong effort on oil shale characterization in the Division of Fossil Fuels as part of the major Institute program on oil shale research; and
- work on iron ore projects should be concentrated on developing new conceptual scientific advances, and should be transferred to the Division of Mineral Engineering at the earliest opportunity.

Subject Review in Progress

Plant Pathology

Plant diseases are a major limiting factor to increasing Australian agricultural production, resulting in an estimated loss of 12% each year.

Since the 1970s there have been considerable changes in the range of agricultural, horticultural and forestry species grown and in management systems and land uses. Consequently, we are now experiencing a potential expansion of plant disease occurrence and intensity in Australia.

In spite of heavy costs and all that is currently done to control diseases, there continues to be unacceptable levels of losses of marketable produce.

Large gaps exist in plant disease research in Australia, including the areas of crop loss assessment, genetics of pathogenic organisms, disease epidemiology, mechanisms of fungicidal action, and the detection and transfer of resistance genes into crop plants.

In 1981 plant pathology was designated by the Executive as one of the high priority research areas for expansion. A review of plant pathology was commissioned by the Executive in early 1982 to provide advice on priorities for plant pathology research in the Organization. The review committee, under the chairmanship of Professor B.J. Deverall, University of Sydney, submitted its report, which is now under consideration by the Executive, in February 1983.

Divisional Reviews in Progress

Divisions of Mineralogy and Mineral Physics

The Executive has commissioned a review of the Divisions of Mineralogy and Mineral Physics. The review committee will examine:

- The work and management of the two Divisions; and
- The objectives and relative priorities that should be set for the Institute of Energy and Earth Resources' mineral exploration research activities.

In conducting the review, the committee will take into account Government and Organizational policies concerning mineral exploration research and, in particular, to an agreement reached in 1982 between CSIRO and the then Department of National Development and Energy on the respective roles of CSIRO and the Bureau of Mineral Resources, Geology and Geophysics in this field. This agreement was reported on in chapter 7 of the CSIRO Annual Report 1981/82 The Minerals (Exploration) Research Liaison Committee (MERLCO) will be consulted as appropriate.

Review of the Division of Materials Science

The CSIRO Annual Report 1981/82 recorded the establishment of a review of the Division of Materials Science. The review committee has now reported to the Executive. The Executive is considering the report's recommendations and will take decisions on them early in 1983/84.

Review of the Division of Textile Physics

The CSIRO Annual Report 1981/82 advised of the establishment of a review of the Division of Textile Physics. The review committee has now reported to the Executive. The Executive is considering the report's recommendations and will take decisions on them early in 1983/84.

Review of the Division of Protein Chemistry and the Molecular and Cellular Biology Unit

The CSIRO Annual Report 1981/82 advised of the establishment of a review of the Division of Protein Chemistry and the Molecular and Cellular Biology Unit. The review committee has now reported to the Executive. The Executive is considering the report's recommendations and will take decisions on them early in 1983/84.

Review of the Division of Computing Research

The CSIRO Annual Report 1981/82 reported the establishment of a review of the Division of Computing Research. The review committee is expected to report to the Executive shortly. The Executive will consider the report's recommendations and take decisions on them in mid-1983/84.

Review of the Division of Human Nutrition

A committee was established in July 1982 to review the Division of Human Nutrition prior to the end of the Chief's term of office. This review is continuing. Executive consideration is expected to take place in mid 1983/84.

7. Australia Telescope

One of the fields of scientific endeavour in which Australia is internationally renowned is radio astronomy, the exploration of the universe by means of radio telescopes. The construction of innovative radio telescopes and the development of their role in unravelling the secrets of the universe were pioneered by Australian scientists following their wartime effort in the development of radar. The outstanding achievements of the scientists brought great prestige to Australia and led, in the 1960s, to the construction of several fine radio telescopes, some financed with major contributions from USA funds: the Parkes 64-m telescope, completed in 1961; the 1.6-km Molonglo Cross array, completed in 1965 and recently upgraded; the Culgoora radioheliograph for studying emissions from the sun, completed in 1967; and the Fleurs synthesis telescope, commissioned in 1973.

Even 20 years after its commissioning the Parkes radio telescope is still making major new discoveries. For example, the most distant known quasar PKS 2000-330 was found first with the Parkes telescope. However, this telescope can no longer satisfy many of the needs of current astronomy, in contrast to new installations in Europe, the USA, USSR and Japan. By the turn of the century it is probable that the observational requirements of radio astronomers will be beyond the capabilities of all current Australian radio telescopes. For example, astronomers will need to look at wavelengths which these telescopes cannot receive or at detail they cannot resolve.

In 1975, a group of scientists from CSIRO and the Australian universities formed a national steering committee to develop a proposal for a modern radio telescope. In 1982 this proposal was considered by the Commonwealth Government as a project to celebrate Australia's bicentennial year and funding was approved to the extent of $25 million, at January 1982 values, with $820,000 allocated for the 1982/83 financial year. In March 1983, the new Government indicated that it would continue to support the project, now known as the Australia Telescope. Responsibility for the construction of the Australia Telescope as a national facility was given to CSIRO, and in particular to the Division of Radiophysics. A Scientific Objectives Committee with wide representation from the Australian astronomical community has considered the scientific priorities whilst an Advisory Committee, including overseas advisers, has assisted in defining the overall project. Based on the deliberations of these committees and design studies on the antennas by a firm of engineering consultants, the optimum location and size of the antennas has been determined. These details are (April 1983) being documented for presentation to the Parliamentary Public Works Committee later in 1983. Provided that this Committee reports its satisfaction with the project, it is expected that the Australia Telescope will be operational in 1988.

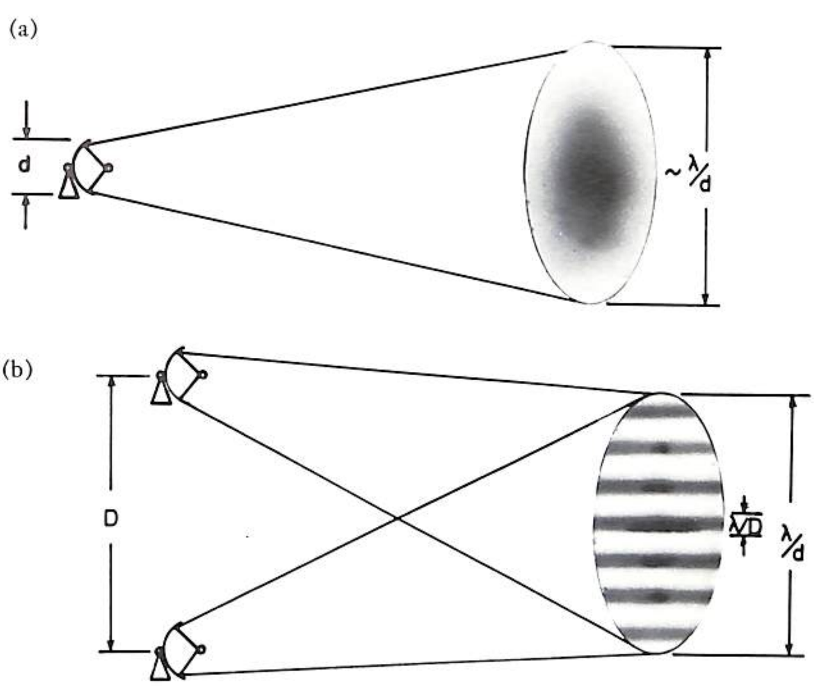
The progress of much of science, and of astronomy in particular, is determined by the sensitivity and resolution of the instruments that are used. In astronomical terms, sensitivity represents the ability to detect or observe faint objects. For example, fainter stars can be seen with a telescope than with the naked eye and, by using a camera on the telescope, still fainter stars can be detected. Resolution represents the ability to distinguish between two adjacent objects. At low resolution, objects are blurred and detail cannot be distinguished; as the resolution is improved so is the detail of the image. The sensitivity of a telescope is determined by the area of its aperture and by the quality of its detector. Resolution is fundamentally limited by the size of the telescope and in particular by the diameter of its aperture in wavelengths of the radiation being detected. For filled aperture telescopes such as the Parkes radio telescope, doubling the diameter of the telescope doubles the resolution while the sensitivity, which depends on the area, is quadrupled.

While the diameter of the telescope is a fundamental limitation on its resolution, there are many other practical limitations. The resolution of optical telescopes, for example, is limited by turbulence in the atmosphere. The maximum resolution attainable by earth-bound optical telescopes is about one arc second which is equivalent to being able to see the Sydney GPO clock from Canberra or see a suburban shopping centre from the moon. Since the resolution also depends on the wavelength of the radiation being observed, a radio telescope operating at a wavelength of 3 cm would need to be 6 km in diameter to achieve the same resolution of details. By comparison, the Parkes radio telescope is only 64 m in diameter.

How can such large antennas be achieved? Clearly not by building a single dish. However, by combining the signals received by several antennas, an aperture as large as their separation can be synthesized. In this way the resolution of a telescope can be improved by a very large factor while the sensitivity (which is proportional to the total collecting area), is improved by a more modest factor. To see how the synthesis method works we start by considering just a single antenna. When this is aimed at a point in the sky, it collects radiation not just from that point, but from a circular region of sky, as in Fig 1a. This region is in fact a cone, whose vertex angle depends on the diameter of the antenna and determines the resolution of the telescope. Also, not all parts of the circular region have their radiation collected equally efficiently; the efficiency falls off from the centre towards the edge as indicated by the shading in Fig 1a. This pattern is known as the 'beam' of the antenna.

If we now take two similar antennas aimed at the same point in the sky and combine their signals in an appropriate way, the beam is changed as shown in Fig 1b. Here we see first that the envelope of the pattern is the same as that in Fig 1a for a single antenna. However, within this envelope there is structure, in fact an interference pattern, that results when the signals from the two antennas are combined. The angular scale of the structure is determined by the separation of the antennas, D, and the wavelength of the radiation, λ, and its orientation by the orientation of the antennas. Larger spacings result in finer interference structure.

Figure 1. Schematic diagram illustrating the principles of earth-rotation synthesis.



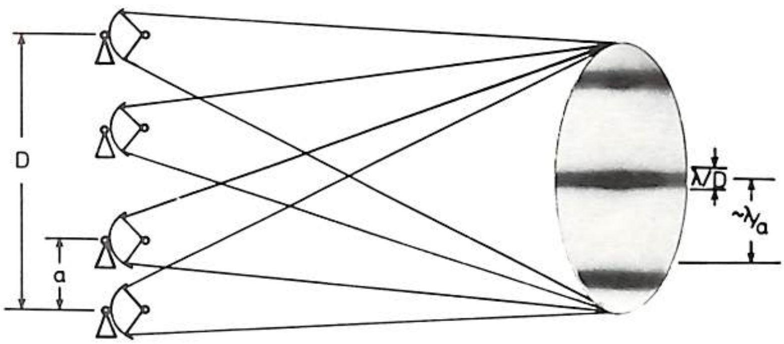
A single antenna collects radiation from a region of sky with an efficiency indicated by the shading. This pattern is known as the primary beam of the antenna.

If two antennas are aimed at the same point and their signals combined, the primary beam is modulated by an interference pattern.

If we look at the sky with a beam of the form of Fig 1b, we will obtain a very strange view of the objects we study. Considerable information can be extracted from observations with just two antennas, but such a system does not have a very 'clean' beam, that is, there are many directions from which radiation is collected with almost equal efficiency. If we place several more antennas in our array, the beam is improved in that the ratio of spacing to width of the interference fringes is increased as illustrated in Fig 1c. This beam is improved over that in Fig 1b, but is still not adequate to form an image of the sky since it has high resolution in only one direction.

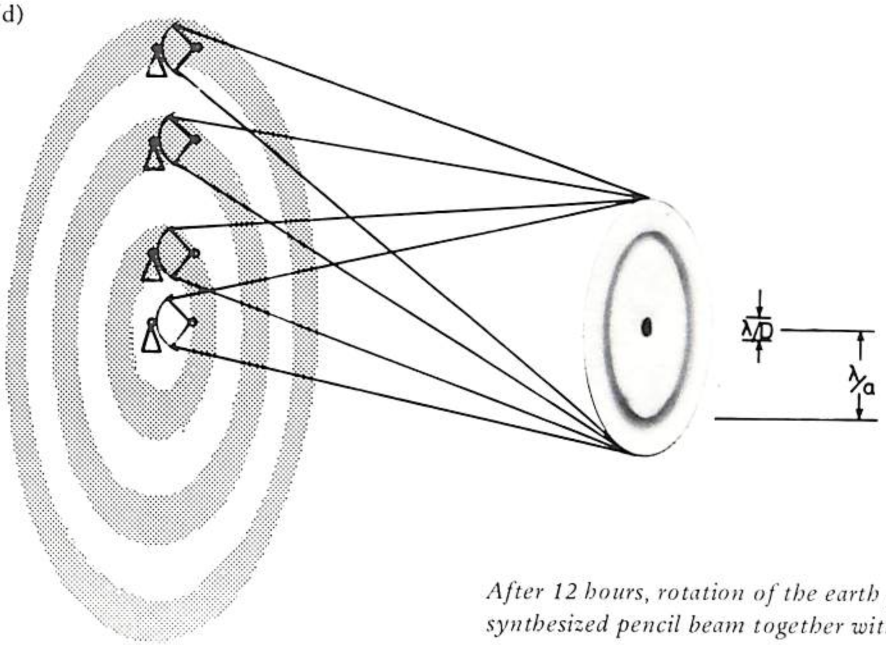
A beam which has high resolution in all directions could be formed by combining signals from a two-dimensional array of antennas as is done, for example, at the CSIRO's radio heliograph at Culgoora. This instrument has 96 antennas arranged around a circle of diameter 3 km and produces a circular beam. However, modern high-performance antennas and receivers are expensive and this solution is not practical for a general purpose radio telescope. Fortunately there is an alternative solution known as *earth-rotation synthesis*. If the antenna array shown in Fig 1c

(c)



With an array of antennas, the spacing between the interference fringes is increased.

(d)



After 12 hours, rotation of the earth produces a synthesized pencil beam together with a grating ring.

were to track a given point on the sky for 12 hours, the orientation of the interference pattern on the sky would change as the earth rotated. Summation of the signals produced during this period would result in a circular, relatively clean beam pattern of high resolution as illustrated in Fig 1d.

The quality of such a beam is largely determined by the number of different *baselines* or antenna separations which are available. It is important to note that it is only the *relative* positions of the antennas, not their absolute positions, which is important. For an array of N antennas there are a total of N(N-1)/2 independent baselines. For example, with four antennas, six different antenna separations can be obtained. One can improve the quality of the beam still further by moving the antennas to different relative locations, so that a new set of baselines is obtained, and observing for a further 12 hours. This process can of course be repeated until a satisfactory number of baselines is obtained.

This technique of earth-rotation synthesis will be exploited by the Australia Telescope. As proposed, the Australia Telescope consists of two separate arrays, the *compact array* consisting of six antennas along an east-west line at Culgoora, and the *long baseline array* in which the antennas of the compact array are linked to a similar antenna at or near Siding Spring Observatory and the Parkes 64-m radio telescope. It is likely that one of the NASA antennas at Tidbinbilla near Canberra will be linked into the long baseline array for much of the time giving a maximum baseline, and hence effective aperture diameter, of 570 km. This is made possible by the fact that NASA is contructing a microwave radio link between Tidbinbilla and Parkes as part of the instrumentation required for the Voyager fly-by of Uranus in 1986. Fig 2 illustrates the proposed configuration. In the compact array five of the antennas are mounted on a 3 km section of rail track and can be moved to various 'stations' located along this track. The sixth antenna is located on a short section of track a further 3 km away giving a maximum baseline of 6 km. The new antennas will be 22 m in diameter and capable of operating at frequencies between 400 MHz and 50 GHz corresponding to wavelengths of 75 cm and 7 mm respectively. Fig 3 shows the prototype design for the antenna resulting from a design study undertaken by the engineering consultants Macdonald, Wagner and Priddle of Sydney. At the shortest wavelength, 7 mm, the resolution of the compact array will be 0.2 arc seconds, better than can be obtained with ground-based optical telescopes. A representation of the beam pattern obtained for the compact array after five 12-hour observing periods is shown in Fig 4. The resolution of the long baseline array will be one hundred times greater, only 0.002 arc seconds at a wavelength of 7 mm, equivalent to being able to see the Sydney GPO clock, not from Canberra, but from the moon. By comparison, an optical telescope with the same resolution would have to be 50 m in diameter, ten times bigger than the 200-inch telescope at Mt. Palomar, and, moreover, situated in space. The capabilities of the Australia Telescope are enormous. They could be extended still further by linking in other antennas at different locations in Australia, for example, between Culgoora and Siding Spring and, to give larger baselines, in Tasmania and Western Australia. With such an array one could synthesize a telescope as big as Australia itself!

Having described the Australia Telescope and its principles of operation in some detail, we now address two questions: first, what astronomy will be done with it and second, what benefits, other than astronomical, will Australia derive?

The Australia Telescope will have the power, not only to complement observations by ground-based telescopes such as the Anglo-Australian Telescope, a 4-m diameter optical telescope located on Siding Spring mountain, but to complement observations by telescopes in space. A large telescope, the Space Telescope, 2.4 m in diameter, observing at optical and ultra-violet wavelengths with a resolution of about 0.1 arc seconds, is expected to be launched in 1986 by a United States-European consortium. Other orbiting telescopes, observing in wavelength bands not accessible from the earth such as the infrared and X-ray bands, are proposed for launch around the beginning of the next decade. Much of the recent progress in astrophysics has come by combining and comparing observations made in different wavelength bands such as the radio and X-ray bands, and the Australia Telescope will play a vital role in future work of this type.

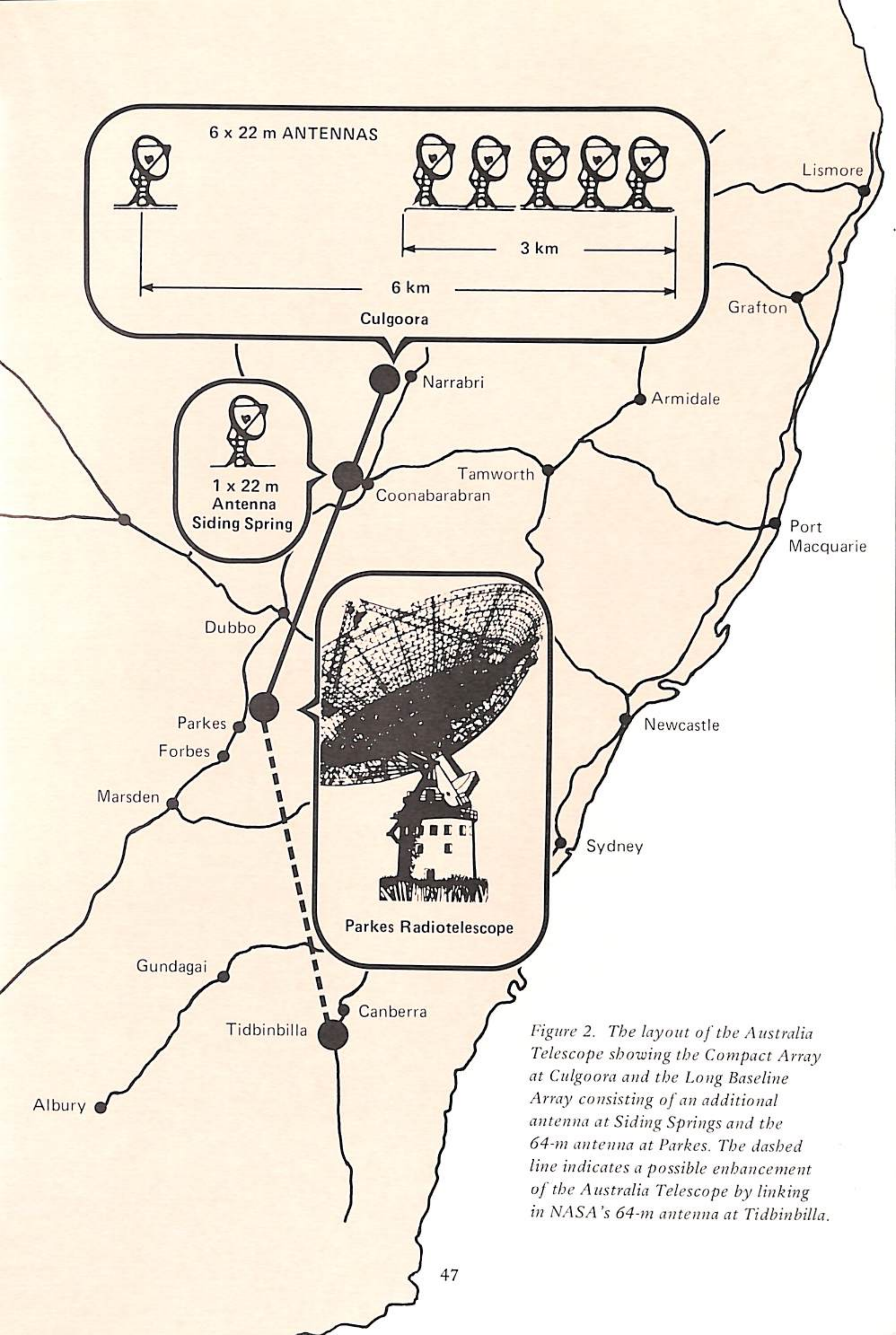


Figure 2. The layout of the Australia Telescope showing the Compact Array at Culgoora and the Long Baseline Array consisting of an additional antenna at Siding Springs and the 64-m antenna at Parkes. The dashed line indicates a possible enhancement of the Australia Telescope by linking in NASA's 64-m antenna at Tidbinbilla.

Figure 3. A model of a preliminary design for the 22-m antenna.

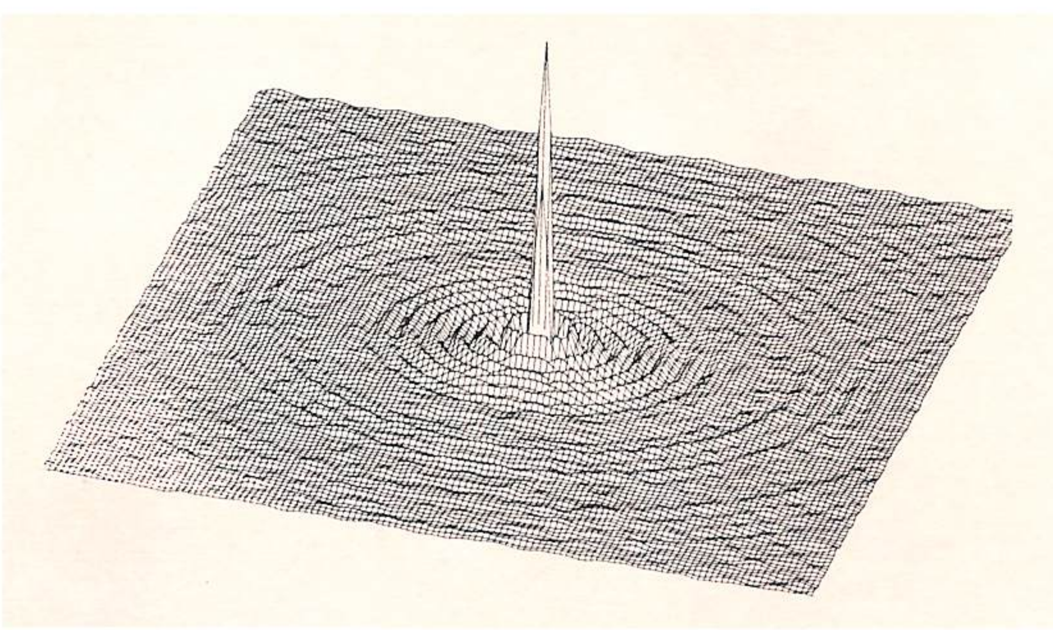


Figure 4. A representation of the beam pattern (cf Fig. 1(d)) obtained from the Compact Array after five 12-hour observing periods.

A property of the Australia Telescope that is not and cannot be duplicated by other major radio astronomical centres is its ability to observe the southern sky. The southern sky is particularly well endowed with interesting astronomical objects. The centre of our own galaxy, the Milky Way, passes almost overhead in New South Wales and the Australia Telescope is uniquely situated to be able to make detailed observations of it. So far south that no northern hemisphere observatory can see them are the Magellanic Clouds, the nearest external galaxies to our own. The nearest star, Alpha-Centauri, and the nearest radio galaxy, Centaurus A, are both in the southern hemisphere.

The centre of our galaxy is a very strong source of radio waves and the location of dense and fast moving clouds of interstellar gas. There is evidence for high velocity ejection of gas from the nuclear regions. The energy source for all of this activity is not currently understood. Other astronomical objects such as maser sources, very intense sources of spectral line emission associated with certain types of stars and protostars, and pulsars, extremely compact stars, believed to be the end-point of stellar evolution, which emit radio radiation in the form of a periodic train of pulses, are concentrated towards the galactic centre. Clouds of interstellar dust and gas are more numerous towards the galactic centre; in these clouds, which cannot be penetrated by optical and ultra-violet telescopes, stars are born and extra-terrestrial life may be created.

The Magellanic Clouds have played an important part in astronomy, largely because they are an isolated system at a known distance. Comparison of objects in the Clouds with similar objects in our and other galaxies allows calibration of distances, sizes and luminosities in a relatively unambiguous way. For example, recent studies at X-ray and radio frequencies of supernova remnants (the massive expanding clouds of very hot gas created when a star explodes), in the Magellanic Clouds have added considerably to our understanding of the evolution of these objects.

One of the strengths of the Australia Telescope will be its ability to produce radio images of the sky on many different angular scales, that is, to zoom in from a broad picture to study fine detail of the image. The compact array will have a field of view more than a degree across enabling maps to be made of large scale sources such as nearby radio galaxies. In galaxies such as Centaurus A the radio emission extends far beyond the optical image of the galaxy. The long baseline array will be able to probe right into the core of such galaxies giving a detailed picture of the centre of activity. Our understanding of the source of all this activity in the nucleii of galaxies and quasars is very incomplete; to improve this understanding is one of the major challenges in current astrophysics. Fig 5 shows a composite image of the radio galaxy NGC 6251 obtained with three different radio telescopes illustrating the power of this technique. The ability to make images on all of these scales with a single instrument will be unique to the Australia Telescope.

Hydrogen is the most abundant element in the universe. Radio astronomy has a unique and powerful tool in the spectral line emitted by neutral hydrogen at a wavelength of 21 cm corresponding to a frequency of 1.4 GHz. Using this spectral line, radio astronomers can map the distribution of hydrogen, for example in spiral galaxies. By measuring the difference between the observed frequency of the line and the known rest frequency, the velocity of the emitting gas can be determined from the Doppler relation. In this way the velocity structure of the emitting gas can also be mapped, leading to a complete dynamical picture of the object under study. Just how the beautiful spiral structure observed in many galaxies, for example the Whirlpool galaxy shown in Fig 6a, originates and is maintained is not currently well understood. This problem is particularly acute in the type of galaxy known as a barred spiral. It so happens that the largest and most spectacular of the barred spirals, for example the galaxy known as NGC 1300 shown in Fig 6b, are in the southern hemisphere.

All of these classes of object will be prime candidates for study by the Australia Telescope. However, the most significant science to come out of the Australia Telescope could well be something that has not been predicted. For with each generation of new instruments, new science has emerged to challenge and add to our understanding of the Cosmos.

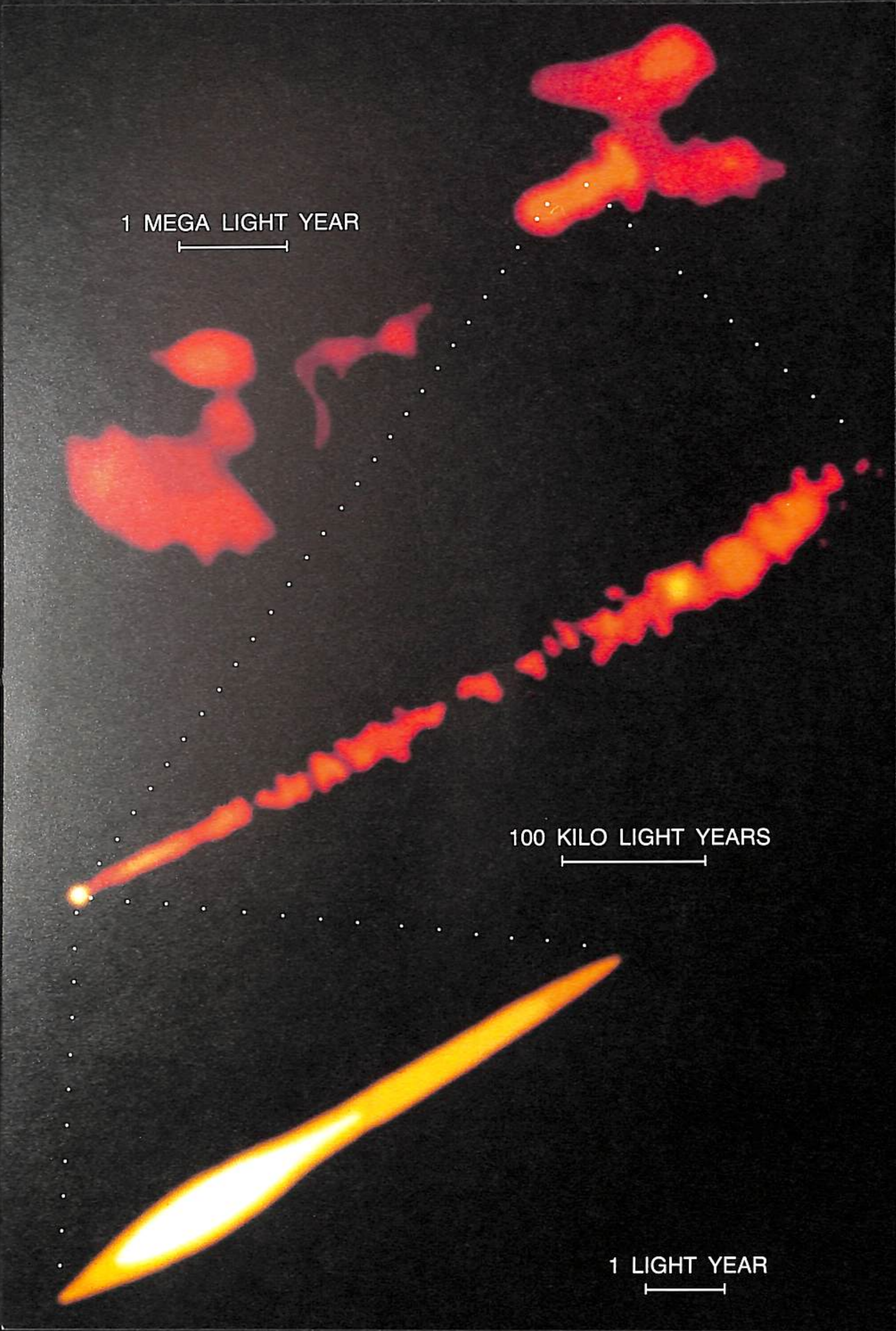

1 MEGA LIGHT YEAR
100 KILO LIGHT YEARS
1 LIGHT YEAR

Figure 5. A composite image in false colour of the radio galaxy NGC 6251 taken with three different radio telescopes with different resolution to illustrate the power of the Australia Telescope's ability to 'zoom'.

At the top, a low resolution map shows the gross structure of the galaxy. The distance scale shown is one million light years.

The second map shows a selected area of the first map, taken at a resolution roughly ten times greater than the first. The distance scale is now one hundred thousand light years.

The bottom map shows a detail from the second map, magnified by a factor of one hundred thousand. The distance scale is now one light year, and the effective 'zoom' from the top map to the bottom is one million to one. The Australia Telescope, operating in the Very Long Baseline mode and connected to antennas around Australia, could achieve this performance. (One light year equals approximately 9.5 million million kilometres.)

Photograph courtesy of California Institute of Technology.

In order to carry out these astronomical measurements to the required accuracy, the locations of the antennas must be known to very high precision. If the position of a radio-source in the sky is already known, the process can be reversed and the positions of the antennas can be deduced. Thus one has a powerful surveying instrument that would, for example, be capable of determining the position of a portable antenna to an accuracy of millimetres over the whole of the Australian continent and even on other continents such as Antarctica. Such geodesic measurements would enable scientists to see how far and in what direction the plates of the earth's crust are moving. The movement of these plates is believed to be a crucial factor in causing earthquakes. Moreover, the knowledge of the fault lines associated with the movement of tectonic plates is useful for mineral and petroleum exploration, because deposits often occur along these fault lines in the earth's crust.

The technology associated with the Australia Telescope is highly innovative and will be of great benefit to Australian industry. The antennas have been the subject of an intensive design study and a very high performance-to-cost ratio has been achieved. The expertise developed will allow highly efficient ground stations for satellite communications to be designed and built in Australia. The antenna feeds will need to be efficient collectors of radiation which accurately maintain the polarization of the incoming radiation over a wide range of frequencies. The techniques used to design feeds for radio astronomy antennas have been applied to upgrade the OTC antennas at Moree and Carnarvon, considerably extending their useful life. Advances in cryogenic receiver technology required for the Australia Telescope will also be of benefit to the telecommunications industry. Data transmission and processing is another aspect of the Australia Telescope where developments will benefit other fields of endeavour. For the compact array, data will be transmitted from the antennas to the central control area via optical fibres of very wide bandwidth. These fibres are just beginning to make an impact in the telecommunications industry. The signal processing will be carried out using digital correlators which make use of a new generation of VLSI design technology being developed by CSIRO. Such VLSI technology is applicable to many areas of electronics. Finally, the techniques of image processing and image display required for the Australia Telescope are closely related to those used in several other areas, including medical imaging, satellite imaging of the earth's surface and geophysical prospecting.

The Australia Telescope is a challenging project which will provide a unique scientific instrument, not only for radio astronomy, its prime purpose, but also for geodesy and geodynamics. The technology that must be developed for the telescope will be Australian and will have applications across a whole range of endeavours from medicine to mining.

Figure 6. Optical photographs of two spiral galaxies: (a) the Whirlpool Galaxy; and (b) a barred spiral galaxy NGC 1300. Questions about the origin of these spiral structures and how they are maintained could be answered by using the Australia Telescope.

8 International aid

CSIRO has been involved in aid and development assistance activities since the 1950s. Major activities have included land-use surveys in Papua New Guinea, the training of Colombo Plan Fellows, and the establishment of the Centre for Animal Research and Development in Indonesia.

The Independent Inquiry into CSIRO in 1977 considered CSIRO's involvement in activities for development assistance and recommended that:

> 'Research activities should also be considered in relation to our international obligations, particularly to developing countries. . . .'

and that:

> 'CSIRO should contribute scientific and technical research to foreign aid programs, whether the work is carried out in Australia or abroad. The consequential funding should be examined in relation to aid programs.'

This recommendation was endorsed by the Government and was reflected in the Science and Industry Research Amendment Act 1978. The latter read in part:

'9. The functions of the Organization are—

(a) to carry out scientific research for any of the following purposes: . . . (iii) contributing to . . . the performance of the . . . the international responsibilities of the Commonwealth;

(c) to act as a means of liaison between Australia and other countries in matters connected with scientific research;

(d) to train, and assist in the training of, research workers in the field of science . . .'

In 1978 the Executive established the Centre for International Research Cooperation (CIRC) to provide a focal point for the Organization's aid and development assistance activities. The terms of reference of the Centre were revised in 1982 following a review of the Organization's international activities and are reproduced in Appendix III.

CSIRO Activities

There are three major categories of CSIRO's aid and development assistance activity:

- participation in aid projects;
- provision of scientific experts for short-term consultancies; and
- training of scientists and technicians in CSIRO laboratories.

Many senior CSIRO scientists also serve on the policy, advisory and management committees of bilateral and multilateral donor agencies such as:

- Consultative Committee for Research and Development (CCRD);
- Australian Development Assistance Bureau (ADAB);
- Australian Centre for International Agricultural Research (ACIAR);
- Consultative Group for International Agricultural Research (CGIAR); and
- United Nations Agencies including FAO and WHO.

The extent of CSIRO's participation in aid programs is based on criteria such as the likely benefits to the recipient country, the relationship of the work to existing programs of research, the existence and availability of appropriate expertise and staff, the availability of resources, and the existing level of outside funding as a proportion of the total funding of the relevant Division.

The demand for CSIRO's participation in development assistance activities is rising but the resources available to fulfil this demand have remained relatively static in recent years. Under these circumstances there is limited leeway for further expansion.

Expenditure on development assistance activities from funds appropriated directly to CSIRO is limited to the salaries and operating costs of CIRC, which totalled approximately $360 000 for 1982/83. During the same period the Organization's involvement on a cost recovery basis in aid-related projects, training and consultancies totalled about $4.5 million. It is expected that this level of activity will continue in 1983/84 and that projects funded by ACIAR will add a further $1 million to the total.

In general CSIRO can make relatively little contribution on a continuing basis to so-called 'grass-roots' aid since this consists primarily of the transfer, adaptation and implementation of well known technologies. This is essentially an extension exercise which can be undertaken more effectively by bodies such as State Departments of Agriculture. However, there is considerable expertise in CSIRO which can be tapped to provide short-term specialist consultants to these programs.

CSIRO makes its main contribution in the introduction of new technologies and in assisting the development of sound research capabilities in third world countries. Many research institutions in such countries lack skills in research management and the setting of priorities. CSIRO can provide assistance in these areas.

Until recently, the involvement of CSIRO in the Australian Government's foreign aid program has been largely responsive. Its activities were undertaken as a result of requests for assistance from ADAB, which itself only acts responsively in its bilateral aid program. This was the policy of the previous Government and also forms the basis for the present Government's approach to development cooperation.

Following its review of international relations in 1982, the Executive decided that CSIRO should adopt a more active approach by identifying areas of research where an expansion of the Organization's normal research programs could make a significant contribution to the benefit of a developing country. In considering such expansions CSIRO takes into account any perception by Australian industry that such research could disadvantage it in world trade by assisting industries in developing countries which may in the future become major competitors. CSIRO will also draw to the attention of funding bodies opportunities it sees for research by other research performing bodies to help overcome problems facing developing countries.

Review of Policy and Internal Arrangements

As mentioned previously, the Executive commissioned a review in 1982 to examine arrangements for the administration of, and the development of policies for, CSIRO's contribution to Australia's aid program, its participation in bilateral and multilateral science agreements, and the conduct of research related to problems experienced by developing countries.

The review committee was required to examine and report on:

- the scope and nature of international activities involving CSIRO now and those likely to arise over the next five years, with particular reference to the likely balance between the operational and policy aspects of these activities; and
- appropriate administrative and organizational arrangements for undertaking these activities.

The principal outcome of Executive considerations of the review report was the adoption of the following policy guidelines for CSIRO's international activities:

- Although it has no direct and primary role in national policy formation, CSIRO has a significant contribution to make to the formulation and execution of national policy on international science and technology. CSIRO's participation in international activities such as aid programs, its cooperation with international organizations such as United Nations agencies and the OECD, and the applications of research in developing countries, is based on the contribution of the expertise, skills and experience of its individual scientists and of the Organization as a whole.
- The extent of CSIRO's participation in aid programs should be based on criteria such as

relevance to existing programs of research, existence of appropriate expertise and staff, cost recovery, the availability of resources relative to existing commitments, and the existing level of outside funding in relation to Divisional core programs. Research for applications in developing countries in particular provides the opportunity for the Organization to adopt an active approach to development assistance as such research can enhance and extend existing programs.

The Executive also adopted Organizational arrangements designed to provide for:

- an Organizational focus to facilitate international relations and the development of policy and procedures;
- the administration and management of international activities;
- operational involvement in projects, consultancies, delegations, visits and training, and in the conduct of research for development; and
- representation at an Organizational level.

9. Use and care of animals in CSIRO

Community interest in animal welfare has increased in recent years and a prime concern relates to the use of animals in research. The aims of such research may include the immediate benefit of the animal itself, the immediate benefit of man, or acquiring a better understanding of man or the animal and the diseases which cause ill health in either. Thus the handling, treatment and observation of experimental animals ranges from intensive studies carried out in cages to those undertaken in the unfenced habitat of native and introduced fauna, and the animals may be wild, domesticated, or specifically-bred.

Animals in CSIRO Research

CSIRO accepts responsibility for the welfare of the animals used in its research programs and has long been involved with improving standards of care of animals. A wide range of animals is used, including the domestic animals—sheep, cattle, pigs, goats and poultry which are the basis of Australia's animal production industries—and laboratory animals such as rats, mice, guinea pigs, marmosets and rabbits. In addition, wild fauna are used in research directed towards their conservation and management.

Most CSIRO research requiring the use of live animals is concerned with animal health and production. Major resources are devoted by CSIRO to the control and prevention of animal diseases, and to research on a wide range of animal husbandry topics including nutrition, reproduction, and management of farm animals, and their adaptation to and survival in Australia's harsh environments. Most of this animal health research is aimed at reducing disease and parasite infestation (and hence avoiding or alleviating suffering) in animal populations, and achieving increased efficiency in animal production. These studies cannot be carried to a conclusion without the use of test animals. For example, before a new vaccine for disease control or an insecticide for sheep blowfly control can be declared safe or efficient, direct tests on animals are required.

CSIRO is not involved with routine testing of cosmetics, human pharmacological agents, household products and addictive narcotics, or with the use of experimental animals for undergraduate teaching of surgical techniques or for vehicle accident studies.

Codes of Practice

CSIRO has been actively involved in the development of various codes of practice, particularly the 1982 revision of the NH & MRC/CSIRO 'Code of Practice for the Care and Use of Animals in Research in Australia'. This Code has been prepared for the higher warm-blooded vertebrates with relatively well developed forebrains which are used in research. These animals apparently experience pain in a manner similar to humans but with a lesser degree of awareness. CSIRO will continue to use this Code as the basis for its practices concerning experimental animals.

Through the Standing Committee of the Australian Agricultural Council, CSIRO has also been actively involved in the development of national codes of practice relating to various aspects of animal husbandry and the handling of animals. CSIRO will continue this activity and expects to adopt relevant codes as they become available.

Legislation

The prevention of cruelty to animals is dealt with on a regional rather than a national basis, and a wide variety of State and Territory departments and instrumentalities are involved in administering the relevant legislation. Apart from the Acts that specifically deal with this matter, relevant isolated clauses appear in a variety of other State and Commonwealth Acts. Aspects of animal welfare are thus covered by many items of legislation which are administered by a variety of Commonwealth, State and Territory departments.

As far as possible CSIRO complies with the standards of conduct or performance required under State laws. Where such standards are not laid down, CSIRO observes its own standards and makes these known to the State administrators responsible for implementing the appropriate Acts. These standards have been derived from the NH & MRC/CSIRO Code which ensures that the animals used for research purposes are treated as humanely as possible. The Organization will, however, consider modifying these standards if they diverge significantly from those of a State. CSIRO will continue to cooperate with States by permitting authorized officials to enter CSIRO premises and observe its experimental animals, and will make available copies of relevant CSIRO policies on request. It will also provide to these officials, on request, the names and locations of CSIRO research workers engaged in animal experiments.

Animal Experimentation Ethics Committee

CSIRO considers that the key to maintaining standards of care for its experimental animals lies with Animal Experimentation Ethics Committees as recommended in the NH & MRC/CSIRO Code. A large proportion of animal research in CSIRO is already subject to examination by such Committees, and Chiefs and Officers-in-Charge will now be responsible for establishing Committees to cover all animal research in CSIRO. On sites where the extent or frequency of animal research activities is insufficient to justify the establishment of a site Committee, the work will be considered by a Committee with regional responsibility.

CSIRO will provide appropriate State authorities with details of the membership of its Animal Experimentation Ethics Committees on request. It will also, on request, provide these authorities with details of, and will participate in discussions on, the experimental techniques endorsed by these Committees.

Conclusion

It is CSIRO's view that adoption of the NH & MRC/CSIRO Code and cognizance of relevant animal welfare legislation by its research workers will help to ensure that pain and distress to experimental animals will be minimized.

10. Management

CSIRO is governed by an Executive of three full-time members and five part-time members. The latter are drawn from primary, secondary and tertiary industries, and from the tertiary education sector. The Chairman, who must be a full-time member, is ex officio the chief executive of the Organization, responsible to the Executive for its day-to-day operation.

The Executive is primarily concerned with:

- the development of policies relating to the scientific and technical direction of the Organization and its internal management;
- relationships with government, advisory bodies and other institutions;
- the definition of broad areas of research;
- the securing and distribution of resources to each area; and
- monitoring the effective performance of the Organization.

The Executive is supported by an Executive Committee comprising the three full-time members of the Executive and the Directors of the Institutes, the Bureau of Scientific Services and the Planning and Evaluation Advisory Unit, assisted by the heads of the three arms of the Organization's central administration.

The research work of the Organization is carried out in five Institutes, each headed by a Director. Institutes are groupings of Divisions and Units with related research interests. The latter are headed by Chiefs and Officers-in-Charge respectively. Divisions and Units are each responsible for a coherent set of research programs, with Units generally being responsible for narrower fields of research and having fewer staff than Divisions.

Directors are responsible to the Executive for the management of their Institutes, with particular emphasis on priorities and objectives for research programs and on organizational arrangements. Chiefs and Officers-in-Charge are responsible to their respective Directors for the management of their Divisions and Units, with particular emphasis on scientific leadership and the day-to-day allocation of resources to achieve agreed objectives. In addition, all Directors, Chiefs and Officers-in-Charge participate through committees and reviews in organizational decision-making beyond the confines of their immediate responsibilities.

A Bureau of Scientific Services, headed by a Director, is responsible for facilitating and promoting the transfer and utilization of technology and scientific and technical information.

A Planning and Evaluation Advisory Unit, headed by a Director, assists the Executive in the development of policies and priorities for the conduct of research.

Policy and administrative support services are provided to members of the Executive and Directors by the Organization's central administration as follows:

- by an Office of the Executive, in respect of broad policy formulation and organizational coordination and development;
- by a Finance and Administration Branch, in respect of the CSIRO budget system, works, buildings and property management services, administrative systems development and the Regional Administrative Offices; and
- by a Personnel Branch, in respect of personnel, industrial relations, pay and conditions, and occupational safety and health policies.

The broad objectives and fields of research or functions of the various CSIRO Institutes and their component Divisions and Units, the Bureau of Scientific Services and the Planning and Evaluation Advisory Unit are given in Appendix III. A more detailed account of the objectives of current CSIRO research may be found in the publication 'Directory of CSIRO Research Programs 1983'.

Ministerial Arrangements

CSIRO reports to Parliament through a Minister appointed for the purpose by the Governor-General, acting with the advice of the Federal Executive Council. In recent years this Minister has been the Minister for Science and Technology.

In March 1983, at the time of the change of government, CSIRO proposed to the Prime Minister Designate that it should report to Parliament through the Prime Minister but with another Minister delegated to assume day-to-day responsibility. It was suggested that the latter would appropriately be the Minister for Science and Technology.

CSIRO is unusual in having responsibilities to carry out research on behalf of a number of Ministries, and the proposal was intended to strength these working relationships while preserving its links with the Science and Technology portfolio. It would have been a return to the arrangement which existed from the formation of CSIR in 1926 until 1966 (including the times when Mr Dedman and Mr [later Lord] Casey were Ministers responsible for CSIRO).

The proposal was not adopted.

Executive and Staff Changes

Executive Changes

Dr W.L. Hughes, CBE, a part-time member of the Executive, retired on 8 September 1982 upon the completion of his second term of appointment.

Mr G.G. Spurling was appointed a part-time member of the Executive for a period of three years, commencing 9 September 1982, following the retirement of Dr Hughes. Mr Spurling is Managing Director of Mitsubishi Motors Australia Limited and has extensive experience in manufacturing industry. Mr Spurling had been a member of the CSIRO South Australian State Committee prior to his appointment to the Executive.

Mr P.D.A. Wright was appointed a part-time member of the Executive for a second term of three years, expiring on 3 February 1986.

Professor D.P. Craig was appointed a part-time member of the Executive for a second term. His appointment extends from 26 March 1983 to 22 December 1984.

Senior Staff Changes

Professor N.H. Fletcher, FAA, Professor of Physics at the University of New England, Armidale, NSW, was appointed Director of the Institute of Physical Sciences for a period of five years from 14 February 1983. He succeeded Dr J.R. Philip, FAA, FRS, whose term as Director of the Institute of Physical Sciences expired on 31 January 1983. Dr Philip resumed his post as Chief, Division of Environmental Mechanics in February 1983.

Dr A.F. Reid, FAA, Chief Research Scientist with the Division of Mineral Chemistry, was appointed Chief, Division of Mineral Engineering for a term of seven years, commencing 1 December 1982.

Dr B.H.G. Brady, Associate Professor of Mining Engineering at the Department of Civil and Mineral Engineering, University of Minnesota, was appointed Chief, Division of Applied Geomechanics (now Geomechanics) for a period of seven years, commencing 21 March 1983.

Dr D.E. Smiles was appointed Chief of the Division of Soils for a seven-year term from 1 January 1983. Dr Smiles replaced Dr A.E. Martin, who completed his term as Chief, Division of Soils, on 31 December 1982. Dr Martin returned to full-time research duties in the Division of Horticultural Research. Prior to this appointment Dr Smiles had been Acting Chief of the Division of Environmental Mechanics.

Dr A.K. Lascelles relinquished his post as Chief of the Division of Animal Health on 31 December 1982. He returned to full-time research duties at the Division's McMaster Laboratory in Sydney. Dr A.D. Donald was appointed Acting Chief of the Division on 1 January 1983.

Dr C.J. Krebs, Chief of the Division of Wildlife Research, was appointed Chief of the new Division of Wildlife and Rangelands Research for a seven-year term, commencing 17 May 1982.

Dr W. Hewertson, Strategic Planning and Feedstocks Adviser, ICI Heavy Chemicals Group, ICI Corporate Laboratory, UK, was appointed Chief of the new Division of Chemical and Wood Technology. The new Division incorporates the old Division of Chemical Technology and the Agricultural Engineering Group which was part of the now-disbanded Division of Mechanical Engineering. Dr Hewertson's appointment is for a period of seven years from 1 February 1983.

Dr T.P. Speed, Head of the Department of Mathematics, University of Western Australia, was appointed Chief, Division of Mathematics and Statistics for a seven-year term, commencing 7 January 1983.

Dr B.S. Harrap was appointed Acting Officer-in-Charge of the Centre for International Research Cooperation (CIRC), following the retirement of Mr A.F. Gurnett-Smith on 2 July 1982. Dr B.K. Filshie, Senior Principal Research Scientist, Division of Entomology, was appointed Officer-in-Charge of CIRC for a period of seven years from 14 March 1983.

Dr C.W. Wrigley was appointed Officer-in-Charge of the Wheat Research Unit following the retirement of Mr E.E. Bond. His appointment is for a seven-year term, commencing 1 January 1983.

Dr R.D. Brock returned to Australia from his posting as Counsellor (Scientific), Tokyo, on 1 September 1982. With his return, the transfer of the scientific liaison function from CSIRO to the Department of Science and Technology became fully effective.

Organizational Changes

The Division of Wildlife Research and the Rangelands Research Unit were amalgamated on 16 December 1982 to form a Division of Wildlife and Rangelands Research within the Institute of Biological Resources.

A Division of Chemical and Wood Technology was formed on 1 February 1983 within the Institute of Industrial Technology. It was established from the former Division of Chemical Technology, which included a section that had previously been transferred from the Division of Building Research, and the Agricultural Engineering Group, which was formerly part of the now disbanded Division of Mechanical Engineering. The Division will include an Industrial Microbiology Section. The decision to establish the Division of Chemical and Wood Technology followed reconsideration of a decision taken in 1981, but which was implemented, to establish a Division of Cellulose Research and an Industrial Microbiology Unit.

The Division of Applied Geomechanics was renamed the Division of Geomechanics on 14 April 1983.

A Division of Atmospheric Research was established within the Institute of Physical Sciences on 18 April 1983 from the former Divisions of Atmospheric Physics and Cloud Physics.

The Australian National Animal Health Laboratory (ANAHL) is to be separated from the Division of Animal Health on 1 July 1983 and formed into an independent research unit within the Institute of Animal and Food Sciences.

Institute Reviews

Institute of Biological Resources

A review of the Institute of Biological Resources was undertaken prior to the retirement of the Director, Mr M.V. Tracey, in August 1983.

The review committee's main recommendations concerning the Institute's structure and functions, which were subsequently endorsed by the Executive, were as follows:

. the Institute's present structure and objectives are to be retained; and

- the Executive will ask the incoming Director to re-assess the balance of research activities in the Institute and report to the Executive within one year.

Institute of Physical Sciences

Towards the end of the term of appointment of Dr J.R. Philip as Director of the Institute of Physical Sciences, the Executive appointed an internal committee to assess the Institute's overall structure, objectives and balance of activities, and to propose any necessary changes for consideration by the Executive.

The review committee reported to the Executive in December 1982. In its report, the committee noted that decisions from a number of other studies would be likely to have implications for the Institute of Physical Sciences. These included the Planning and Evaluation Advisory Unit's planning exercises on CSIRO's manufacturing industry research and on tertiary industry research, the work of the Executive sub-committee developing the Organization's policy for research for manufacturing industry, the reviews of the Divisions of Materials Science and of Computing Research, and the reviews of CSIRO's library and information services and of the Organization's administrative arrangements.

In response to the Institute of Physical Sciences review committee's recommendations, the Executive endorsed the present structure of the Institute and approved amended objectives for the Institute. These objectives appear in Appendix III of this report. The Executive also decided that consultative arrangements between the Institute of Physical Sciences and the Institute of Industrial Technology should be strengthened, with the aim of improving the effectiveness of research conducted for the manufacturing sector of Australian industry.

Administrative Arrangements

The CSIRO Annual Report 1981/82 described the formation of a committee to prepare a new administrative plan for CSIRO.

The committee has consulted widely with the Organization's senior managers, administrative staff and staff associations, and has received over 60 submissions to date. It is developing an administrative plan involving optimal use of modern technology to secure the rapid availability of management information and to improve the efficiency of administrative transactions.

The principal features of the plan include:

- devolution to Divisions of functions involving discretion at the workface;
- development of an integrated management information system; and
- formation of a central processing office to handle a number of functions presently performed in Regional Administrative Offices.

A number of representative task forces have been formed to develop these proposals further so that a comprehensive plan can be submitted to the Executive in December 1983. It is hoped to commence implementing revised administrative arrangements early in 1984.

Review of Library and Information Services

CSIRO's library and information services support the Organization's primary role, the conduct of research, as they provide information and a means for disseminating the information gained or generated in the conduct of research.

Following a review of CSIRO's library and information services, the Executive has restated its policies for the provision of these services within CSIRO and will be restructuring the relevant groups. Also, it was decided that the title Central Information, Library and Editorial Section should be modified to Centre for Information, Library and Editorial Services, which bears the same acronym, CILES. Before details of structure and the responsibilities of senior officers, including those of the Manager, Information Services, are decided, expert advice will be sought.

The proposed new structure will bring together the library services, the computer-based information services and the technical inquiry services in order to improve the information service; publication remains a separate activity.

Consultation and collaboration with library and information agencies (for example, the National Library of Australia, which is the major depository of scientific information in the country, the libraries of Australian universities and government departments, and particularly the Australian Libraries and Information Council) is an important facet of CSIRO's role. The Executive believes that CSIRO should cooperate in the development of nationally integrated library services, using modern technology in order to avoid unnecessary duplication of resources, to facilitate dissemination of information and to promote CSIRO's interests.

Objectives

The objectives of the Centre for Information, Library and Editorial Services will be:

- To provide comprehensive and coordinated library, information and publishing services within CSIRO.
- To facilitate access to CSIRO's library and information services by non-CSIRO users. These services should be based on the Organization's own research, and on its utilization and interpretation of world science and technology gained for application in areas of CSIRO's expertise.
- To cooperate with other library and related organizations, especially the National Library of Australia and the Australian Libraries and Information Council, in the development of a national library network and the facilitation of national resource sharing.
- To apply and, where appropriate, develop traditional and computer-based means by which first-rate library, information and publishing services can be provided.

Review of Internal Audit

The Executive has recently reviewed the Organization's internal audit function to ensure that it provides services to management consistent with modern practice. The CSIRO Internal Audit Charter has been revised and a CSIRO Internal Audit Committee appointed.

Developments in the Organization's approach to the internal audit function are consistent with current trends towards strengthened and enhanced internal management review processes in public undertakings. The new arrangements are also designed to meet the special needs of CSIRO's decentralized style of management.

The new Charter sets out objectives which are aimed at describing the expected outcomes of the internal audit function and the scope of its operation. The Charter specifically precludes the Internal Audit Group from assessing the effectiveness of scientific research programs because of other well-developed processes designed for that purpose.

The Report of the Independent Inquiry into CSIRO led to changes in the management structure of CSIRO which necessitated corresponding changes in the Internal Audit Group's reporting arrangements. The Internal Audit Group is now directly responsible to the Chairman of CSIRO as the chief executive. The Charter includes an appropriately revised reporting scheme.

The Internal Audit Committee comprises representatives from each level of management within the Organization and is chaired by a member of the Executive.

The main features of the new CSIRO Internal Audit Charter follow.

Policy

It is the policy of the Executive of CSIRO to maintain an internal audit function to provide an independent appraisal of the Organization's financial, accounting, and other operations. Internal audit is an element of managerial control which functions by assessing the adequacy of, and measuring and evaluating the effectiveness of, other controls and communicating the results.

Objectives

The scope of internal audit encompasses the measurement and evaluation of the adequacy and effectiveness of the Organization's system of internal control, and quality of performance. This comprehends:

- the reliability and integrity of information, including certification of the Organization's annual financial statements;
- compliance with policies, plans, procedures, laws and regulations;
- the safeguarding of assets;
- the economical and efficient use of resources;
- the accomplishment of established objectives or goals.

Internal audit will not take any responsibility for the assessment of the effectiveness of scientific research programs and policies. The Executive has established review and other processes which are designed to fulfil these requirements.

Relationships

- The Internal Audit Group reports to the Chairman as chief executive. The Chairman may delegate responsibility for day-to-day operations to the Executive Secretary. For administrative purposes, the Internal Audit Group will be located within the Office of the Executive.
- The Internal Audit Group will have full access to the Organization's properties, people and records at reasonable times. An Internal Auditor may require relevant officers to furnish information and explanations in respect of matters which are the subject of audit review.
- An Internal Auditor has no authority to direct officers (other than other Internal Auditors) in the discharge of their duties. However, it is expected that an auditor will offer advice during the course of an audit directed to improving performance.
- Internal audit is only one element of managerial control and the Group is expected to co-operate with other internal or external review groups, both generally and in the performance of the audit program. It is likewise required that the Internal Audit Group be consulted and asked to comment on new and revised administrative policies and procedures prior to their implementation.
- The Auditor-General has, by virtue of the Science and Industry Research Act 1949, a responsibility for the overall audit of the Organization's financial activities. The Internal Audit Group will render all possible assistance to the Auditor-General's Office, including the provision of work plans and access to internal audit working papers.

Implementation

- The audit approach should have regard to the established lines of management authority in the Organization. This applies particularly in respect to follow-up of an audit.
- The Internal Audit Group will adopt the systems-based approach.
- To enable it to achieve its objectives, the Internal Audit Group will prepare an annual plan. The plan will have regard to the assessed requirements to achieve internal audit objectives and will take account of priorities for the areas to be covered. Assessment of auditing priorities will take into account materiality and the views of management as to vulnerable or risk activities.
- Audit programs will be prepared to meet the requirements of the approved audit plan.
- Field work will be performed in accordance with the audit plan and associated programs. Working papers will comply with the CSIRO Internal Audit Manual.

Review of Commercial Activities

The CSIRO Annual Report 1981/82 advised of the establishment of a review of CSIRO's policies, procedures and administrative arrangements for its technology transfer function. The review committee reported to the Executive in May 1983. The Executive is now considering the report's 62 recommendations and will take decisions on them early in 1983/84.

Review of Archives

CSIRO's policy since 1965 has been to keep its own archives rather than to deposit them with the Australian Archives. This involves ensuring that records of permanent value are kept safe, identifiable, retrievable and available in accordance with Freedom of Information and Archives legislation, and the proper disposal of other records.

A review committee was appointed in 1982 with the task of assessing the value of CSIRO's archives and archiving, and the resources required, and advising on the wisdom of CSIRO carrying out its own archiving. It was constituted to represent scientists, historians of science, academia and the archives profession. The report will be considered by the Executive in late 1983.

Freedom of Information

The Freedom of Information Act 1982 came into effect on 1 December 1982. CSIRO established a small Freedom of Information unit to handle requests under the Act for access to documents held by the Organization. Eight such requests were received during the reporting year.

The Freedom of Information Act requires certain information about operations under the Act to be reported in the annual reports of agencies subject to the legislation. Appendix IV sets out this information in respect of CSIRO and the CSIRO Advisory Council.

Separately, CSIRO introduced new guidelines for giving CSIRO staff access to personal information about them held by the Organization. These guidelines are described in Chapter 11.

11. Consultative Council and personnel policies

Consultative Council

The establishment, role and composition of the CSIRO Consultative Council were described in detail in the CSIRO Annual Report 1979/80. The Council was established under section 56 of the Science and Industry Research Act 1949, following amendment of the Act in 1978. The Council's functions are 'to consider, and to report to the Executive on, any matter affecting, or of general interest to, the officers of the Organization, including any such matter that is referred to the Council by the Executive'.

The Council comprises a Chairman who is a full-time member of the Executive; seven other members appointed by the Executive; and eight representatives of staff associations covering the various staff groups in CSIRO. As reflected in these representation arrangements, the Council provides a forum for consultation between staff associations and senior management.

The Council's seventh, eighth and ninth meetings were held in Adelaide, Canberra and Melbourne respectively. The Council normally meets only twice each year, in April and October. However, a special meeting was arranged in February 1983 to discuss the Organization's retirement policy; this topic is covered later in this chapter.

At its seventh meeting, in October 1982, the Council considered the final report of its sub-committee on a CSIRO Amenities Code. The Council had established the sub-committee in April 1981 to examine the existing codes and legislation and to make recommendations on a suitable amenities code for CSIRO. Following recommendations from the Council, the Executive approved the adoption of guidelines for the provision of staff amenities in CSIRO, including personal, first aid, refreshment and recreational facilities. The guidelines also cover special arrangements for handicapped persons.

A sub-committee on the Terms and Conditions of Service finalized draft guidelines for the keeping of personal records on staff. These were subsequently endorsed by the Executive for adoption throughout the Organization. The guidelines are discussed below. This sub-committee also participated in the retirement policy review.

The Council's sub-committees on the Employment of Women and on Technological Change are scheduled to present final reports in October 1983, while the work of the Remote Localities sub-committee is continuing.

Other matters which have been considered by Council include:

- the implementation of staff counselling and personal counselling schemes;
- the ratio of support to professional staff, and the constraints within which the Organization's staff resources are managed;
- the selection and appointment process; and
- occupational safety and health matters.

Access to Personal Records

In November 1982, the Executive adopted guidelines for the keeping of personal records on staff. These guidelines provide the basis for handling routine requests from CSIRO officers for access to, or amendment of, personal records on them held by the Organization. They formalize and consolidate the previous informal arrangements for granting access, and reflect the rights of access and amendment conferred by the Freedom of Information Act 1982. Where a decision under the guidelines is disputed, officers have the right of internal review under the Organization's grievance procedure.

CSIRO's objective in maintaining personal records is to ensure that adequate accurate information is available for its personnel management requirements, while at the same time protecting the legitimate privacy of its officers. In particular, the Organization's guidelines for the keeping of personal records reflect its obligation to:

- minimize intrusion into the private affairs of its officers;
- collect, use and disclose information in a way that is as fair as possible to its officers; and
- safeguard the confidentiality of personal records.

The Organization's procedures for granting access to personal records are in keeping with its philosophy of maintaining open communications with its staff. These procedures include the provision of regular opportunities for staff to obtain counselling on matters of concern to them.

The scope of the guidelines does not extend to requests for access to records generated by external sources or to requests by CSIRO officers for access to information other than their personal records.

Requests lodged under the Freedom of Information Act are processed through the Organization's central Freedom of Information Unit. Details of CSIRO's approach to handling such requests are contained in Appendix IV of this report.

General information on handling requests for access to personal and other records was conveyed to staff through Organization-wide seminars conducted in early 1983.

Occupational Safety and Health

The Organization's approach to occupational safety and health was outlined in the CSIRO Annual Report 1981/82. A key feature of this approach is the ongoing role of Divisional safety officers and safety committees in educating staff and promoting local awareness of safety considerations. The activities of these safety officers and committees are coordinated and monitored at Headquarters. A CSIRO Occupational Safety and Health Policy Committee provides advice to the Executive on the Organization's safety and health policy and programs. Most of these arrangements have been in operation for a number of years and have not been subject to an extensive review for some time. Events during 1982/83 led the Executive to instigate such a review in order to examine the effectiveness of its occupational safety and health policies and procedures throughout the Organization.

Committee of Inquiry

Dr Rinaldo Bergamasco, who had been working at the Division of Applied Organic Chemistry, died in December 1982 from a malignant melanoma. Shortly before his death Dr Bergamasco had publicly expressed concern that the chemical environment in which he had worked had contributed to the lowering of his resistance to the disease. In April 1983 the Minister announced the formation of a Committee of Inquiry into Safety Standards at the CSIRO Applied Organic Chemistry and Advanced Materials Laboratories at Fishermen's Bend, Victoria.

The Committee comprised Professor R.R. Andrew, Director of Medical Education at St Francis Xavier Cabrini Hospital, Victoria (Chairman); Professor L.J. Opit, Department of Social and Preventive Medicine, Monash University; and Professor W.R. Jackson, Department of Organic Chemistry, Monash University. The Committee's report, which was tabled in Parliament on 17 May 1983, indicated that the Committee had not found any evidence to link Dr Bergamasco's death to his occupation or work environment, although it made a number of recommendations on safety matters at the laboratories concerned. When tabling the report, the Minister indicated that the Government would bring down a considered response in the Budget sittings after full consultation with CSIRO.

Review Committee

As safety is an issue of general concern to staff at all CSIRO establishments, the Executive decided that a wider review was desirable. Accordingly, it established a committee with the following membership and terms of reference.

Chairman

Professor D.P. Craig, part-time member of the Executive and Professor of Chemistry, Research School of Chemistry, ANU.

Members

Dr P.G. Alfredson, Chief of the Division of Energy Chemistry, and formerly Chief of the AAEC Division of Chemical Technology.

Mr N.J. Betts, Director, Physical Working Environment, Department of Employment and Industrial Relations.

Mr R.D. Bond, Principal Research Scientist, Division of Soils, and Vice-President, CSIRO Officers Association.

Mr B. Cain, Technical Officer, Division of Food Research, and President, CSIRO Technical Association.

Dr K.A. Ferguson, Director, Institute of Animal and Food Sciences, and Chairman of the CSIRO Occupational Safety and Health Policy Committee.

Dr A.J. McMichael, Senior Principal Research Scientist, Division of Human Nutrition, an authority on epidemiological research.

Mr C.W. Peterson, Assistant Research Manager, ICI, and Federal President, National Safety Council of Australia.

Terms of reference

1. To review the Organization's policies and procedures for the management of occupational safety and health matters and to report and make recommendations to the Executive on whether and, if so, how these might be improved.
2. Without restricting the scope of the review, the matters to be examined should include:
   - the policy relating to the allocation of responsibilities between Directors, Chiefs of Divisions and Officers-in-Charge, safety committees, safety officers and supervisors generally;
   - the legal responsibilities of Chiefs of Divisions and Officers-in-Charge and other supervisors, as representatives of the Executive, to ensure the safe practice of research and other work;
   - procedures for the appraisal of accidents and occupational health incidents to ensure adequate precautions are taken to avoid the repetition of such accidents and incidents;
   - procedures for the assessment of, and reporting on, safety and occupational health hazards prior to engaging in new experimental work or the use of new equipment;
   - procedures for reporting to Headquarters, and compiling statistics on, accidents and occupational health incidents;
   - the use of protective clothing and safety equipment and how this might be improved;
   - procedures for the medical screening of staff;
   - procedures for ensuring that the design of new buildings and major alterations satisfy all relevant safety requirements;
   - the coordination and promotion of occupational safety and health activities;
   - the adequacy of staff resources devoted to the above activities.

The Executive has also referred to the committee for its consideration those recommendations of the Andrew Committee of Inquiry which deal with occupational safety and health management. Professor Craig's committee will be consulting with bodies such as the AAEC, the Commonwealth Institute of Health, some universities, companies and the Attorney-General's Department. The committee is due to report to the Executive before the end of October 1983.

Other activities

The Review Committee on occupational safety and health is working in close consultation with the Occupational Safety and Health Policy Committee. This standing committee, chaired by Dr K.A. Ferguson, Director of the Institute of Animal and Food Sciences, provides a medium for consultation between the Organization and staff associations on matters of concern in the safety and health areas. Topics considered in 1982/83 included health checks for officers working in potentially hazardous situations, the operations of Divisional safety and health committees, and the management of stress.

In July 1982, a safety policy review was undertaken with the involvement of the Policy Committee. The review culminated in the issue of a revised statement of CSIRO's occupational safety and health policy and practices. This statement incorporated changes which have been progressively introduced in accordance with the Code of General Principles on Occupational Safety and Health endorsed by the Commonwealth Government.

There are currently over 60 part-time safety officers located at Divisions and Units. They provide advice on general safety and health matters at their individual locations, in accordance with CSIRO's policy and practices. In addition, at many locations there are specially designated safety officers in specific fields or activities such as electrical work, underwater diving, the use of radioisotopes and work with recombinant DNA. At approximately 50 locations Australia-wide the work of safety officers is complemented by local safety committees, frequently with specialist sub-committees responsible for safety in particular spheres. A cross-section of staff is represented on these local committees.

The provision of advice on safety matters by officers with a detailed knowledge of local conditions is consistent with a preventive approach to occupational safety and health. This approach allows for on-the-spot surveillance for potential occupational safety and health problems. Many potential difficulties can be foreseen and forestalled and, in the event that problems do occur, assistance and advice is available locally.

In monitoring the safety and occupational health of CSIRO officers, safety officers and safety committees apply a number of standards which have been adopted by, or apply to, CSIRO. As well as the Code of General Principles on Occupational Safety and Health and relevant subsidiary codes of practice, these include the Standards Association of Australia occupational safety standards and the National Health and Medical Research Council occupational health guides.

Retirement Policy

Chapter 12 of the CSIRO Annual Report 1981/82 recorded the then current review of the Organization's procedures for retirement on the grounds of age and inefficiency. This review, which has since been completed, has involved extensive consultation with staff associations, aimed at ensuring that the Organization's retirement procedures will operate in the most effective and equitable manner possible.

An important feature of these discussions has been the question of voluntary early retirement at age 55 years. The staff associations support the introduction of provisions to enable voluntary early retirement. The Australian Council of Trade Unions encourages the early introduction of such provisions in those areas of Australian Government employment not covered by the Commonwealth Employees (Redeployment and Retirement) Act 1979.

The introduction of voluntary early retirement remains an objective of the Executive. The Executive is prepared to amend the CSIRO Terms and Conditions of Service provided this is consistent with Executive policy.

Guidelines for the Promotion of Research Scientists

The need for clearly defined and documented guidelines for assessing staff for promotion was highlighted in a recommendation of the Independent Inquiry into CSIRO which reported in 1977. In recent years such guidelines have been developed for major staff groups, including experimental officers and technical staff.

During 1982/83, guidelines for the promotion of research staff were finalized on the basis of material agreed in arbitration between CSIRO, the Public Service Board and the CSIRO Officers Association (CSIROOA). The completion of the guidelines followed extensive consultation throughout the Organization and with the CSIROOA. They were also presented to the Advisory Council for comment.

The guidelines comprise detailed descriptions of the role of research scientists, of the distinctions between the grades, and of the criteria for assessing whether a scientist merits promotion. They also give specific guidance on preparing promotion proposals. Existing promotion practices are documented based on the principles agreed in arbitration. At the same time, a particular feature is the emphasis on the equivalence of fundamental research and technological research for industry for the purposes of promotion. Irrespective of the objectives of their programs of research, all research scientists in CSIRO have equal opportunities for advancement. Throughout the guidelines, the emphasis is on the scientists' achievements and their significance, and the degree of originality and innovativeness involved in their work. The evidence of these qualities is not restricted to publications, but depends largely on the nature of the research being undertaken. The guidelines in final form are to be circulated early in the 1983/84 financial year.

Staff Training and Development

In 1982 the Executive decided that a review should be conducted of the Organization's staff training and development needs, and the extent to which these were being met. The review was conducted during 1982/83 by a senior university academic who was engaged as a consultant. He was assisted in this task by a senior staff development executive from a large technology-based private company and by a group of senior CSIRO managers who together formed a steering committee.

In preparing his report, the consultant conducted several surveys within CSIRO to obtain a wide cross-section of views on the effectiveness of current training programs, and on areas which would require greater attention in the future. A number of these surveys concentrated on seeking advice from course participants and their work colleagues on the effectiveness of specific programs.

The consultant's report was circulated within the Organization and to staff associations in May 1983. When this consultation phase is completed, a report on the review will be considered by the Executive.

Training of Research Workers

Paragraphs 9(d) and (e) of the Science and Industry Research Act 1949 describe, respectively, as functions of the Organization:

> 'to train, and to assist in the training of, research workers in the field of science and to cooperate with tertiary-education institutions in relation to education in that field;' and
> 'to establish and award fellowships and studentships for research . . .'

CSIRO views its role in training research workers as an important means of furthering the interests of the Australian community. There are several ways in which CSIRO carries out its research training function.

Participation in Tertiary Education

CSIRO makes a significant contribution to the training of research workers through supervision of postgraduate students and by staff giving lectures in universities and other tertiary education institutions at both undergraduate and postgraduate levels.

The Independent Inquiry into CSIRO found that, in a two- to three-year period, some 400 postgraduate students were supervised by CSIRO scientists. This involved scientists from almost all Divisions and all Australian universities. A survey conducted by the joint CSIRO/AVCC committee in 1979 showed that such supervision was a particularly important feature of interaction with the Australian National University, Macquarie University and the Universities of Melbourne, New England and Queensland.

Training for Overseas Students

CSIRO assists in the training of research workers from developing countries, usually at the request of United Nations agencies, of the Australian Development Assistance Bureau or of the governments of the countries concerned. In 1982, 42 overseas students were assisted through CSIRO's Centre for International Research Cooperation (CIRC), compared with 25 students in 1981. Students assisted by CSIRO in this way come from Asia, the Middle East, India, South America, the Pacific and Africa.

Visits by overseas students require a significant training effort by the participating Divisions but are generally found to be mutually beneficial. Students who remain in Divisions for significant periods are able to participate in a particular research program, thereby developing an appreciation of how scientific principles are applied towards meeting specific research objectives.

CSIRO Postdoctoral Awards

The CSIRO Annual Report 1980/81 reported that, following a review, CSIRO's postdoctoral studentships of one year's duration had been replaced by a smaller number of awards of two years' duration. The new postdoctoral awards were first offered in 1981. CSIRO makes ten such awards each year, on the basis of academic excellence and relevance of a student's work to the Organization's research programs. Interest in the awards continues to be strong and they attract applicants of outstanding ability. The 1982 awards were allocated to students whose work is relevant to the programs of CSIRO's Divisions of Animal Health, Chemical Physics, Plant Industry, Entomology, Fisheries Research, Manufacturing Technology, Animal Production and the Molecular and Cellular Biology Unit.

The allocation of awards is decided by a Postdoctoral Awards Selection Committee. Committee members include two CSIRO Institute Directors, one of whom is committee chairman, a former CSIRO postdoctoral student, and a university professor from each of the six States and the Australian Capital Territory. Committee members are chosen to provide, as far as possible, representation of the full range of scientific disciplines.

The offer of two-year as opposed to one-year awards proved to have a number of advantages. For the students, the two-year period offers a more realistic time-scale within which to advance significantly a research project. The proviso that the second year is tenable in Australia ensures a direct benefit to the Organization and to the Australian community. Some students are located within Australian universities for their second year and this fosters collaboration between CSIRO and the universities.

Youth Employment Training

CSIRO recognizes that it has a responsibility to assist in training the nation's youth for future employment. The Organization trains apprentices in a range of trades and participates in Commonwealth training schemes such as the Special Youth Employment Training Program (SYETP) and the National Employment Strategy for Aborigines (NESA).

Apprentices

The Organization has approximately 90 apprentices in training at any time. They are generally placed in Divisional or site workshops, located in most States and the ACT. The trade areas in which apprentices are employed, and the proportion of apprentices in each, are: engineering 75%; building 23%; printing 2%.

The Organization retains these apprentices in its employ for the duration of their period of training. At the conclusion of training, apprentices are able to apply for appointment to appropriate positions with the Organization. However, CSIRO's requirements for trades staff are not such that it can provide continued employment for most of its apprentices. It regards its training effort in this area as an important means of giving young people an opportunity to develop skills and experience which will enable them to move into the general workforce.

Special Youth Employment Training Program

CSIRO participates in the Special Youth Employment Training Program (SYETP) at its various Divisions throughout Australia. During 1982/83 approximately 720 young people benefited from the scheme through placement in a range of CSIRO establishments. The majority of young people accepted gain experience providing assistance in the technical, clerical, workshop, laboratory services and stores areas. Opportunities are also provided for young people interested in data processing, typing, teleprinting, and gardening, or in work as farm assistants or animal attendants.

National Employment Strategy for Aborigines

Under NESA, 35 young Aborigines were placed with the Organization during 1982/83, including a limited number of apprentices. Most people placed under NESA were located in CSIRO Divisions in Rockhampton, Townsville, Brisbane, Armidale, Griffith and Katherine. The majority of these young people gained experience in similar employment areas to those taken on under the SYETP.

Commonwealth Work Experience Program

CSIRO Divisions throughout Australia have participated during 1982/83 in the Commonwealth Work Experience Program for school students. Work experience in CSIRO Divisions is available for up to ten working days per student per annum in aggregate, or up to 15 days with the school's permission.

CSIRO sees its role in relation to this type of program as assisting young people in making a smooth transition from school to work. The students gain an appreciation of the work of a CSIRO Division and of particular sets of duties. The objective of such experience is to help them make informed decisions about which career they would like to pursue.

Wage Restraint

During 1982 there was considerable concern throughout the community at the continuing spiral of wage increases, given the difficult economic conditions in Australia at that time. In view of the general move towards restraint, the Executive resolved, in August 1982, that it should publicly support the Government's call for wage restraint. It aimed to set an example by seeking to defer acceptance for a period of 12 months of the pay increase for members of the Executive determined in July 1982 by the Remuneration Tribunal.

The Executive's intention was to join with private enterprise, organizations and other public bodies in efforts to counteract the spiral of wage increases occurring at the time. This general move towards wage restraint on the part of government and private enterprise organizations culminated in the introduction, in December 1982, of the Salaries and Wages Pause Act 1982. The Act suspended for 12 months the powers of the Remuneration Tribunal, the Academic Salaries Tribunal and remuneration fixing authorities to increase rates of remuneration in Commonwealth employment.

Collaborative Research Funds

The CSIRO Annual Report 1981/82 advised of the establishment of a joint collaborative research fund, on a dollar for dollar basis, between CSIRO and the Australian National University (ANU). It foreshadowed similar arrangements with other universities. The aim of such arrangements is to strengthen CSIRO and university research activities by encouraging greater interaction between relevant research groups. The funds are intended to stimulate the development of interaction between groups which have not previously collaborated, as well as strengthening existing collaborative arrangements.

In 1982/83, further funds were established to foster collaborative research between CSIRO and an additional six universities. Universities with which new collaborative research funds were established are the Universities of Sydney, Melbourne, Queensland, Wollongong, and the Macquarie and Monash Universities. The original arrangement between CSIRO and the ANU has also been extended. The total amount currently available to the collaborative research funds is $700 000 per annum. This represents the combined contributions of CSIRO and the participating universities.

12. Activities

CSIRO Submissions to Parliamentary and Official Inquiries

CSIRO made submissions during 1982/83 to several official inquiries with implications for the Organization's activities in scientific or industrial research. Details of these submissions are given below.

Inquiry into Commonwealth Laboratories

Early in 1982 the then Government established an Independent Committee of Inquiry into Commonwealth Laboratory Services and Facilities. A major aim of the Inquiry was to identify any services provided by Commonwealth Laboratories that could be transferred to either State or the private sectors. Following the general election of 5 March 1983, the Government revised the committee's terms of reference so that any recommendations concerning services would be made on the grounds of efficiency and effectiveness. This approach contrasted with the old terms of reference which placed greater emphasis on a diminution of Commonwealth operations.

Information has been provided to the committee in respect of all research service operations conducted within the Organization's laboratories together with details of the facilities, equipment and staff involved in delivering the services. The committee has supplemented this detailed information by visiting a large number of CSIRO laboratories. In addition, CSIRO has made the following submissions to the Inquiry:

- a report on implementation of those Government decisions on the recommendations of the Committee of Independent Inquiry into CSIRO that were relevant to the committee's original terms of reference;
- supplementary information on the Organization's statutory responsibility to establish and maintain physical standards of measurement as a basis for a nation-wide calibration service; and
- supplementary information on CSIRONET, the Organization's computing service network which was established to meet its internal computing needs but which is also available to government departments and instrumentalities, universities and other approved users.

Government Review of the Australian Overseas Aid Program

The Organization's submission to this Review noted that CSIRO's involvement in the Australian Overseas Aid Program was confined to the work of a small number of scientists until the 1970s. An increase in the science and technology content of Australia's aid program and a consequent increase in the number of requests received by CSIRO for assistance occurred about the same time as the Independent Inquiry into CSIRO in 1977. These developments resulted in the introduction of a more systematic approach to foreign aid by CSIRO. A Centre for International Research Cooperation was formed in 1978.

Matters dealt with in the submission included the needs for:

- CSIRO to be sensitive to perceptions that its involvement in overseas aid may disadvantage Australian industry in world trade;
- improved methods for the appraisal and evaluation of aid projects;
- adequate mechanisms for extension and implementation of overseas aid research;
- improved funding arrangements; and
- appropriate selection procedures in respect of training programs.

Industries Assistance Commission

The Industries Assistance Commission (IAC) inquires into the level and forms of government assistance received by Australian industries and reports its findings and makes recommendations to the responsible Minister. As defined in the IAC Act, 'assistance' has a very broad interpretation and can encompass a range of topics of interest to CSIRO, such as arrangements for research relevant to industry needs. Such arrangements complement the normal range of government assistance options on which it would be inappropriate for CSIRO to comment; for example tariffs, import quotas, subsidies, bounties and various forms of taxation incentives.

During 1983, the IAC conducted three integrated inquiries into areas of high technology concerned respectively with computer hardware and software, robots and metal-working machine tools. Details of the submissions made by CSIRO to each of these inquiries are summarized below:

1. Computer hardware and software

There is a need to make a continuing national investment in research and development to underpin the computer hardware and software industries. This activity would include:

. improved access to overseas technology;
. increasing the accessibility of the Australian Industry Research and Development Incentives Scheme (AIRDIS) to computing research and development;
. improving infrastructures for research and development, including more systematic approaches to information technology forecasting.

Information on CSIRO's role, included:

. providing a base for the establishment of centres of excellence in the longer term;
. transferring technology (both local and overseas in origin) to Australian enterprises which have the potential to utilise it;
. coordinating Australian computing standards with those of international standards organizations;
. advising Government on computer systems acquisition; and
. maintaining and developing the CSIRONET computing service as a national asset.

2. Robots

Robotics was identified as the forerunner of a wave of technological developments which will influence manufacturing industry. The importance of encouraging local research and development in areas of relevance to manufacturing technology was emphasized. Areas of opportunity include sensors, micro-electronics, computer software and graphics. Any long-term policy of assistance and support to the manufacturing industry must include mechanisms to ensure that a sufficient level of suitably qualified people graduate from Australian educational institutions at all levels.

3. Metal working machine tools

Manufacturing combines physical and information processing, including materials handling, parts storage, fabrication processes, materials requirement planning, raw stock and inventory control, production scheduling, parts routing and warehousing. Robots, machine tools, computers and software are all components of this total manufacturing process and it is essential to take an integrated view of these factors. Australian manufacturers should be encouraged to move towards an integration of the various aspects of the design and manufacturing process.

CSIRO Calendar of Events

During the reporting year, CSIRO was concerned with a wide range of community, industry and international matters. Divisions took part in externally organized displays and held open days and seminars themselves, to inform members of the community of some of the issues involved in current research programs. The Executive continued its program of visiting Divisions and Units. The following events have been selected as some examples of such activities.

July 1982

- Dr J.P. Wild addressed the guests at the official ceremony to mark the beginning of construction of the Marine Laboratories in Hobart, at which the Hon. Michael Hodgman, MP, then Minister for the Capital Territory and Federal Member for Dennison, unveiled a plaque.
- Executive members visited the Lucas Heights Research Laboratories (Sydney) where Dr J.P. Wild addressed the staff transferred to CSIRO from the Australian Atomic Energy Commission.
- Dr N.K. Boardman addressed a Japanese delegation to Australia on CSIRO's role and priorities.

August 1982

- Dr J.P. Wild attended the International Astronomical Union Congress in Greece.
- The tenth David Rivett Memorial lecture was presented at the University of Queensland by Professor Sir Geoffrey Allen, FRS. The topic was 'The Molecular Understanding of Flow in Polymers'.
- The Executive visited the Divisions of Tropical Crops and Pastures and Tropical Animal Science.
- Dr G.H. Taylor addressed the Royal Australian Chemical Institute on 'Accountability in Science'.

September 1982

- Dr J.P. Wild attended Interscan discussions at Los Angeles, Kansas City and Washington.
- Exhibits from the Divisions of Fisheries Research and Oceanography were displayed at the Australian Fisheries Exposition, at Circular Quay, Sydney.

October 1982

- The first Executive meeting to be held in the Northern Territory was held at Alice Springs. Places visited by the Executive on its tour of northern Australia included the Rangelands Laboratory at Alice Springs, Manbulloo, Katherine Research Station, Darwin Laboratories and the Narramoor Base Camp at Kapalga.
- An open day and special display was held at the Parkes radiotelescope to celebrate its 21st anniversary.

November 1982

- Dr J.P. Wild officially opened the Controlled Pollination Unit at the Division of Tropical Crops and Pastures, Samford Research Station, Queensland.
- Dr J.P. Wild addressed a seminar on 'How Australian Leaders see the Nation's Prospects', staged by W.D. Scott in Sydney. Dr Wild's address was entitled 'Prospects in Research and Development'.
- Dr N.K. Boardman addressed the Australian Cotton Growers Research Association at Goondiwindi on 'Agricultural and Related Biological Research in CSIRO'.
- Dr N.K. Boardman addressed the Conzinc Riotinto Australia Scientific Advisory Board on 'Recent and Relevant Applications of Biological Research'.
- The Divisions of Applied Physics, Textile Physics, Applied Organic Chemistry and Manufacturing Technology displayed exhibits at the Third Technology Exhibition in Melbourne, held in conjunction with TOC82, the Technology Opportunities Convention.

February 1983

- Executive members visited a number of Divisions and Laboratories in Perth, including the Division of Groundwater Research, the Division of Mineralogy, the Helena Valley Laboratory and the Marmion Laboratory. Visits were also made to the University of Western Australia, WAIT and the WA Department of Agriculture Research Station at Merridan.

March 1983

. Open days were held at the Division of Textile Industry and at Parkes.

April 1983

. Dr N.K. Boardman visited Indonesia and Papua New Guinea in his capacity as a Member of the Board of Management and as a Member of the Policy Advisory Council of the Australian Centre for International Agricultural Research (ACIAR).
. Dr J.P. Wild opened the 37th Annual General Conference of APPITA at Mt Gambier, South Australia.
. Dr J.P. Wild opened the Annual Conference of the Australian Society of Sugar Cane Technologists in Mackay, Queensland.
. Dr G.H. Taylor addressed the Australian Welding Research Association.
. Dr G.H. Taylor presented the keynote address at the Dow Chemistry Seminar.
. On behalf of the Australian National Commission for UNESCO, Mr L.G. Wilson attended a sub-regional meeting of the UNESCO Commissions of the Asia Region. The conference was held in New Delhi.

May 1983

. Executive members visited several Divisions in South Australia including Human Nutrition, Manufacturing Technology, Computing Research, Soils, Horticultural Research and Forest Research (Mt Gambier). Visits were also made to Roxby Downs, Mitsubishi Motors Ltd and the SA Woods and Forests Department.

June 1983

. The Minister for Science and Technology, the Hon. Barry O. Jones, MP, opened the Executive Seminar on 'CSIRO and Australian Manufacturing Industry' held in Melbourne.

13. Science and Industry Endowment Fund

The Science and Industry Endowment Act 1926 established a Science and Industry Endowment Fund (SIEF) to provide assistance to persons engaged in scientific research, and for the training of students in scientific research. The members of the Executive of CSIRO are the trustees of the Fund. The Fund consists of the original capital of £100 000 appropriated by the Act and of the income derived from the investment of that amount. In accordance with the Act, an audited statement of income and expenditure relating to the Fund is tabled in Parliament each year by the Minister for Finance. In response to recent Government decisions arising out of a report from the Senate Standing Committee on Finance and Government Operations, a more extensive presentation of SIEF activities is presented in this report.

History

Until 1964, the bulk of funds from the SIEF were used to finance overseas visits for young Australian graduate or postgraduate students to enable them to make personal contact with their colleagues, and to provide them with the opportunity to carry out research in overseas laboratories. Although the categories of people who have been supported have not changed in recent years, the trustees have generally provided financial assistance in the past few years to persons already engaged in scientific research, rather than for specific new training opportunities for students in scientific research. The shift has been due to the availability of other sources of funding for research training schemes, such as the Commonwealth Postgraduate Awards and the Australian Research Grants scheme. CSIRO still maintains a training scheme for the extension of research activities. This scheme is financed through normal CSIRO Appropriation funds and supports postdoctoral research, which is reported on in Chapter 11.

Policy

The criteria used by the trustees in deciding whether to support a project are :

- the research project must be of an individual nature and the competence and standing of the applicant, whether as a professional or an amateur researcher, must have been demonstrated;
- the research may encourage greater interest in scientific research among young people, for example, school science competitions or extra curricular programs operated by interested members of the community;
- financial assistance is provided to support study programs in overseas institutions or to support attendance at a scientific meeting only when other financial support generally is not available.

Recipients of grants are required to report on the investigations undertaken with assistance from the Fund, and to acknowledge the Fund in any publication arising from such assistance. No commercial use may be made of the results of supported research without the consent of the trustees; and no portion of the grant can be used for purposes other than those originally provided for without the consent of the trustees. All equipment or apparatus purchased by the Fund remains the property of the Fund, although the trustees may decide to relinquish equity after a reasonable period. Usually a single grant only is given to any one recipient.

Issue of Grants

In the year ending 30 June 1983, the Fund provided ten grants totalling $26 334, about the same amount provided in previous years. Applications for grants during 1982/83 are listed in Table 7.

Following a current review of administrative procedures concerning the Fund, it is expected that applications will be called annually. Procedures will provide for advertising the Fund more widely and making it more competitive.

TABLE 7

Name of applicant	Project	Amount $
Science Teachers' Association	Science competition	100
Mr A.A. Page	Micro-computer for data reduction of optical observation of flare stars	6077
Ms P. Greenslade	Travel expenses to France to study taxonomy of Australian Collembola	3730
Mr K.M. Moore	Field trip; taxonomy of Psyllidae	1600
Dr J.M. Leis	Travel expenses International Symposium on Ontogeny and Systematics of Fishes	2500
Mrs Penny Olsen	Biology of peregrine falcon and little eagle in Canberra region	3327
Dr W. Zeidler	Travel grant; not approved	–
Mr M.P. Morrow	Purchase of high powered microscope; not approved	–
Mr D. Herald	Travel grant to Java to observe solar eclipse	1300
Mr B.I. Robertson	Travel to Bass Strait to study sea birds	1677
Dr G.E. Williams	Research into solar activity of rock samples from the precambrian age	5125
Dr F.E. Wells	Airfare to Hong Kong International Workshop on Malaco-fauna	898
		26 334

14. Finance and works

Introduction

In 1982/83 CSIRO's expenditure from all sources of funds directly available to the Organization totalled $313 million. Direct appropriations by the Government this financial year provided 85% ($265 million) of these funds, with a further 11% ($34 million) being provided by other contributors, and the remaining 4% ($14 million) from revenue earned by the Organization and from unspent funds of the previous year.

Table 8 summarizes the origins of the funds made available to CSIRO for 1982/83. It excludes $63 million spent on CSIRO's behalf by the Department of Housing and Construction for major building projects ($58 million) and repairs and maintenance to existing assets ($5 million).

Good progress was made on all building projects, with the Australian National Animal Health Laboratory (ANAHL) nearing completion. Repairs and maintenance costs on existing buildings continued to rise, and put great pressure on the limited funds available.

Appropriation Resources

Operating expenditure in 1982/83 from direct Appropriation and revenue amounted to $269 million. This represented an 18% increase over operating expenditure of the previous year (after removing the effects of the extra pay day in 1981/82). The bulk of the increase was due to funds received for specific purposes which included inescapable salary increases ($23 million), the transfer of functions from the Australian Atomic Energy Commission ($7 million), additional running costs of ANAHL ($2 million), and costs associated with the relocation of CSIRO laboratories ($2 million). The total amount received towards cost increases due to inflation was $5.6 million but one quarter of this sum was required to meet electricity cost rises, particularly in New South Wales. Strict economy measures therefore continue to be necessary.

The staffing level of CSIRO's appropriation-funded programs was increased to accommodate the increased staffing requirements of ANAHL (50), the Australia Telescope (8) and Freedom of Information activities (4).

Mechanisms for Funding Research

Following the Independent Inquiry into CSIRO, the Government in 1978 decided that, as far as possible, research of general interest to the Commonwealth should be funded through budgetary appropriations to CSIRO. This decision complemented other decisions re-affirming CSIRO's role as the Commonwealth's principal strategic research agency.

Since that time several new Commonwealth research-funding schemes have been created or planned: the National Energy Research, Development and Demonstration (NERDD) program, the National Water Research Council, and a proposed biotechnology research scheme.

CSIRO supports these schemes because they provide mechanisms for supporting research that is of immediate interest to Ministers. CSIRO would be concerned, however, if schemes of this nature continued to be the only avenues for real expansions for scientific research and development.

The schemes are well suited to promoting experimental and engineering developmental work, demonstration plants for new technologies and tactical research (where the outcomes are generally predictable before the work is undertaken). They are not so well suited to the longer-term, more strategic kinds of research traditionally carried out by CSIRO. Australia needs to

TABLE 8

Source of funds	Salaries and general running expenses ($)	Contributions ($)	Capital works and services and major items of equipment ($)	Total ($)
Appropriation including Revenue	268 294 859	823 830	9 972 994	279 091 683
Wool Research Trust Fund	10 682 623	–	414 923	11 097 546
Meat Research Trust Account	4 180 295	–	88 864	4 269 159
Wheat Research Trust Account	875 260	–	–	875 260
Dairying Research Trust Account	345 826	–	–	345 826
Fishing Industry Research Trust Account	392 537	–	–	392 537
Oilseeds Research Trust Account	111 005	–	–	111 005
Dried Fruits Research Trust Account	69 543	–	–	69 543
Poultry Industry Trust Fund	115 426	–	–	115 426
Chicken Meat Research Trust Account	101 080	–	–	101 080
Pig Industry Research Trust Account	91 798	–	–	91 798
Barley Research Trust Account	2 000	–	–	2 000
NERDDC–Coal Research Trust Account	1 485 577	–	–	1 485 577
NERDDC–Appropriation Fund	2 014 541	–	43 434	2 057 975
Rural Credits Development Fund	406 051	–	–	406 051
Other contributors	12 657 706	–	130 914	12 788 620
Total	**301 826 127**	**823 830**	**10 651 129**	**313 301 086**

maintain a balance in the growth of strategic research as well as tactical research and developmental work. The use of Ministerial funding schemes to the exclusion of increased funding for CSIRO could harm this balance.

Interdepartmental Charging Policy

In May 1978, the then Minister for Finance examined the arrangements that applied for charging statutory authorities when services were supplied to them by Departments and other authorities. As a result of the examination, a directive was issued by the Department of Finance that, in future, all services were to be charged for. This was a radical departure from previous practice, where budget-dependent authorities like CSIRO were treated as government departments and charges for most services were not levied. This matter is still under consideration by the Government. If confirmed, it will be necessary for CSIRO to be provided with the necessary funds to cover the costs of the services involved.

Cyber 205 Computer

CSIRO has acquired by lease from Control Data Australia Pty Ltd an Advanced Cyber 205 Computer to replace the existing Cyber 76. The central processing unit comprises one scalar processor and two pipelined vector processors and is capable of carrying out more than 400 million additions or multiplications in a second. A similar amount of computing would require about 100 seconds on the Cyber 76.

The Advanced Cyber 205 represents a significant increase in computing power and will be accessible nationally through the CSIRONET computing network. Particular scientific benefits from its use are perceived in such diverse areas as satellite image processing, oceanographic sciences, mineral exploration, quantum chemical studies, determination of protein structures and the simulation of VLSI circuit designs.

It is envisaged that the computer will be installed at the Division of Computing Research in early 1984, and that special charging arrangements will apply, bearing in mind the national significance of this facility and the need to ensure optimal utilization of this powerful research tool.

Australia Telescope

Construction of the Australia Telescope was approved by the Government. It is estimated that it will cost approximately $30.7 million (March 1983 prices). The telescope is a combination of new antennas and existing facilities. Six new 22 m antennas will be constructed at Culgoora, near Narrabri, NSW, and one at Siding Spring, near Coonabarabran, NSW, and these will be linked by microwaves to the existing 64 m telescope at Parkes, NSW.

The project is due for completion in 1988—the bicentennial year—and will be operated as a national facility. It is described in more detail in Chapter 7.

Oceanographic Research Vessel

A contract has been placed with North Queensland Engineers and Agents Pty Ltd of Cairns, Qld, for the design and construction of a 55 m oceanographic research vessel which will be operated from Hobart by the Division of Oceanography. The vessel will be a modern and efficient working platform for deep-sea oceanographic research in climatic areas ranging from tropical to sub-temperate zones. It will be comprehensively equipped for physical, chemical and biological oceanography, and will also have a limited capacity for geological work.

The vessel will be operated as a national facility. The contract price is $12.2 million and the vessel is expected to be delivered in January 1985.

Capital Works and Property

It was noted in the CSIRO Annual Report 1981/82 that the CSIRO Executive had agreed in principle to capital works, repairs and maintenance, and acquisitions funds being appropriated directly to CSIRO, commencing with the 1983/84 financial year. Following consultation with the Departments of Finance and Housing and Construction and with the Department of Administrative Services, agreements in principle about the management of CSIRO capital works, repairs and maintenance and acquisitions funds have been reached, in the context of CSIRO directly administering the funds concerned.

During 1982/83 an internal review of property and accommodation holdings was commenced. The Organization also cooperated with the Department of Administrative Services in the Department's review of CSIRO property as part of a Government-initiated Commonwealth Property Review. The Organization's review of Queensland and Western Australian properties was completed, and programs aimed at improved utilization of some properties in Victoria and New South Wales have commenced. To date 20 properties have been declared surplus to CSIRO requirements.

Funds provided in 1982/83 for repairs and maintenance were less than those necessary to maintain CSIRO facilities at an appropriate standard. Unless there is a large infusion of funds for this purpose within the next two years there will need to be significant capital outlays to replace items that have not been maintained properly.

Details of Progress with Major Buildings

Australian National Animal Health Laboratory (ANAHL)

The construction of the Australian National Animal Health Laboratory is nearing completion and commissioning of major items of plant has already commenced. Transfer to CSIRO of the scientific support and administration building and the engineering services building occurred at the end of April 1983. Other sections of the facility will be progressively handed over to CSIRO during the remainder of 1983 and early 1984, the proposed vaccine production facility being the last section to be handed over. Current expenditure on the project is $146.1 million.

Recently there has been an increase in public awareness of the project. Site inspections by interested primary producer groups and organizations have been arranged by CSIRO with the cooperation of the Department of Housing and Construction. In the past twelve months just on 4000 visitors have been taken on conducted tours of the facility. These visits increase the level of community understanding of the complex issues surrounding the construction and operation of ANAHL.

Chemical Technology Laboratories

The building complex for the Division of Chemical and Wood Technology, at Clayton, Victoria, was occupied progressively from October 1982. The majority of the staff moved from the Yarra Bank Road site early in 1983. The new buildings also accommodate the regional headquarters for the Division of Mathematics and Statistics and a Clayton site canteen/ conference centre. The building complex includes workshops and library which will be shared with the Division of Applied Organic Chemistry when this Division is relocated at Clayton.

Materials Science Laboratories

The contract has been let for the construction of the Materials Science Laboratories at Clayton and work has commenced at the site. It is expected that construction will be completed in the latter part of 1985. The value of the contract is $9.2 million. Construction of these facilities will permit the Division of Materials Science to vacate its accommodation at the University of Melbourne and at Fishermen's Bend.

Applied Organic Chemistry Laboratories

Design work has commenced on the Applied Organic Chemistry Laboratories to be constructed at Clayton and it is expected that tenders will be called in March 1984 with project completion scheduled for mid-1986. The current estimate of cost is $13 million. When complete, CSIRO will vacate a leased site at Fishermen's Bend.

CSIRO Marine Laboratories

Work began on the Marine Laboratories at Battery Point, Hobart in mid-1982. The support facilities building will be occupied by CSIRO in the near future. The three laboratory wings and the administration building are about 25% complete and CSIRO expects to occupy the laboratories in mid-1984. Some staff of the Division of Oceanography are already located in Hobart.

Projects costing more than $250 000 which were completed during 1982/83 are listed below:

Institute of Animal and Food Sciences	**Animal Production**, Prospect, NSW—erection of animal genetics research laboratories and offices—$1 280 570. **Molecular and Cellular Biology Unit**, North Ryde, NSW—alterations for laboratories and associated services in Building No. 12—$932 778.
Institute of Biological Resources	**Wildlife Research**, Gungahlin, ACT—erection of animal house Building No. 31—$1 198 682.
Institute of Energy and Earth Resources	**Mineral Chemistry**, Port Melbourne, Vic.—erection of analytical services laboratory—$444 413. **IEER Laboratories**, North Ryde, NSW—upgrading of fume extraction in Building No. 12—$487 956. **IEER Laboratories**, North Ryde, NSW—upgrading of water supply services—$664 748. **Minerals Research Laboratories**, North Ryde, NSW—erection of general purpose laboratory No. 2 Building No. 38—$2 012 727.
Institute of Industrial Technology	**Chemical Technology Laboratories**, Clayton, Vic.—$13 755 155. **Textile Industry**, Geelong, Vic.—erection of textile machinery development building—$634 870. **Manufacturing Technology**, Woodville North, SA—alterations to Building No. 2—$845 216.

OFFICE OF THE
AUDITOR GENERAL

Canberra House, Marcus Clarke St.,
Canberra City, A.C.T. 2601
Telephone 48 4711

F83/378

11 November 1983

The Honourable the Minister for
Science and Technology
Parliament House
CANBERRA ACT 2600

Dear Minister

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION
AUDIT REPORT ON FINANCIAL STATEMENTS

Pursuant to sub-section 57(3) of the Science and Industry Research Act 1949, the Commonwealth Scientific and Industrial Research Organization has submitted for my report financial statements for the year ended 30 June 1983. These comprise–

Summary of Receipts and Payments
Consolidated Statement of Payments
Statement of Payments – General Research Account
Statement of Payments – Specific Research Account, and
notes to and forming part of the accounts.

The financial statements, which have been prepared having regard to the policies outlined in note 1, are in the form approved by the Minister for Finance under sub-section 57(1) of the Act. A copy of the statements is attached for your information.

I now report in terms of sub-section 57(3) of the Act that the statements are in agreement with the accounts and records of the Organization and in my opinion–

- the statements are based on proper accounts and records, and
- the receipt, expenditure and investment of moneys, and the acquisition and disposal of assets, by the Organization during the year have been in accordance with the Act, except that the Organization expended moneys from the General Research Account otherwise than in accordance with approved estimates of expenditure, contrary to sub-section 49(2) of the Act, and incurred obligations for expenditure on capital works and services in excess of the approved forward obligations, contrary to section 51 of the Act.

Yours faithfully

(Sgd) K. Brigden

K F Brigden
Auditor-General

Commonwealth Scientific and Industrial Research Organization
Summary of Receipts and Payments for the year ended 30 June 1983

(Figures in brackets refer to 1981/82 financial year)

	Funds held 1 July 1982 ($)	Receipts ($)	Total funds available ($)	Payments ($)	Funds held 30 June 1983 ($)
General Research Account	4 988 932 (948 466)	277 267 647* (241 439 397)	282 256 579 (242 387 863)	279 091 683 (237 398 931)	3 164 896 (4 988 932)
Specific Research Account	4 347 125 (4 564 924)	33 944 522 (29 433 415)	38 291 647 (33 998 339)	34 209 403 (29 651 214)	4 082 244 (4 347 125)
Other Trust Moneys**	335 792 (216 020)	4 731 233 (3 931 519)	5 067 025 (4 147 539)	4 479 400 (3 811 747)	587 625 (335 792)
Total	**9 671 849** **(5 729 410)**	**315 943 402** **(274 804 331)**	**325 615 251** **(280 533 741)**	**317 780 486†** **(270 861 892)**	**7 834 765‡** **(9 671 849)**

* See Note 2
** See Note 3
† See Note 4
‡ See Note 5

J.P. Wild
(*Chairman*)

G.I. Batchelor
(*Acting Assistant Secretary, Management Services*)

Commonwealth Scientific and Industrial Research Organization
Consolidated Statement of Payments for the year ended 30 June 1983

1981/82 ($)		1982/83 ($)
	Headquarters (including Regional Administrative Offices)	
10 270 109	Salaries and allowances	10 273 620
409 118	Travelling and subsistence	486 407
627 383	Postage, telegrams and telephone	666 504
3 149 066	Incidental and other expenditure	3 989 817
210 912	Advisory Council	233 500
47 408	State Committees	81 365
14 713 996		15 731 213
	Research Programs	
	Institute of Animal and Food Sciences	
258 793	Institute Headquarters	293 876
9 976 823	Animal Health	10 875 652
12 235 050	Animal Production	12 187 218
7 373 983	Fisheries Research	8 182 479
11 105 710	Food Research	12 008 852
2 916 576	Human Nutrition	3 173 962
2 188 176	Molecular and Cellular Biology	2 839 410
2 212 822	Project for Animal Research and Development	1 885 753
56 373*	Tropical Animal Science	6 375 072
622 521	Wheat Research	670 743
48 946 827		58 493 017
	Institute of Biological Resources	
275 274	Institute Headquarters	432 070
2 310 638	Centre for Irrigation Research**	2 520 790
11 801 918	Entomology	11 966 779
7 054 832	Forest Research	8 906 325
2 468 234	Horticultural Research	2 779 132
5 810 938	Land Resources Management	–
12 542 139	Plant Industry	14 202 396
6 892 219	Soils	7 505 909
8 924 198	Tropical Crops and Pastures	9 632 297
5 033 582	Water and Land Resources‡	5 650 026
4 504 213+	Wildlife and Rangelands Research	7 323 472
67 618 185		70 919 196

* Tropical Animal Science was a newly created Division during 1981/82.

** Formerly known as Irrigation Research.

† In 1982/83 expenditure is recorded separately under Wildlife and Rangelands Research (Institute of Biological Resources) and Groundwater Research (Institute of Energy and Earth Resources).

‡ Formerly known as Land Use Research.

\+ In 1981/82 part of Wildlife and Rangelands expenditure was recorded under Land Resources Management (Institute of Biological Resources).

1981/82 ($)		1982/83 ($)
	Institute of Energy and Earth Resources	
280 956	Institute Headquarters	409 259
3 504 410	Geomechanics*	3 831 062
1 530 769	Energy Chemistry	4 564 487
2 766 579	Energy Technology	3 547 682
– **	Groundwater Research	2 877 486
21 654 392	Mining, Minerals and Energy	26 622 081
798 624	Physical Technology	1 007 250
30 535 730		42 859 307
	Institute of Industrial Technology	
333 711	Institute Headquarters	340 315
3 972 968	Applied Organic Chemistry	4 527 423
6 405 047	Building Research	6 942 134
6 588 994	Chemical and Wood Technology†	7 653 147
3 602 670	Manufacturing Technology	3 910 798
4 468 962	Protein Chemistry	5 008 441
6 429 387	Textile Industry	7 293 172
3 724 392	Textile Physics	4 206 336
35 526 131		39 881 766
	Institute of Physical Sciences	
255 666	Institute Headquarters	295 097
13 460 622	Applied Physics	14 660 755
5 508 532	Atmospheric Research‡	5 090 667
623 536	Australian Numerical Meteorology Research Centre	620 600
4 091 599	Chemical Physics	4 983 130
7 952 079	Computing Research	10 258 286+
1 027 031	Environmental Mechanics	1 257 100
3 107 782	Materials Science	3 528 739
3 854 915	Mathematics and Statistics	4 201 887
3 534 571	Oceanography	4 864 352
6 497 867	Radiophysics	7 370 836
– ++	Research Aircraft Facility	669 475
49 914 200		57 800 924

* Formerly known as Applied Geomechanics.

** In 1981/82 Groundwater Research expenditure was recorded under Land Resources Management (Institute of Biological Resources).

† Chemical and Wood Technology is an amalgamation of Chemical Technology and Agricultural Engineering.

‡ Atmospheric Research is an amalgamation of Atmospheric Physics and Cloud Physics.

\+ Expenditure for Computing Research excludes $3 617 857,

++ In 1981/82 expenditure for Research Aircraft Facility was integrated with Atmospheric Research (Institute of Physical Sciences).

1981/82 ($)		1982/83 ($)
	Bureau of Scientific Services	
333 427	Bureau Headquarters	374 267
5 530 145	Central Information, Library and Editorial Section	6 015 446
400 381	Centre for International Research Cooperation	318 794
1 683 139	Commercial Group	2 118 874
1 584 375	Science Communication Unit	1 587 824
9 531 467		10 415 205
4 188 546	Miscellaneous	5 725 499
246 261 086	Total Research Programs	286 094 914
788 912	**Contributions**	823 830
788 912		823 830
	Capital Works and Services	
1 567 279	Buildings, works, plant and developmental expenditure	1 102 822
3 655 154	Major items of laboratory equipment	5 230 011
63 718	Construction of research vessel	3 926 994
–	The Australia Telescope*	391 302
5 286 151		10 651 129
	Other Trust Moneys	
663 126	Remittance of revenue from investigations financed from Industry Trust Accounts	401 804
3 148 621	Other miscellaneous remittances	4 077 596
3 811 747		4 479 400
270 861 892**	**Total Expenditure**	**317 780 486**

* Approved as a bicentennial initiative in 1982/83.
** Dissection details of 1981/82 expenditure have been adjusted where necessary, to allow comparison with 1982/83 figures.

J.P. Wild
(Chairman)

G.I. Batchelor
(Acting Assistant Secretary, Management Services)

Commonwealth Scientific and Industrial Research Organization
Statement of Payments—General Research Account—for the year ended 30 June 1983

1981/82 ($)		1982/83 ($)
	Headquarters (including Regional Administrative Offices)	
10 270 109	Salaries and allowances	10 273 620
406 772	Travelling and subsistence	481 334
627 383	Postage, telegrams and telephone	666 504
3 149 066	Incidental and other expenditure	3 989 817
210 912	Advisory Council	233 500
47 408	State Committees	81 365
14 711 650		15 726 140
	Research Programs	
	Institute of Animal and Food Sciences	
258 793	Institute Headquarters	293 876
9 029 742	Animal Health	10 012 225
8 793 289	Animal Production	8 240 562
6 983 550	Fisheries Research	7 675 338
8 942 092	Food Research	9 297 056
2 771 822	Human Nutrition	3 040 500
2 041 511	Molecular and Cellular Biology	2 597 910
123 155*	Project for Animal Research and Development	–
56 373**	Tropical Animal Science	5 354 499
359 149	Wheat Research	347 364
39 359 476		46 859 330
	Institute of Biological Resources	
275 274	Institute Headquarters	432 070
2 103 114	Centre for Irrigation Research†	2 296 152
9 133 953	Entomology	9 587 998
6 904 272	Forest Research	8 682 399
2 388 315	Horticultural Research	2 675 676
5 496 879	Land Resources Management	– ‡
11 776 253	Plant Industry	13 181 700
6 516 446	Soils	7 166 398
8 186 628	Tropical Crops and Pastures	8 804 771
4 387 591	Water and Land Resources+	4 864 599
4 146 204++	Wildlife and Rangelands Research	6 705 984
61 314 929		64 397 747

* Expenditure represents Employer's Share of Superannuation which was funded from CSIRO Appropriation in 1981/82.

** Tropical Animal Science was a newly created Division during 1981/82.

† Formerly known as Irrigation Research.

‡ In 1982/83 expenditure is recorded separately under Wildlife and Rangelands Research (Institute of Biological Resources) and Groundwater Research (Institute of Energy and Earth Resources).

\+ Formerly known as Land Use Research.

++ In 1981/82 part of Wildlife and Rangelands expenditure was recorded under Land Resources Management Institute of Biological Resources).

1981/82 ($)		1982/83 ($)
	Institute of Energy and Earth Resources	
280 956	Institute Headquarters	406 097
2 324 238	Geomechanics*	2 679 096
1 528 009	Energy Chemistry	4 545 299
2 442 011	Energy Technology	3 159 142
– **	Groundwater Research	2 700 077
17 571 547	Mining, Minerals and Energy	21 994 616
702 516	Physical Technology	865 841
24 849 277		36 350 168
	Institute of Industrial Technology	
333 711	Institute Headquarters	340 315
3 858 214	Applied Organic Chemistry	4 394 794
6 232 776	Building Research	6 731 276
5 948 858	Chemical and Wood Technology†	7 028 317
3 509 510	Manufacturing Technology	3 759 898
4 457 186	Protein Chemistry	4 998 092
3 059 248	Textile Industry	3 049 797
2 434 921	Textile Physics	2 548 296
29 834 424		32 850 785
	Institute of Physical Sciences	
255 666	Institute Headquarters	295 097
13 382 772	Applied Physics	14 505 195
5 317 829	Atmospheric Research‡	4 944 299
613 307	Australian Numerical Meteorology Research Centre	620 600
4 091 599	Chemical Physics	4 939 949
7 738 394	Computing Research	10 067 098+
1 014 980	Environmental Mechanics	1 257 100
2 812 622	Materials Science	3 252 395
3 837 129	Mathematics and Statistics	4 131 798
3 516 995	Oceanography	4 839 834
6 157 549	Radiophysics	7 081 632
– ++	Research Aircraft Facility	669 475
48 738 842		56 604 472

* Formerly known as Applied Geomechanics.

** In 1981/82 Groundwater Research expenditure was recorded under Land Resources Management (Institute of Biological Resources).

† Chemical and Wood Technology is an amalgamation of Chemical Technology and Agricultural Engineering.

‡ Atmospheric Research is an amalgamation of Atmospheric Physics and Cloud Physics.

\+ Expenditure for Computing Research excludes $3 617 857, which is the value of CSIRONET services provided to CSIRO users. (See Note 6.)

++ In 1981/82 expenditure for Research Aircraft Facility was integrated with Atmospheric Research (Institute of Physical Sciences).

1981/82 ($)		1982/83 ($)
	Bureau of Scientific Services	
333 427	Bureau Headquarters	362 198
5 298 772	Central Information, Library and Editorial Section	5 788 600
348 128	Centre for International Research Cooperation	318 794
1 683 139	Commercial Group	2 118 874
1 528 582	Science Communication Unit	1 535 393
9 192 048		10 123 859
3 964 897	Miscellaneous	5 382 358
217 253 893	Total Research Programs	252 568 719
788 912	**Contributions**	823 830
788 912		823 830
	Capital Works and Services	
1 404 038	Buildings, works, plant and developmental expenditure	1 020 384
3 176 720	Major items of laboratory equipment	4 634 314
63 718	Construction of research vessel	3 926 994
–	The Australia Telescope*	391 302
4 644 476		9 972 994
237 398 931*	**Total Expenditure**	**279 091 683**

* Approved as a bicentennial initiative in 1982/83.
** Dissection details of 1981/82 expenditure have been adjusted, where necessary, to allow comparison with 1982/83 figures.

J.P. Wild
(Chairman)

G.I. Batchelor
(Acting Assistant Secretary, Management Services)

Commonwealth Scientific and Industrial Research Organization
Statement of Payments–Specific Research Account–for the year ended 30 June 1983

1981/82 ($)		1982/83 ($)
	Headquarters (including Regional Administrative Offices)	
2 346	Travelling and subsistence	5 073
2 346		5 073
	Research Programs	
	Institute of Animal and Food Sciences	
947 081	Animal Health	863 427
3 441 761	Animal Production	3 946 656
390 433	Fisheries Research	507 141
2 163 618	Food Research	2 711 796
144 754	Human Nutrition	133 462
146 665	Molecular and Cellular Biology	241 500
2 089 667	Project for Animal Research and Development	1 885 753
– *	Tropical Animal Science	1 020 573
263 372	Wheat Research	323 379
9 587 351		11 633 687
	Institute of Biological Resources	
207 524	Centre for Irrigation Research**	224 638
2 667 965	Entomology	2 378 781
150 560	Forest Research	223 926
79 919	Horticultural Research	103 456
314 059	Land Resources Management	– †
765 886	Plant Industry	1 020 696
375 773	Soils	339 511
737 570	Tropical Crops and Pastures	827 526
645 991	Water and Land Resources‡	785 427
358 009+	Wildlife and Rangelands Research	617 488
6 303 256		6 521 449

* Tropical Animal Science was a newly created Division during 1981/82.

** Formerly known as Irrigation Research.

† In 1982/83 expenditure is recorded separately under Wildlife and Rangelands Research (Institute of Biological Resources) and Groundwater Research (Institute of Energy and Earth Resources).

‡ Formerly known as Land Use Research.

\+ In 1981/82 part of Wildlife and Rangelands expenditure was recorded under Land Resources Management (Institute of Biological Resources).

1981/82 ($)		1982/83 ($)
	Institute of Energy and Earth Resources	
–	Institute Headquarters	3 162
1 180 172	Geomechanics*	1 151 966
2 760	Energy Chemistry	19 188
324 568	Energy Technology	388 540
– **	Groundwater Research	177 409
4 082 845	Mining, Minerals and Energy	4 627465
96 108	Physical Technology	141 409
5 686 453		6 509 139
	Institute of Industrial Technology	
114 754	Applied Organic Chemistry	132 629
172 271	Building Research	210 858
640 136	Chemical and Wood Technology†	624 830
93 160	Manufacturing Technology	150 900
11 776	Protein Chemistry	10 349
3 370 139	Textile Industry	4 243 375
1 289 471	Textile Physics	1 658 040
5 691 707		7 030 981
	Institute of Physical Sciences	
77 850	Applied Physics	155 560
190 703	Atmospheric Research‡	146 368
10 229	Australian Numerical Meteorology Research Centre	–
–	Chemical Physics	43 181
213 685	Computing Research	191 188
12 051	Environmental Mechanics	–
295 160	Materials Science	276 344
17 786	Mathematics and Statistics	70 089
17 576	Oceanography	24 518
340 318	Radiophysics	289 204
1 175 358		1 196 452

* Formerly known as Applied Geomechanics.

** In 1981/82 Groundwater Research expenditure was recorded under Land Resources Manavement (Institute of Biological Resources).

† Chemical and Wood Technology is an amalgamation of Chemical Technology and Agricultural Engineering.

‡ Atmospheric Research is an amalgamation of Atmospheric Physics and Cloud Physics.

1981/82 ($)		1982/83 ($)
	Bureau of Scientific Services	
–	Bureau Headquarters	12 069
231 373	Central Information, Library and Editorial Section	226 846
52 253	Centre for International Research Cooperation	–
55 793	Science Communication Unit	52 431
339 419		291 346
223 649	Miscellaneous	343 141
29 007 193	Total Research Programs	33 526 195
	Capital Works and Services	
163 241	Buildings, works, plant and developmental expenditure	82 438
478 434	Major items of laboratory equipment	595 697
641 675		678 135
29 651 214*	**Total Expenditure**	**34 209 403**

* Dissection details of 1981/82 expenditure have been adjusted, where necessary, to allow comparison with 1982/83 figures.

J.P. Wild
(*Chairman*)

G.I. Batchelor
(*Acting Assistant Secretary, Management Services*)

Commonwealth Scientific and Industrial Research Organization
Notes to and forming part of the Accounts for the Year ended 30 June 1983

1. CSIRO's operations are funded principally from Parliamentary Appropriations. Accordingly its main accounts are kept on a cash basis, that is, no account is taken of accruals and only the amounts received and spent in a financial year are brought to account.

2. Receipts to the General Research Account comprise:

	1981/82 ($)	1982/83 ($)
Appropriations–Consolidated Revenue Fund		
Operational	223 067 000	258 206 000
Capital	8 500 000	6 985 000
	231 567 000	265 191 000
Revenue and other Receipts		
General Operations		
Sale of publications	505 374	640 664
Receipts in respect of expenditure in former years	563 547	466 576
Sale of produce, including livestock	429 733	470 490
Royalties from patents	61 622	181 937
Fees for tests and other services	230 277	345 527
Interest on investments	408 699	596 661
Miscellaneous receipts	425 523	613 442
	2 624 775	3 315 297
CSIRONET Operations		
Computing service charges	7 085 438	8 740 048
Receipts in respect of expenditure in former years	142 354	7 779
Miscellaneous receipts	19 830	13 523
	7 247 622	8 761 350
	9 872 397	12 076 647
Total Receipts	241 439 397	277 267 647

3. Other Trust Moneys Account is the repository for moneys held temporarily on behalf of other organizations and individuals.

4. Total expenditure comprises:

	1981/82 ($)	1982/83 ($)
Salaries	194 313 962	219 028 027
Travel	7 798 764	8 634 880
Equipment	11 427 022	17 465 218
Maintenance	52 022 012	62 001 184
Capital	5 300 132	10 651 177
	270 861 892	317 780 486

5. Funds held at 30 June 1983 included investments totalling $4 158 200. The comparative investments figure at 30 June 1982 was $6 658 200. Of the total funds held, $1 407 500 represents funds which had been appropriated to CSIRO but which were not to be expended in 1982/83.

Investments (at cost) held as at 30 June 1983:

	$
Trust Funds	
Commonwealth Inscribed Stock	50 000
State Electricity Commission of Victoria	18 200
Melbourne and Metropolitan Board of Works	12 000
Canberra Permanent Building Society	78 000
	158 200
Other Investments	
Reserve Bank of Australia Interest Bearing Deposits	4 000 000
TOTAL	4 158 200

6. Receipts and payments relating to the provision of CSIRONET computer services are as follows:

	1981/82 ($)	1982/83 ($)
Receipts		
CSIRO users	3 316 819	3 617 857
Other users	7 085 438	8 740 048
Receipts in respect of expenditure in former years	142 354	7 779
Miscellaneous receipts	19 830	13 523
	10 564 441	12 379 207
Payments		
Operational expenditure	11 055 213	13 684 955*
Capital expenditure	685 574	220 561
	11 740 787	13 905 516

* Of the operational expenditure recorded for CSIRONET the Division of Computing Research research activities were funded by CSIRO Appropriation to the Division of $1 831 600.

7. In addition to moneys expended directly by CSIRO, the undermentioned Departments incurred expenditure from Parliamentary Appropriations for CSIRO purposes.

	1981/82 ($)	1982/83 ($)
Department of Transport and Construction:		
Repairs and maintenance	4 380 727	5 000 998
Buildings and works	54 930 242	58 009 240
	59 310 969	63 010 238
Department of Administrative Services:		
Acquisition of sites and buildings	2 615 440	4 796

8. During 1980/81 CSIRO joined with Knight Actuaries Pty Limited and The Australian Mineral Development Laboratories in the establishment of Siromath Pty Limited, a company registered in the State of Victoria, for the purposes of providing a high level mathematical and statistical consultancy organization to industry, commerce, governments, educational institutions and other persons. CSIRO is represented on the Board of Directors and the Management Committee of the Company.

On 30 June 1981 CSIRO exercised its option to purchase a one-third shareholding in Siromath Pty Limited. CSIRO purchased a $1 share in the Company and as at 30/6/83 CSIRO has subscribed a total of $36 000 to the working capital of Siromath Pty Limited.

9. Following the death in December of 1980 of Miss T. McMaster, the life interest left to her by her father, the late F.D. McMaster, fell to CSIRO. The interest is in the form of 60601 shares (or 32.05% of the issued capital) in F.D. McMaster Pty Ltd. The principal asset of the company is a property at Cassilis NSW named 'Dalkeith'. CSIRO is currently negotiating the disposal of its shareholding in F.D. McMaster Pty Ltd.

J.P. Wild
(Chairman)

G.I. Batchelor
(Acting Assistant Secretary, Management Services)

Advisory Council and State and Territory Committee

The Science and Industry Research Act 1949 requires the Organization to publish advice provided by the CSIRO Advisory Council during the reporting year, together with comments by the Executive on that advice.

This section includes advice provided between 1 July 1982 and 30 June 1983, and comments on that advice By agreement with Council, it also reports generally on the activities of Council, the six State Committees and the Northern Territory Committee for the same period.

15. Advisory Council and State and Territory Committes-advice and activities

Advisory Council

The function of the Advisory Council is to furnish advice to the Executive on:

- The objectives that should be pursued by the Organization and the priorities to be followed to achieve those objectives;
- industrial or economic matters that may be of importance in formulating those objectives;
- the identification of the interests of the Australian community that may be furthered by the Organization; and
- any other matter that is referred to it by the Executive for advice.

In the year under review, Council met four times and four of its five Standing Committees held meetings to examine and provide advice on a number of CSIRO review reports. The standing committee system (described in the CSIRO Annual Report 1981/82) continued to develop, and a fifth committee was established to advise Council on information and social impact matters arising from CSIRO's research activities. During the year, Professor P. Scott agreed to chair the Natural Environment and Renewable Natural Resources Standing Committee and Dr B.W. Scott was appointed Chairman of the Information and Social Impact Standing Committee.

Advice on CSIRO's review reports is an important Council activity in which State and Territory Committees are increasingly playing a part. In some cases they make their contributions direct; in other cases members are coopted on to Council's Standing Committees. In this way, Council's advice has been broadened and made more representative of national attitudes towards CSIRO's research programs.

Changes in Membership

Full lists of members are set out in Appendix II. Professor L.M. Birt, Vice-Chancellor of the University of New South Wales, completed his term of appointment and was reappointed as a member from 1 August 1982.

Mr R.J. Kirby, Managing Director, James N. Kirby Holdings Pty Ltd, was appointed to Council. Following the retirement of Professor Sir Geoffrey Badger as Chairman of the Australian Science and Technology Council, his successor, Professor R.O. Slatyer, became an observer of Council. Mr B.O. Jones and Senator A.M. Thomas ceased to be members after the Federal election on 5 March 1983, in accordance with arrangements for parliamentary party representation. Mr P.R. Staples and Dr H.R. Edwards were subsequently nominated by their parliamentary parties as members of Council.

Council Advice

The Science and Industry Research Act 1949 requires that advice received from the Advisory Council by the Executive be reported in the Organization's annual report, together with comments on that advice by the Executive. This year, Council's report deals with work in progress and informal advice provided by Standing Committees.

Work has continued on contributions to a major planning document on manufacturing industry research, preparatory to an Executive statement of policies and priorities for that sector of CSIRO's research effort. Work has also gone into the initial planning documents on tertiary industry research and public health research, and into a preliminary study of information technologies research. Council has continued to develop, through its Rural Industries Standing Committee, further views on CSIRO's agricultural research policies and priorities, following the Executive's statement in the 1981/82 annual report.

Informal submissions to review committees and comments on review reports have continued to be a major activity of the Standing Committees.

Council is currently contributing to CSIRO's sector reviews of manufacturing industries and community interests research. Formal advice arising from this work will be reported in next year's report by Council. Informal advice provided by Council in the present reporting year is described below.

CSIRO Reviews

Manufacturing Industry Research

Council arranged five meetings, involving 30 industrialists and industry research leaders, to contribute to CSIRO's planning document on manufacturing industry research. Following these meetings, Council prepared a paper which drew attention to the need for closer integration of CSIRO and industry objectives and commented on the inadequate level of CSIRO resources devoted to manufacturing industry compared with the requirements of the programs suggested. Council will examine and comment on the Executive's proposed policy and priorities statement before it is finalized.

Tertiary Industry Research

Council has contributed to the preparation of CSIRO's strategic planning document on tertiary industry research and has provided informal advice on a section dealing with information technology.

Public Health Research

Ad hoc meetings were held to consider the draft Planning and Evaluation Advisory Unit study on CSIRO's research for public health and a report will be made to Council in due course.

Rangelands Research in CSIRO

Council has taken a close interest in the rearrangement of CSIRO's wildlife and rangelands research, following their amalgamation within the new Division of Wildlife and Rangelands Research. Members of Council have emphasized the long-term nature of rangelands work and the potential for improvement in the productive capacity of these lands and the animals on them. Council has stressed the need for increased staff at the rangelands laboratory at Alice Springs, where the opportunity for using LANDSAT data can be maximized.

Council also continues to be concerned that CSIRO should find the best means available for collaborating with the States and Northern Territory Departments concerned with the development and conservation of Australian rangelands.

Library and Information Services in CSIRO

Council provided advice on the preliminary findings of a review of library and information services, and has continued to take an interest in the Executive's plans for their improvement.

Australian National Animal Health Laboratory

Following extensive discussion in Council and in Standing Committee meetings, a contribution was made to the debate about the importation of live viruses for research in Australia into animal diseases.

Other Reviews

During the year, Council contributed to subject reviews of plant pathology, agricultural engineering research, international activities and commercial activities.

Reviews of Divisions that Council discussed included: Fossil Fuels, Computing Research, Textile Physics, Protein Chemistry and the Molecular and Cellular Biology Unit, Human Nutrition, Mineralogy and Mineral Physics, and Materials Science.

Membership of CSIRO Review Committees

Council considered the composition and balance of CSIRO review committees after several members had expressed the view that committees should be multi-disciplinary and include representatives of users wherever appropriate to the subject matter. Council has recommended that an appropriate CSIRO policy on the appointment of potential users of CSIRO research and development should be promulgated. It also considered that more non-CSIRO chairmen of committees should be appointed. In addition, agreement was reached with CSIRO that the Executive would consult Council's Chairman, Sir Peter Derham, about the intended membership of review committees.

Survey by Professor A.J. Birch

In June 1983, Professor A.J. Birch addressed Council on the subject of his survey of the Organization's response and actions following Government decisions on the Report of the Independent Inquiry into CSIRO (1977).

In a position paper about his survey, Professor Birch commented on the Advisory Council's functions of advising the Executive and reflecting community views on CSIRO's research programs and priorities. Council's response to the position paper was forwarded to Professor Birch at the end of June 1983, before he reported his conclusions to the Minister for Science and Technology.

Other Council Activities

Amongst its other activities, Council submitted suggestions about major new research initiatives; 'Directory of CSIRO Research Programs' was examined in its revised format; Council strongly supported the Australia Telescope project as part of the Australian bicentenary program; advice was prepared during the year on upgrading LANDSAT and on the Australian National Conservation Strategy. Council's Standing Committees have taken note of the reports of several Senate Standing Committees and Government inquiries relevant to their interests in CSIRO's research and advisory arrangements.

Several members of Council have attended Executive seminars held during the year on topics of current or future research in the Organization.

During the year, the Chairman of the CSIRO Advisory Council, visited CSIRO State Committees in New South Wales, South Australia, Queensland, Victoria, and the Northern Territory Committee. Mr J.H.S. Heussler, Chairman of Council's Rural Industries Standing Committee, visited South Australia, Western Australia, Alice Springs and Darwin in connection with rangelands research and other developments in CSIRO's rural research.

STATE AND TERRITORY COMMITTEES

New South Wales

The New South Wales State Committee met formally on four occasions during the year. The Committee concentrated on promoting industry and community awareness of CSIRO's research activities and was particularly encouraged by the excellent feedback it received from the manufacturing industry seminar held last year.

Visits were made to the CSIRO Division of Animal Health's McMaster Laboratory, the Divisions of Energy Chemistry and Mineral Physics at Lucas Heights, and the Division of Radiophysics at Epping.

The Committee also visited the Narrabri-Wee Waa area. This visit was co-hosted by CSIRO, the Namoi Cotton Co-operative Ltd and Cotton Seed Distributors Pty Ltd. The Committee inspected the CSIRO radioheliograph at Culgoora, which will be the focal point of the Australia Telescope project, and the CSIRO Cotton Research Unit at Myall Vale Research Station. It noted the excellent relationship that has developed between the Cotton Research Unit, the New South Wales Department of Agriculture, the cotton growers and the industry generally. The successful development of SIRATAC, a computerized farm management system for growing cotton, is an excellent example of collaboration between industry and research workers.

The Manufacturing Industry sub-committee visited the Division of Applied Physics and also met with the Chief of the Division of Manufacturing Technology. In response to an inquiry, the sub-committee arranged for representatives of the Divisions of Applied Physics and Manufacturing Technology to visit and advise on certain production problems. This visit stimulated the initiation of a research project on metal forming in the Division of Applied Physics. Assistance is being given to this Division to form a liaison committee to enable it to increase its industrial contacts.

CSIRO and industry representatives attended a robotics demonstration arranged by Metal Manufactures Ltd in conjunction with the State Committee.

In conjunction with CSIRO's Information and Liaison Officer for New South Wales, the Committee wrote to some 500 firms advising them of the services available in CSIRO for technical information and advice.

The Rural Industry sub-committee visited the Divisions of Plant Industry and Entomology, while the Minerals and Energy sub-committee visited the Divisions of Mineral Chemistry and Mineral Engineering.

Submissions were made either by the Committee or by individual members to the reviews of the CSIRO Divisions of Textile Physics, Fossil Fuels, Animal Health, Mineral Physics, Protein Chemistry and the Molecular and Cellular Biology Unit. Members were also involved in several Advisory Council activities.

Queensland

The Queensland State Committee met formally on seven occasions during the year. Members contributed to the reviews of the Divisions of Fossil Fuels, Computing Research, International Activities, Commercial Activities, Textile Physics, Human Nutrition, Mineralogy and Mineral Physics and took part in standing committees of the Advisory Council.

The Chairman of the CSIRO Advisory Council met the Committee on the occasion of its visit and inspection of CSIRO's Meat Research Laboratory. During the year, CSIRO's Deputy Executive Secretary addressed the Committee. Also, the manager of SIROMATH spoke to the Committee and a panel of invited industrialists on the work and scope of SIROMATH.

On the occasion of the meeting of the Advisory Council in Brisbane, members of the State Committee joined the Council and inspected CSIRO's Cunningham and Long Pocket Laboratories, where the work of the two Divisions of Tropical Crops and Pastures and Tropical Animal Science was demonstrated.

A seminar for engineers was arranged by the Institution of Engineers in Australia in collaboration with the State Committee. CSIRO speakers delivered talks on robotics, water engineering and remote sensing techniques.

An inspection of CSIRO's work in the Gladstone area was arranged, and speakers from the Divisions of Energy Technology, Fossil Fuels, Energy Chemistry and the Physical Technology Unit described the work being carried out in the fields of shale oil production and chimney plume dispersal. The Committee also inspected the Tropical Cattle Research Centre and the 'Belmont' National Cattle Breeding Station at Rockhampton. The opportunity was taken to speak with industry leaders and educationalists in the Rockhampton area. The Chairman of the CSIRO Advisory Council accompanied the Committee on these inspections.

The Committee welcomed the move to coopt additional members who would specifically bring to the meetings the views of women and trade unions. Mrs J. Sheridan, president of the Brisbane branch of ZONTA, Mr R. Dempsey, assistant secretary of the Trades and Labour Council and Mr M. Vining representing the Australian Workers' Union, joined the Committee discussions in the latter half of the year.

Two members were appointed to represent the Committee on other CSIRO advisory bodies.

South Australia

The South Australian State Committee held five business meetings during 1982/83. The Committee was able to inspect the work being carried out at the Divisions of Computing Research (VLSI Group), Human Nutrition (Kintore Avenue Laboratories) and Soils.

The State Committee arranged a seminar at Whyalla for the Iron Triangle Community in August 1982. Members and senior CSIRO personnel were able to meet with community leaders at industry visits and other functions. It was apparent that there was concern in the region at the lack of data relating to the biology and oceanographic features of the Spencer and St Vincent Gulfs. A submission on this question has been lodged with the Advisory Council.

During the same week, the State Committee arranged an educational program on aspects of CSIRO's research through a series of lectures to secondary school students at Port Pirie, Port Augusta and Whyalla. Between 400 and 500 science students attended presentations by CSIRO scientists on the subjects of soils and soil structure, diet and exercise, metallurgy in relation to forensic science, and technological learning aids for the handicapped. Teachers were enthusiastic at the opportunity of contact with CSIRO research workers.

The policy of promoting CSIRO's interests in South Australia was pursued through a seminar held in May at Mount Gambier. The Organization's work was explained to an audience of community leaders, including business and professional people. The Committee is also collaborating with the Department of Science and Technology over the information technology week to be held in Adelaide at the end of July 1983.

The Committee has contributed to the development of CSIRO's policy through involvement in major issues such as agricultural engineering, rangelands research, mediterranean zone agriculture, water repellent sands, and the role of research and development in manufacturing industry.

Tasmania

The Tasmanian State Committee met formally on four occasions in 1982/83. In addition to providing input to the Advisory Council on a number of issues, the State Committee again invited speakers from CSIRO Divisions to deliver addresses on topics of particular relevance to Tasmania.

One of the areas previously identified by the Committee as deserving special attention was marine science, and the first address, by the Acting Chief of the Division of Fisheries Research, was on the subject of marine food chains and their relation to ocean dynamics.

There was considerable discussion at several meetings on the question of stimulating development in Tasmania, particularly in the industrial sector. Factors to be considered were the limited size of the industrial base in the State, the requirement for industries to be tailored to local conditions and to take advantage of particular features and resources available in the State, and identification of areas in which CSIRO could be of assistance. In this context, the Chief of the Division of Manufacturing Technology addressed the Committee at a meeting in late 1982 to which a number of representatives of manufacturing firms in the Hobart area were invited. He outlined the progress of the Division and the type of assistance to industry that could be developed. Subsequent discussions ranged from the ways in which CSIRO could provide assistance to small firms with limited cash flow, communications problems between industry and CSIRO, and the possibility of high technology development in small manufacturing processes. Subsequently, a paper on research and development grants to industries in Tasmania was prepared by the Committee.

Plans have been formulated for a short visit by the State Committee to the Tamar region of northern Tasmania during November 1983. This region presents opportunities for intensification of agriculture, forestry and small scale manufacturing industry, and the broad objective of the visit is to improve awareness by the local community of the role played by CSIRO and the State Committee. CSIRO research activities which are relevant to the needs of the region will be identified, and a seminar held at which these activities can be presented and an input from the local community sought. Visits by the State Committee will also be arranged to several industries in the region, as well as to the Maritime College in Launceston.

Victoria

The Victorian State Committee has directed a major effort over the past year to improving the awareness of industry and the people of Victoria to CSIRO's resources, research results and potential. On visits to Divisions throughout the year, the Committee was accompanied by invited guests whose interests were related to the research of the Division. In this way, contact was established with industry leaders, representatives of the agricultural industry, representatives of semi-government and government authorities, and community leaders.

The Committee held five business meetings during the year, and visited the Divisions of Manufacturing Technology, Mineral Engineering, Applied Organic Chemistry and the Australian National Animal Health Laboratory. Submissions were made to the committees reviewing CSIRO's commercial activities and the Divisions of Textile Physics, Protein Chemistry, Fossil Fuels, Mineral Physics and Mineralogy. In addition, members were involved with the reviews of the Central Information, Library and Editorial Section, and the Divisions of Materials Science and Applied Physics.

The Committee has formed standing sub-committees under permanent chairmen to correspond to the Advisory Council's structure and to enhance the contact between the respective committees. This has involved the State Committee directly with the Advisory Council's consideration of CSIRO's role in manufacturing industry, rural, water and tertiary industry research.

Western Australia

The Western Australian State Committee met on seven occasions during 1982/83.

The CSIRO Executive visited Perth in February 1983 and met with State Cabinet Ministers, Heads of Departments and representatives of tertiary institutions to gain an appreciation of State activities; CSIRO laboratories were visited and research programs reviewed. The Committee welcomed the Executive's decision to provide an additional 22 positions in Western Australia.

To promote awareness of CSIRO in Western Australia, a program of visits to laboratories by small groups of community leaders will commence in the next financial year. The Science Communication Unit of CSIRO's Bureau of Scientific Services and the Division of Groundwater Research are collaborating in the organization of this activity. A series of special meetings involving invited speakers, including Chiefs of CSIRO Divisions, has also been implemented. Invitations to these meetings are extended to appropriate industry and community leaders, staff of tertiary institutions and professional bodies. It is proposed to hold up to four such meetings each year.

A report recommending the enhancement of agricultural research in the mediterranean environment of Western Australia was submitted to the Advisory Council during the year.

The Committee is preparing submissions with respect to two new initiatives for consideration in the 1984/85 estimates.

Submissions were made to the committees of review of the Divisions of Textile Physics, Fossil Fuels, Mineralogy and Mineral Physics. A case was also prepared in support of the updating of the LANDSAT receiving station at Alice Springs.

The Committee has maintained a continuing interest in the need for farm machinery research, and has responded to requests for assistance in the study of ryegrass toxicity problems by two organizations in the State.

As a result of close contact with the Advisory Council throughout the year, the Committee created standing committees to correspond with those of the Advisory Council.

The Chairman of the Advisory Council's Rural Industries Standing Committee, together with the secretary of the Council, met with the State Committee in May to discuss several areas related to rural activity.

Northern Territory

The Northern Territory Committee, which was formed in 1982, held its first meeting in September in Darwin and two subsequent meetings in Alice Springs and Katherine. The Committee comprises 12 members with interests and expertise in primary production, conservation of natural resources and the environment, health, mining, architecture, aviation, Aboriginal communities, education and public relations.

The Commitee's first task was to familiarize itself with the research on rangelands, agriculture, horticulture and wildlife being undertaken by CSIRO in the Northern Territory. The Committee has now reviewed the first two topics and their research priorities and will review the latter two during the remainder of 1983.

In association with the Advisory Council's Rural Industries Standing Committee, the Northern Territory Committee has strongly supported moves to increase CSIRO's staff and upgrade facilities for research on rangelands in central Australia.

The Committee has been impressed by the promise shown by CSIRO's research on no-till cropping in the tropics. It has encouraged the Northern Territory authorities to extend trials on a broad-acre basis, aided by advice from CSIRO.

Research

The items in this section have been selected to illustrate something of the wide range of CSIRO's research. More comprehensive information can be obtained from Institute annual reports, from the reports published regularly by Divisions and Units, from a variety of other CSIRO publications listed in 'Serial Publications, Monographs, and Pamphlets Issued by CSIRO', and from 'CSIRO Index' which lists the 200 or so papers produced each month by CSIRO scientists. For information regarding any of these publications, please contact:

The Central Information Service
CSIRO
PO Box 89
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Telephone: (03) 418 7333

16. Australia's fishery resources

In November 1979, Australia declared its jurisdiction over the 200-nautical mile fishing zone, and became responsible for the management of fish stocks in an area equal in size to the continent itself.

Despite optimism that the huge new area would yield a dramatic increase in fishery resources, recent increases in the value of the Australian fishery have come almost exclusively from traditional sources. In fact, 85% of the value of Australia's product still derives from just seven such fisheries—prawns, rock lobsters, the south-east trawl, abalone, southern bluefin tuna, scallops and southern sharks. Nearly all are almost fully exploited and further stocks are unlikely to be found within the Australian fishing zone. However, some of the findings from studies and assessments of other species in the zone have been encouraging.

After a decade which saw the value of its product increase 400%, the Australian fishing industry now rivals the pig and poultry meat industries in value. Most of its catch is exported, with exports reaching a record $323 million in 1981-82. This picture of growth is somewhat deceptive. Although it reflects some increase in landings, particularly of high-value species such as prawns, it is due mainly to increased prices, rather than to increased harvest. With the main species contributing to this growth already approaching maximum exploitation, future expansion of the fishing industry clearly rests with the identification and development of new fisheries. This will require a sustained research effort, not only to identify potential new fisheries, but to ensure they are exploited wisely and profitably.

Historical Influences

Australia possesses one of the world's longest ice-free national coastlines, yet paradoxically contributes only 0.2% of the world's total of fishery products.

One reason for this low level of production is undoubtedly historical. Fish is not traditionally a major source of protein for Australians, and Australia has not developed wide-ranging deep-ocean fishing fleets such as those of Japan and the North Atlantic countries. The industry has traditionally operated nearshore, and on a small scale, supplying fish to the major markets of Australian population centres. Development of fisheries in more remote and sparsely populated regions of the north and west has been limited to high-value species because of the costs of catching, processing and transport. Although foreign fishing ventures operate profitable gill net and trawl fisheries, so far only prawning has proved profitable to the Australian industry in such regions and has contributed much of the increased value to the total Australian fisheries product.

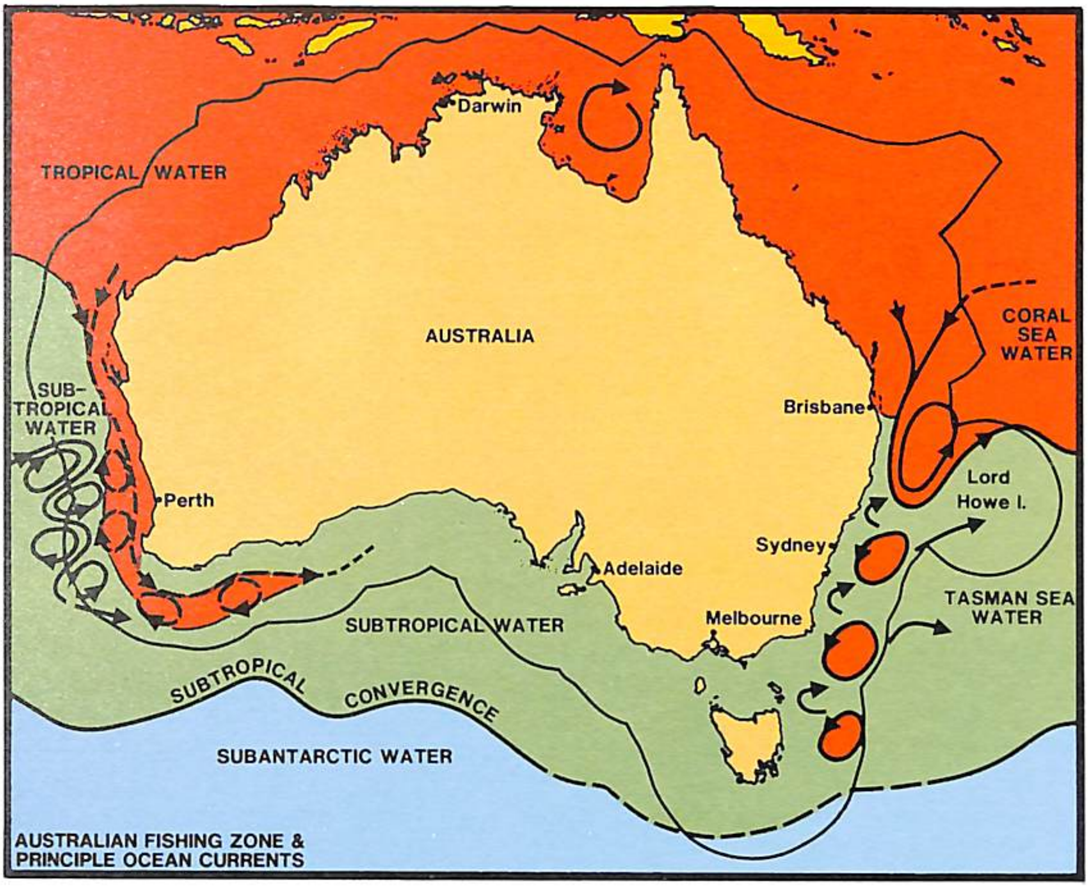
Low Productivity of Australian Waters

A second and more fundamental reason for Australia's low level of fish production is the generally low productivity of its waters. Deep (below 200 m) oceanic water is usually rich in nutrients and where it is brought to the surface by local oceanic flows, in a phenomenon known as upwelling, microscopic marine plants abound. Upwellings which support highly productive fisheries generally occur off the eastern margins of northern hemisphere continents, and on the western margins of the southern continents—the rich anchoveta fishery of the Humboldt Current off western South America is a notable example.

Unfortunately, Australia breaks this pattern. The subtropical convergence, forming the boundary between the nutrient-poor waters of the tropical and sub-tropical Indian and Pacific

Oceans, and the nutrient-rich subantarctic waters, lies south of the continent. Instead of being washed by a nutrient-rich northerly current, Australia's west coast is subject to the southerly, nutrient-poor tropical Leeuwin current, which flows intermittently down the coast and then eastward into the Great Australian Bight (see diagram).

Nevertheless, the surface waters around the Australian coast are enriched by oceanic eddies which bring deep waters to the surface. River runoff and ground water flowing into the sea also provide a degree of enrichment, but because of the nature of Australian soils, these are often themselves low in nutrients, particularly phosphates. CSIRO has found evidence of local enrichment off New South Wales, South Australia, the North West Shelf, the Arafura Sea and the Gulf of Carpentaria. CSIRO has also shown that average levels of inorganic nutrients do not always reliably indicate a water body's productivity. Recent discoveries have shown that catch size relates more to the availability of nutrients and food for larvae after spawning, rather than to overall levels of nutrients during the year. Local or intermittent enrichment phenomena may thus support productive fisheries.



Patterns of oceanic circulation around the Australian continent. Unlike other southern hemisphere continents, there is no nutrient-enriched current flowing northwards along the west coast; instead a predominantly southerly, nutrient-poor tropical current prevails. Some coastal surface waters are, however, enriched by local upwellings and support productive fisheries.

Australia's Fishery Resources

Australia's fishing grounds occur in a wide range of climatic and oceanic conditions, from tropics to temperate areas, and fishing is pursued from the upper reaches of rivers to the deep ocean beyond the continental shelf. The resources vary from immobile species such as oysters to wide-ranging migratory oceanic tunas. Some species live for only one year while others may live 20 years or more. These animals are as specific in their environmental requirements as are those of the land, each species occupying a specific niche at each stage of its life. Although the catch is dominated by fewer than 200 species, many more are caught as a by-product.

If fish are divided by the particular ocean regions they inhabit during their lives, eight categories of marine fisheries resources can be defined:

- Inshore species inhabiting intertidal and subtidal areas (oysters, mussels, abalone);
- Bottom species of the continental shelf inhabiting estuaries or coastal regions for the early part of their lives (prawns, rock lobsters, snapper, bream, flathead, mullet, whiting);
- Bottom species of the continental shelf for all their life (morwong, arrow squid);
- River species, using estuaries and adjacent coastal areas for spawning (barramundi);
- Bottom species of the outer continental shelf, shelf slope and oceanic plateaux (royal red prawns, orange roughy, gemfish);
- Midwater species of the continental shelf (Spanish mackerel, jack mackerel);
- Midwater species of oceanic waters (oceanic squid);
- Pelagic oceanic species (southern bluefin tuna).

Some of the species in these groups are fully exploited, others not at all. Some are utilized by the domestic industry, others are shared with foreign companies, and some are fished exclusively by foreign interests.

Species of coastal regions (for example, rock lobsters, prawns) are particularly susceptible to modification of the coastal environment, while others, by their position at the apex of the food chain, may accumulate naturally-occurring or man-produced toxic substances which render them unsuitable for human consumption (for example, mercury in school shark).

Recognizing the enormous complexity of Australia's fishery resources, CSIRO has emphasized studies aimed at understanding why stocks fluctuate, and the effects of fishing and other human activities upon particular species. Studies on food chains, ecology and biological oceanography are being integrated with research into the biology of particular species during critical life cycle stages. The impact of fishing upon each species is examined within the broad framework of its natural environment.

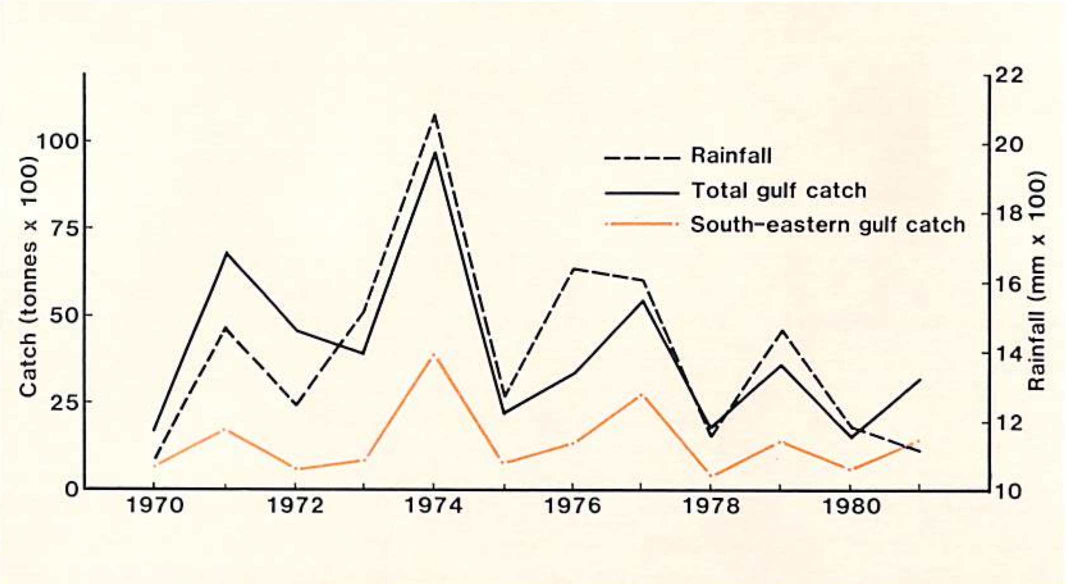
Prawns. Prawning is pursued in all mainland States except Victoria. It is Australia's most valuable fishery, representing 36% of the total value of the catch in 1981. Most of the prawn catch is exported. The greatest catches occur in northern Australia, where six species make up the bulk of the landings—banana prawns (*Penaeus merguiensis*), tiger prawns (*P.esculentus*, *P.semisulcatus*), and endeavour prawns (*Metapenaeus ensis*, *M.endeavouri*) and western king prawns (*P.latisulcatus*). Elsewhere localized fisheries for other species, for example school prawns (*M.macleayi*) and greasyback prawns (*M.bennettae*), supply local markets.

All these species exhibit high fecundity, rapid growth rates and short life span (less than three years). Their eggs are released at sea and hatch into larvae with a short open-ocean stage of 12 weeks. The larvae then move to inshore waters or estuaries and settle on the bottom as post-larvae, subsequently growing into juveniles which eventually move out to sea to spawn as adults in their first year of life. Most species are evenly distributed over the fishing grounds, but in the Gulf of Carpentaria banana prawns become tightly packed into schools that form areas of discoloured water known as 'boils'. This enables the species to be harvested easily, but at the same time makes it vulnerable to overfishing.

In the early years of the banana prawn fishery in the Gulf of Carpentaria catches rose rapidly, but once all fishing grounds were taken up, catches began to fluctuate wildly in spite of a constant fishing effort. Inability to predict the season's catch caused wastage of both capital and product, and there was concern that the fluctuations might herald a collapse of the fishery.

CSIRO research showed that catch fluctuation is due to variability in the banana prawn's natural environment rather than to overfishing. Each female releases 100 000 to 300 000 eggs, and there are two peaks of spawning each year. Only during the spring peak, however, are larvae transported to the estuaries by oceanic currents; after the autumn spawning peak the currents flow predominantly north-westward and the larvae pass out to sea and die.

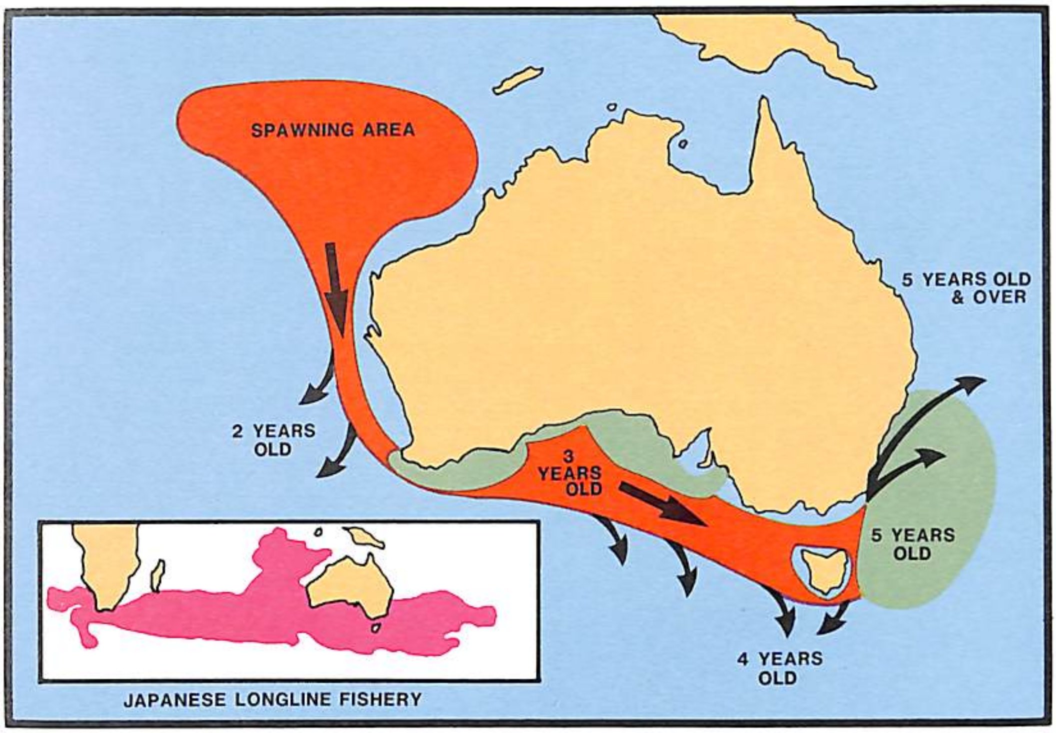
Within the estuaries the banana prawn larvae settle adjacent to the mangroves and grow into juveniles. They move out to sea only after a period of heavy rainfall, coming to rest adjacent to coastal beach zones before moving deeper into the commercial fishing grounds where they reach adult size by autumn. The number of banana prawns moving downstream varies greatly from year to year and is closely correlated with the amount of rain in the catchment area, and is reflected in the year-to-year fluctuations of the fishery (see diagram). From the rainfall figures collected before the fishing season in the south-eastern Gulf, the magnitude of the season's banana prawn catch can be predicted. Catch variation with other species in other parts of the Gulf may be due more to variability in transport of larvae to the estuaries than to variability in rainfall. A new CSIRO study to evaluate the now heavily-fished tiger prawn stocks around Groote Eylandt has recently begun.



The annual catch of banana prawns, **Penaeus merguiensis,** *is closely linked to fluctuating rainfall before the fishing season.*

Western rock lobster. The western rock lobster (*Panulirus cygnus*) fishery is Australia's second most valuable fishery, accounting for more than 25% of the value of fishery exports. It is caught in baited traps in coastal waters, mainly between Geraldton and Cape Naturaliste in Western Australia. CSIRO has elucidated many details of its long and complicated life history. The young larvae have a planktonic life of 9-11 months during which they are transported well off the continental shelf into the Indian Ocean. Ocean currents later return them to the shallow coastal regions of Western Australia where the puerulus, or final larval stage, settles. Young juveniles congregate in shallow coastal limestone reefs (to depths of 10-20m) where they remain for several years. At about 5-6 years of age they migrate onto the continental shelf to depths of 20-150 m where they are fished. The lobsters first spawn at about this time and may achieve an age of more than 15 years.

CSIRO research has revealed two facts of significance to the fishery. In most years the holding capacity of the shallow coastal reefs cannot cope with the number of arriving larvae, and recruitment to the fishery depends on the number of juveniles leaving the reefs. Growth rate and survival of these juveniles depends on the food supply for which they compete—algae, seagrasses, molluscs and crustaceans. Although the coastal waters of Western Australia are poor in nutrients, the standing stock of primary producers—macro algae and seagrasses—is high. Seeking to explain this paradox, CSIRO has shown that the biota of these coastal reefs are able to scavenge low-concentration nutrients from water and to utilize groundwater inputs. Up to 25% of the primary production is recycled in accumulations of detached plant material (wrack) on the beach and in the surf zone. A small animal found in high densities in wrack, the amphipod *Allorchestes compressa*, has been found to play a major role in nutrient recycling. As a major component of the diet of juvenile fish in the surf zone, it is a crucial link between primary producers and other life forms in the food web.



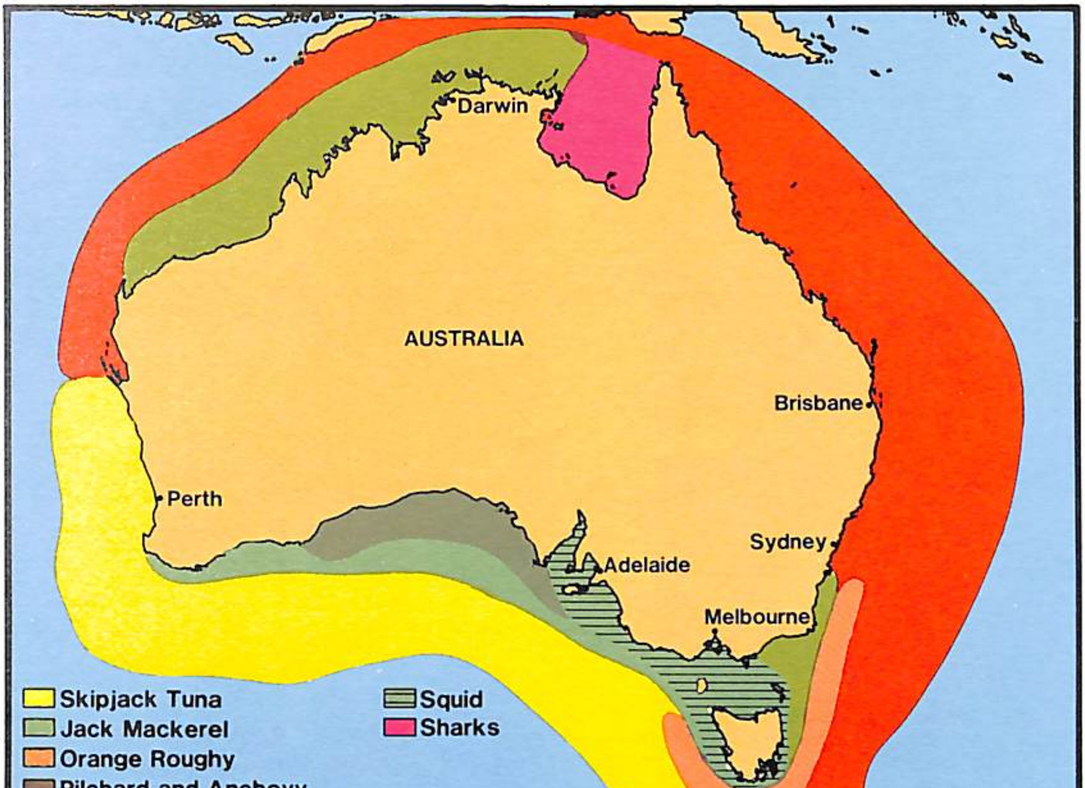
The spawning grounds and migratory pathways of the southern bluefin tuna, Thunnus maccoyii, *showing how different age groups of the species are fished in different regions.*

Southern bluefin tuna. The southern bluefin tuna (*Thunnus maccoyii*) is a highly-migratory oceanic fish which can live for more than 20 years. It is the most important fin fish species caught in Australia, the total value of the catch being $16 million in 1981. The same stock is also fished by Japan and New Zealand, but at a different stage of its life history. The southern bluefin tuna spawns south of the Java coast between September and March when aged seven years or more. Juveniles migrate generally southward to the seas off Australia, then eastward, passing Western Australia, South Australia, Victoria and New South Wales. Juveniles aged 1-5 years are caught by Australian fishermen and scattered adults are caught by Japanese longline fishermen within the Australian fishing zone. Fish passing Australia gradually leave the nearshore fishing areas and are subjected to offshore Japanese longlining (see diagram).

CSIRO studies have revealed that the stock is in a critical biological stage, caused by overfishing. One of the problems in managing the fishery is that the stocks of young fish could be overfished for many years before any effects on the next generation would be noticed. Because of this, and because the Australian, New Zealand and Japanese fisheries are aimed at fish of different ages, CSIRO has developed a novel method for estimating desirable catch levels for each industry, which will stabilize the biomass of the spawning adult fish. The method is based on a mathematical analysis of the age structure of catches, recruitment of fish to the different age groups exploited, and growth rates of the species. A large tagging program has been initiated to update information obtained in the past, and to address questions concerning natural and fishing mortalities, emigration, abundance of local sub-populations, and population structure.

Resource Development

Nearly all existing Australian fisheries occur on the continental shelf within 12 nautical miles of the coast. The 200-nautical mile Australian fishing zone includes large areas of deep water beyond the shelf—only 30% of the zone, in fact, lies within the 200 m depth contour. Major areas of the shelf now added to Australia's jurisdiction lie along the north-west and northern coasts between North West Cape and Torres Strait, with smaller but significant areas in the Great Australian Bight, Bass Strait, and off north-eastern Queensland. Some of these areas are already fished by foreign interests. Taiwanese boats were reported to be catching about 70 000 tonnes of open-ocean and bottom-dwelling fish annually off northern Australia before the declaration of the Australian

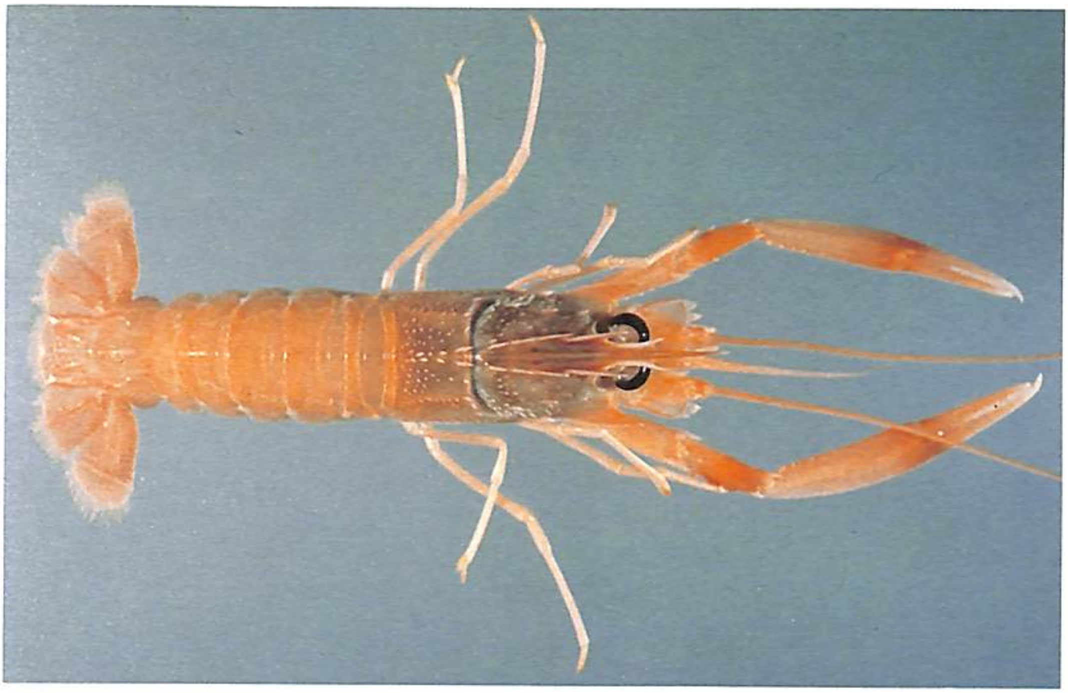


Fishery resources potentially available for Australian development, within the 200-nautical mile fishing zone.

fishing zone. This catch is now limited by bilateral agreement to 20 000 tonnes of bottom-dwelling fish and 7000 tonnes of open-ocean species. A notable resource in southern Australia is the arrow squid, *Nototodarus gouldi*. In 1979-80 a joint Australian-Japanese feasibility fishing program caught 8000 tonnes. Other potential resources (see diagram) include:

. The Coral Sea tunas—yellowfin tuna (*Thunnus albacares*), bigeye tuna (*Thunnus obesus*), and western Pacific skipjack tuna (*Katsuwonus pelamis*).
. Southern open-ocean species—jack mackerel (*Trachurus declivis*), pilchard (*Sardinops neopilchardus*) and blue mackerel (*Scomber australasicus*).
. The southern deepwater species—orange roughy (*Hoplostethus atlanticus*).

The development of new resources is dependent not only on appropriate socio-economic conditions, but also on the biological characteristics of the species which determine the maximum yield that can be derived without destroying the stock, and the type of boat and fishing gear required.



Metapenaeus nephrops, *or scampi, one of several species discovered by CSIRO during a survey of the north-west coast of Australia. Such species, which are regarded as a delicacy, may form the basis of a new deepwater crustacean fishery off the north-west coast of Australia.*

A potential new deepwater crustacean fishery recently identified by CSIRO about 150 km north-west of Port Hedland in Western Australia illustrates these constraints. During experimental trawls substantial quantities of scampi—a crustacean prized by gourmets in many parts of the world—as well as some new prawn types were found at depths between 300-500 m, well beyond the reach of conventional trawling equipment. For the fishery to be developed, CSIRO has examined the shelf waters of northern Australia to determine the principal bottom-dwelling fish and the areas they inhabit. The number of species is large—more than 1,000—but they can be grouped according to their characteristic depth ranges and the types of bottom on which they live.

Shallow coastal waters less than 50 m deep are dominated by small species of scad and trevally (carangids), grunts (pomadasids), goatfish (mullids), silver biddies (gerrids), sardines and anchovies (clupeoids) and leather jackets (*Paramonacanthus* spp.). These sometimes occur in large quantities, catches of 2 tonnes per hour having been recorded.

In deeper waters over muddy sands of the Arafura Sea the predominant fish include hairtail (trichiurids), butterfish (nomeids), threadfin bream (nemipterids), lizard fish (saurids), goatfish (mullids) and the saddle tailed snapper (*Lutjanus malabaricus*).

Deeper bottom fish of the Timor Sea, which has large areas of hard bottom, are characteristically reef fish such as the emperors (lethrinids), snapper (lutjanids) and sweetlips (plectorhynchids).

In the Great Australian Bight all attempts so far to establish commercial fisheries have failed. CSIRO has shown that although bottom-dwelling species do occur, they are restricted to relatively small areas. By comparison with trawl grounds in other parts of the world, the waters are unproductive, probably because of low nutrient concentrations.

Future Prospects

With existing inshore resources almost fully exploited, demersal fisheries off the northern shelf areas could provide opportunities for domestic expansion if markets are available, production costs do not become excessive and fishing by foreign vessels is reduced appropriately. Since such fisheries take a wide range of species, there is a need to know not only the total abundance and productivity of the various species, but also how fishing changes the relative abundance of the species. CSIRO is currently examining these problems in a multi-disciplinary study of the North West Shelf multi-species fishery.

The increasing costs of catching fish in remote areas, and the limits to the numbers of fish that can safely be taken from natural populations, have encouraged the development of farms for fish and shellfish in many countries. Species used are highly-priced fish and shellfish, and a number of viable industries are now operating. In Australia such farming ventures are restricted to various species of oysters and require the input of stock from wild sources. Research into mariculture has proceeded slowly in Australia—there are currently only two significant research programs, one at the Brackish Water Culture Station of the NSW Fisheries Department, and the other a shellfish culture program of the Tasmanian Fisheries Development Authority.

The major biological problems relate to the identification and evaluation of suitable species, the development of appropriate environmental conditions for breeding and larval development, and the development of suitable food. CSIRO has assisted these programs in their attempts to rear larvae, providing pure single-species cultures of algae from its collection of more than 100 species. There is still a need to evaluate the farming potential of different species of marine animals, and to investigate their physiological and nutritional requirements, and, by selective breeding, to improve the stock.

The present methodology for fishery management derives from single species fisheries of temperate areas and is often inappropriate for Australia's fisheries. In Australia the tropical and sub-tropical nature of many of the existing and potential fisheries requires a new approach to the development of scientific management strategies. Through its detailed studies of fishery resources in their natural environment, CSIRO seeks to understand the characteristics of the stock and its environment, and to develop methodologies appropriate to each fishery so alternative management strategies can be evaluated.

Regulation of Fisheries

With the exception of the culture of oysters for the table or for pearls, most of Australia's marine fisheries have been directed at resources freely available to anybody wishing to buy a boat and go fishing. In a developed fishery, such common property resources will become subject to excessive fishing pressure which, in the absence of controls, usually results in the depletion of the resource to a level where the fishing is uneconomic, and stock may be further reduced to extremely low levels.

Recognizing the importance of a stable industry, Australia has established a number of regulatory agencies, divided between the State and Commonwealth Governments. The former exercise control over inland fisheries and marine fisheries within 3 nautical miles of the coastline, with the Commonwealth controlling fisheries in the remaining offshore waters under Australia's jurisdiction.

To facilitate uniformity in regulations and policy, a number of committees and sub-committees with representation from State and Commonwealth Governments deal with specific or regional problems related to particular fisheries. This arrangement is soon to be developed into regional joint authorities.

The CSIRO Division of Fisheries Research provides scientific advice to these committees, but itself has no direct management power. By carrying out scientific research in relation to fisheries under Commonwealth jurisdiction, or at the request of, and in co-operation with the States in relation to fisheries under their control, the Division is able to provide scientific and technological advice for the utilization and conservation of Australia's living marine resources. Previously the Division has been primarily concerned with research into existing fisheries, but with the declaration of the 200-nautical-mile fishing zone, greater emphasis is being placed on undeveloped and potential fisheries. The CSIRO Division of Food Research provides advice and information about the handling and preservation of the catch.

In the past, most fisheries research concentrated on only a few aspects of the food chain, with greatest emphasis on adult stocks. CSIRO now has the expertise to undertake integrated studies of the whole food chain and related physical and chemical processes. The devastating collapse of the Peruvian anchovy fishery was due to a combination of physical and biological factors—a change in wind and ocean circulation patterns, plus overfishing and altered age structures. Such an experience points to a compelling need for an integrative and predictive approach to understanding the exploited and potentially exploitable species in Australian waters, and the food chains on which they depend.

17. New materials

Stone Age, Bronze Age, Iron Age—the names assigned to civilization's ages reflect the profound influence of new materials upon human progress. The modern age is no less characterized by the search for new or improved materials, and the quest for new applications.

Inquiry into the nature and properties of materials may yield new and unexpected applications. The phenomenon of superconductivity, in which a material's electrical resistance vanishes, was originally observed in 1913 in mercury cooled to -269°C. Later, other superconducting materials and applications for the effect were found. There followed a quest for superior materials for these applications—for example, new alloys to improve the performance of electro-magnets wound with superconducting wire. Today, the search has shifted to materials which will be superconducting at higher temperatures, even at room temperature. New properties lead to new materials, new materials to new applications, new applications to new materials with different properties. It is this triple thrust of property, application and material that characterizes materials research.

The brittleness of a ceramic, the decomposition of a polymer by sunlight, or the poor efficiency of an industrial catalyst, can each be ameliorated if the underlying physical or chemical processes are thoroughly understood. This article describes several examples of CSIRO research aimed at developing and understanding new materials, and identifying applications for them.

Ceramics

Ceramics have been produced for thousands of years by firing or baking clay and, more recently, by sintering mineral powders. The well-known properties of ceramics include chemical inertness, corrosion resistance, hardness, and strength at high temperature. However, the use of ceramics in industry has been limited by their brittleness and tendency to shatter if subjected to physical shock or rapid temperature change. A tough, non-brittle ceramic has been needed, but has proved elusive. CSIRO has now developed such a material, based on zirconia.

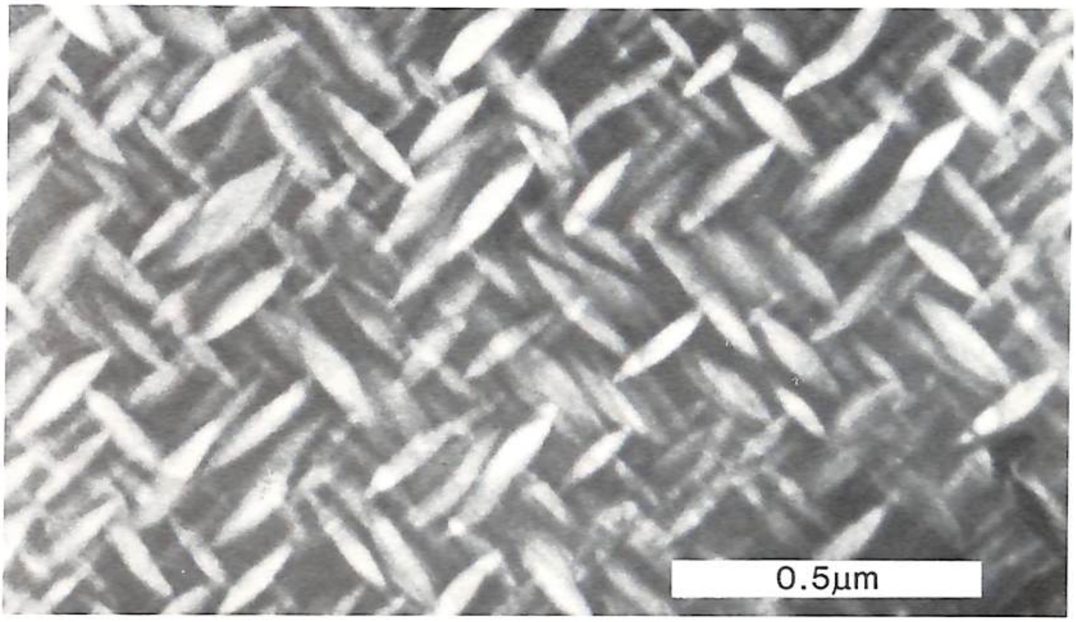
Zirconia is the oxide of the element zirconium and is obtained from the mineral zircon, which is abundant in Australia. Australia supplies about 80% of the world's output, so it is appropriate that work aimed at making use of the resource should be carried out in Australia by CSIRO.

In 1974 a research group at the CSIRO Advanced Materials Laboratory discovered a toughening phenomenon in zirconia ceramics which today promises to be the basis for a large new growth industry.

The material in which the phenomenon was discovered was partially stabilized zirconia (PSZ), and the phenomenon itself is now widely known as transformation toughening.

Like most ceramics, zirconia in its pure form (ZrO_2) is chemically inert, but is a poor ceramic because of a mechanically-damaging phase transformation which occurs in its crystal structure when it is cooled after firing. At very high temperatures the crystal structure is cubic, transforming to tetragonal at intermediate temperatures and monoclinic at lower temperatures. The tetragonal-to-monoclinic transformation is particularly damaging because it is accompanied by a volume expansion of about 4%. The problem can be avoided by 'alloying' zirconia with sufficient oxides of calcia, magnesia or yttria, causing the cubic crystal phase to be retained at all temperatures. This form is called fully stabilized zirconia, and although it is often used in thermal barrier coatings, it has very poor resistance to thermal shock.

Partially stabilized zirconia (PSZ) is produced when the alloying additions fall below the minimum level for full stabilization. Instead of a totally cubic structure, the material then consists of a cubic alloyed matrix containing pure zirconia particles. A version of PSZ with moderate mechanical properties, in which the zirconia particles are moderately large and monoclinic in form at room temperature, has been known and used for some time. However, the breakthrough in ceramic technology came when specimens of PSZ were produced with extremely fine precipitate dispersions.



The microstructure of partially-stabilized zirconia, showing the elongated monoclinic crystals formed when the ceramic is subjected to abrasion. The intricately-interlocked nature of the material makes it exceptionally resistant to cracking.

It was found that in these fine microstructures zirconia precipitates can be predominantly tetragonal, and with careful heat treatment these can be activated so that when localized stresses are applied, they 'flip' from the tetragonal to the monoclinic crystal phase. In doing so, they set up compressive stresses in the neighbouring matrix phase.

Properties quite unique to ceramic materials arise from this tailoring of microstructure:

- Surface grinding induces precipitate transformations close to the surface, which, through dilation, give rise to high surface compressions and enhanced bending strength.
- The same surface compressions increase the ceramic's strength reliability (Weibull Modulus) to unprecedentedly high levels.
- Transformations occurring in the stressed regions near crack tips effectively oppose crack extension and enhance toughness.

These features—high strength, mechanical reliability and toughness—combine to produce a surface that is highly resistant to damage.

They combine further with other characteristics—low thermal conductivity, high thermal expansion, resistance to thermal shock, low specific heat, good high temperature sliding friction and high corrosion resistance—to produce a novel ceramic with great industrial potential.

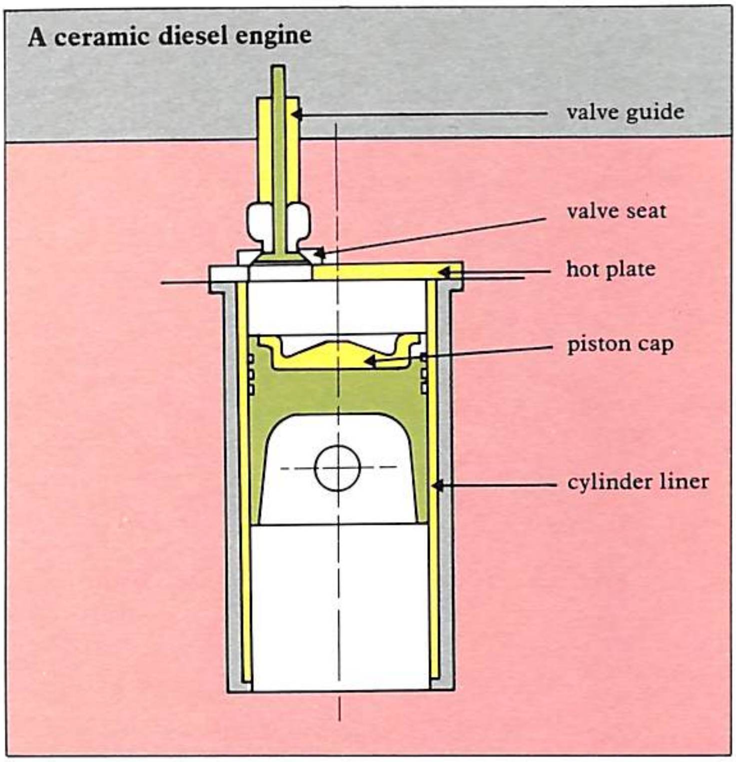
Broadly, it is expected PSZ will be used in the following situations:

- Where abrasion resistance to fine particle damage is required for example, in slurry erosion—employing the ceramic's high surface integrity.
- In scuffing and metal extrusion operations where surface integrity and good friction properties are required.

- On high-temperature diesel engine components where high strength, toughness, reliability, thermal shock resistance, abrasion resistance, high thermal expansion, low thermal conductivity, low specific heat and resistance to sliding seizure are all used to utmost advantage.
- In highly corrosive environments where chemical stability is a prime requirement.

In practice, it has been found that subtle microstructural changes in PSZ can have marked effects on performance, and tailoring of different versions of the ceramic will occupy research and development for some time to come.

Areas shaded yellow indicate areas of a diesel engine where partially-stabilized zirconia components could be substituted—in valve guides, cylinder heads, piston caps and cylinder walls.



An Australian firm is collaborating with CSIRO in manufacturing and developing PSZ components. PSZ extrusion dies are now available world wide, and the market for these dies alone has been estimated at about $10 million. Diesel engine components are being tested in the United States and Japan, and could provide the greatest economic benefit of any application for the new material. Recent work has exploited the toughness and chemical inertness of PSZ in the manufacture of experimental hip joints for animals. Experiments with rabbits have shown PSZ is not attacked by the body, and human prosthetic applications are likely to follow. As research and development of PSZ continues, further applications are likely to be found.

Organic Polymers

The chemical industry has developed many organic polymers—plastics—in the past 50 years, including nylon, polystyrene, polyvinylchloride (PVC) and acrylic. Although relatively new when compared to ceramics, their uses are at least as widespread. Organic polymers are long chain-like molecules composed of many tens of thousands of simple, identical, organic molecules linked together in a process called polymerization. CSIRO is studying many aspects of polymer science, including the area discussed here, polymer defects.

The polymerization of a molecule such as vinyl chloride, CH_2CHCl, proceeds as shown in the diagram. At the centre of a vinyl chloride molecule—a monomer—a pair of carbon atoms are joined by a double chemical bond. Polymerization begins when an initiator or starter molecule (labelled R)

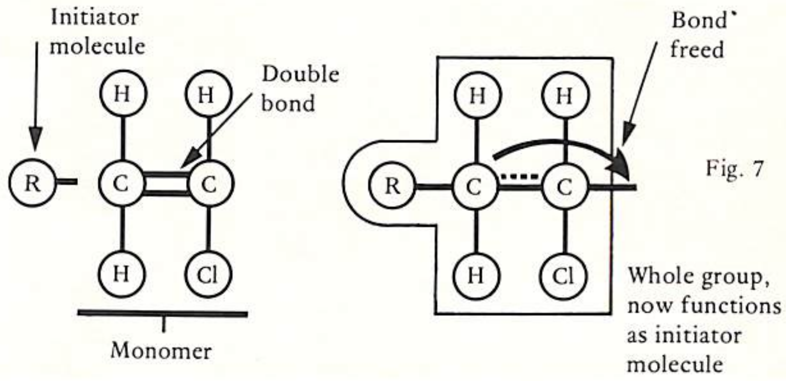
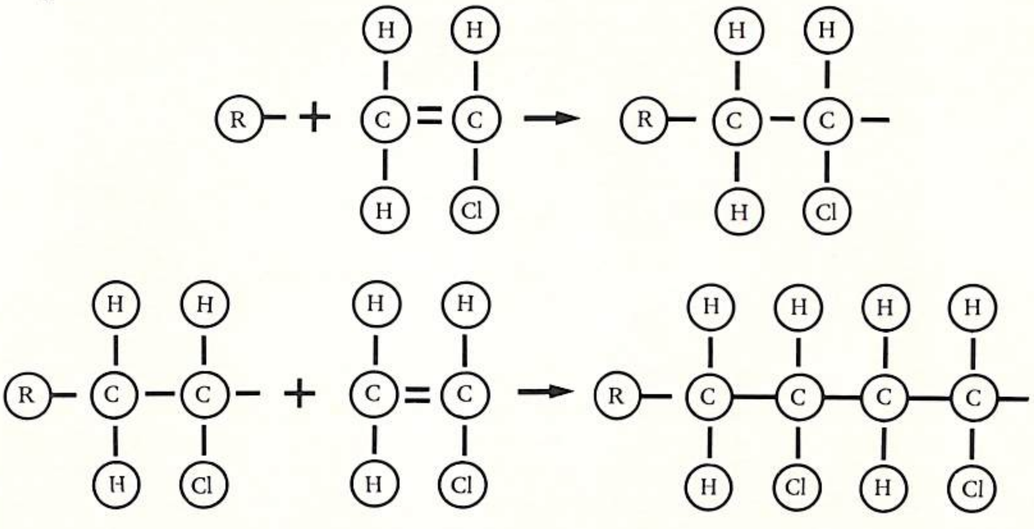


Fig. 7

attaches to the monomer, causing one of the bonds to be freed (Fig. 7). This new molecule encounters another monomer and with its free bond, causes the monomer's double bond to break. This in turn frees yet another bond which can repeat the process with another monomer and so on, in a chemical 'domino effect' (Fig. 8). Ideally, the process would unerringly add extra building

Fig. 8

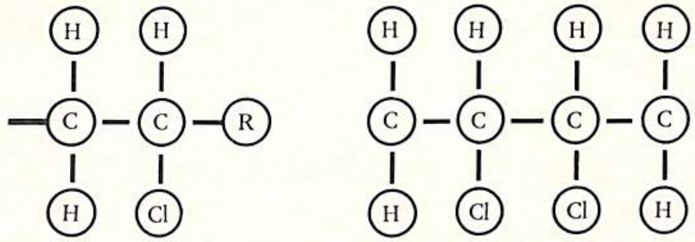


blocks of vinyl chloride until terminated, and the polyvinylchloride produced would remain stable at temperatures exceeding 300°C, the limit promised by its molecular properties. In reality, PVC breaks down at temperatures below 120°C, probably because of errors in the polymerization process. Indeed, the polymer molecule is similar to the well-known zip-fastener—one defect and the entire structure may be undone. An understanding of these defects should lead to the development of improved polymers.

One possible type of defect is the attachment of the initiator molecule on the wrong side of the monomer (Fig. 9), or its incorporation within the chain. Instead of the orderly propagation shown in Fig. 8, back-to-front molecules may result within the chain, or branching may occur. Each defect will be a weak link in the chain and will degrade the plastic's properties.

CSIRO's research into this problem is concerned with identifying and understanding defects, and eliminating them. A defect occurring only once or twice in a chain thousands of units long

Fig. 9



Defect caused by reversal of initiator molecule

poses a formidable identification problem, but by allowing the polymerization reaction to proceed only a few steps, the steps intermediate between monomer and polymer can be analysed in detail. It is much easier to analyse any defect occurring in these intermediate molecules than in the entire polymer chain.

In the past, an industry's choice of a particular initiator molecule tended to be influenced by economics, because initiators were thought to produce the same result regardless of their specific chemistry. CSIRO has found that different initiators do alter defect frequency, and has used the 'arrested reaction' technique to study these differences. Some initiators break down more readily than others, and the rate of breakdown has been found to be temperature-dependent. Understanding the nature and cause of polymer defects will allow them to be eliminated, reducing costs in the chemical industry. Benefits will also flow from improved polymers which more closely approach their theoretical performance limits.

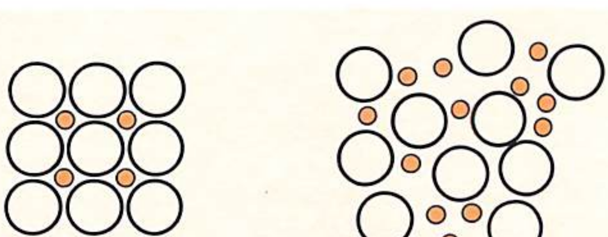
Another possibility arising from these studies is the deliberate introduction of defects into polymers, which will cause them to decompose at a predictable rate when exposed to sunlight or other agents in the environment. Although disposable plastic containers are an obvious use, the field is one in which new applications will wait the technology.

Metallic Glasses

A very recent development in materials science is the discovery of metallic glasses. The type of glass used for centuries in windows or glass objects is an insulator, whereas metallic glasses retain the electrical properties of metals which are normally conductors.

A metal normally solidifies with its constituent atoms arranged in some well-defined and repetitive structure, that is, in a crystalline state. Even if these crystals are only microscopic and the solid contains different crystal forms, its electrical and mechanical properties are dominated by the crystallinity. The atoms of a glass are arranged completely randomly, as in a liquid, giving metallic glasses certain properties not found in normal metals.

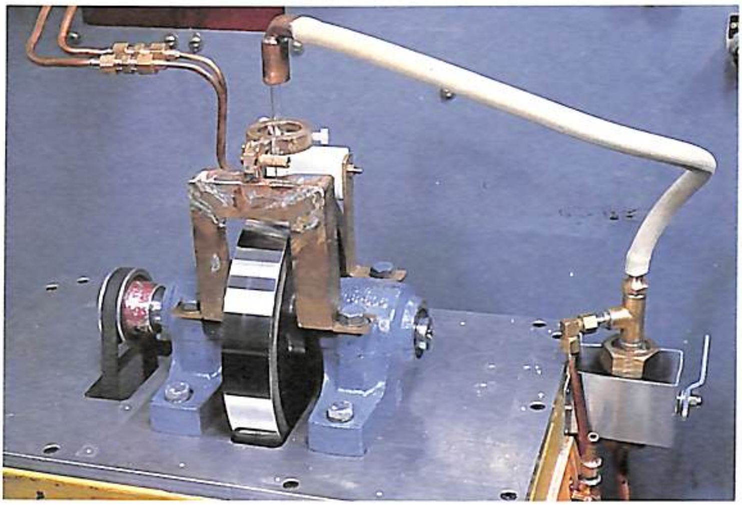
There are a number of different ways to make metallic glasses, but each involves extremely rapid cooling to 'freeze' the atoms before they can become ordered into crystals. Commonly, the molten metal–usually an alloy–is cooled from around 1000°C to room temperature in a thousandth of a second. Two techniques employed for this rapid cooling are laser glazing and quenching on a rotating roller. In the former, an intense laser beam melts a small surface area of the solid.



Normally a metallic alloy exhibits a regular crystalline structure. In a glassy alloy, atoms are randomly distributed.

When the laser is switched off, the melted area loses heat very rapidly to the surrounding region and the melt solidifies in a glassy form. In the latter technique, molten metal is squirted onto a cold, rapidly-rotating metal wheel. At the instant of contact, the metal freezes and is spun off as a ribbon of metallic glass.

The apparatus used to produce glassy metals. The molten sample is propelled by pressurized helium through a quartz nozzle on to the rotating chromium-plated wheel, where it solidifies in about a thousandth of a second and is spun off.



The properties of glassy metal alloys are in many ways superior to those of conventional metals. Ribbons of some iron-based glasses have greater strength than high-tensile steels, yet can be bent double without fracturing. Other glassy alloys have great resistance to wear, or show corrosion resistance superior to stainless steel. Wear-resistant glassy alloys are already being used in tape-recorder heads, while a flexible, corrosion-resistant ribbon could advance the prosaic but highly-profitable razor blade industry by providing a continuous, wind-on razor blade. Flexible glassy metals could also be used to strengthen tyres while minimizing rolling resistance.

In the electrical power industry, transformer cores made of glassy metal alloys have been found to reduce the power losses caused by heating or vibration by more than half. In the United States alone, the cost of such losses is estimated at $1000 million dollars annually. More efficient electrical motors, capable of producing the same power from half the size, could also result. Many other applications await a more thorough understanding of the nature and properties of glassy metals, and the development of new glassy alloys tailored for specific uses. CSIRO and several Australian universities are involved in these studies.

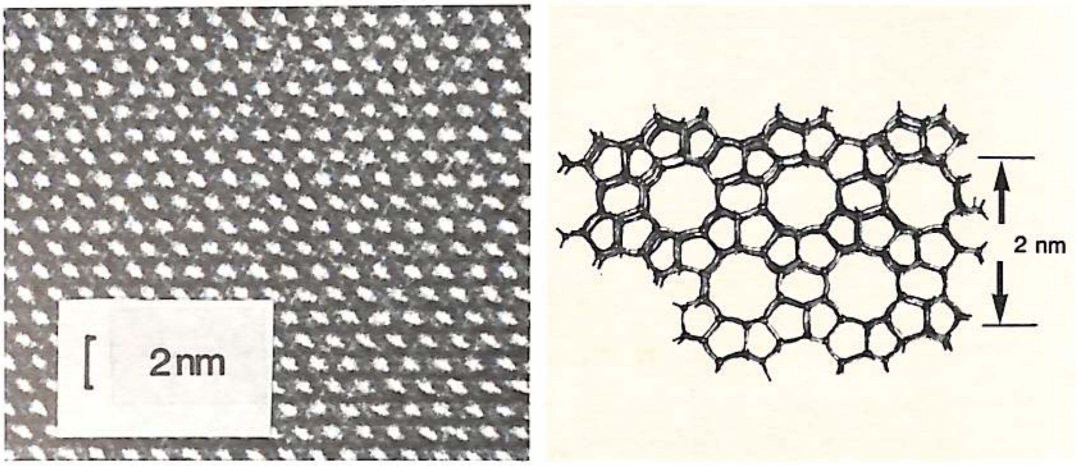
Zeolite Catalysts

The importance of a detailed understanding of the link between the structure of solids and their properties is nowhere better displayed than in CSIRO's work on catalysts. Catalysts are materials that promote particular chemical reactions without being consumed. They are particularly important in the petroleum and petrochemical industries where they assist in the conversion of crude oil to a wide range of products, including fuels, solvents and chemical feedstocks, and in the synthesis of a very wide range of chemical derivatives used in modern society.

Many different catalysts are used in these applications, and in most cases the economic success of an industrial catalytic process is determined by the activity and selectivity with which the catalyst effects the required transformation; that is, the speed of the conversion, and the extent to which the catalyst can suppress the formation of unwanted by-products. The search for ways of improving catalytic activity and selectivity is continuous.

CSIRO is investigating the synthesis and performance of a group of catalysts called zeolites, which offer great benefits in terms of activity and selectivity, particularly the latter. Zeolite catalysts are of great importance in the synthesis and conversion of hydrocarbons and are thus of particular relevance in fuel synthesis.

Zeolites are minerals, mainly alumino-silicates, whose structure contains regular arrays of channels, typically 0.5-1 nanometre in width. In synthetic zeolites, the size of these channels and the active atoms within them can be modified to produce efficient, selective catalysts for specific reactions. The synthesis of para-xylene (which is used ultimately in the manufacture of polyester fibres) is an example where the zeolite channel size can be 'tailored' to select the desired product and to reject the formation of the somewhat larger ortho- and meta-xylene isomers.



An electron micrograph showing the regular channel array of the zeolite catalyst, ZSM-5, magnified more than 3 million times. The channels, which appear as white dots, are the site in which catalytic reactions occur. At right: The skeletal structure of the zeolite is depicted in the model.

Catalysts are essential for the synthesis of fuels and other chemicals from so-called 'syngas', a mixture of carbon monoxide and hydrogen. Syngas can be obtained from sources such as natural gas, coal gasification and from biomass. Using the Fischer-Tropsch Process, (a catalytic process which synthesizes hydrocarbons from hydrogen and carbon monoxide, currently used for synthetic fuel production in South Africa), syngas can be converted to a variety of more complex molecules. Separation and subsequent treatment of these products is a fundamental problem in the process. Selective synthetic zeolite catalysts promise a means of controlling products of the Fischer-Tropsch Process and similar synthesis reactions.

Selectivity can be achieved by geometric constraint at the molecular level, but the chemistry of the sites in the catalyst where reactions take place is also of great importance. Different types of site catalyse different reactions, which may in turn be steps in a chain of reactions leading up to the final product. The progress of a chemical reaction can be controlled by altering the abundance of specific sites, and their accessibility to particular molecules.

Several aspects of catalysis must be understood before catalysts can be improved on something more than a hit-or-miss basis. CSIRO's scientists are studying the chemistry and kinetics of reactions, and the influence of different catalysts. The structure and surface properties of different catalysts are being intensively studied, so their precise role in reactions can be understood. In many cases this requires the use of model catalysts which are simpler than those which are commercially viable, but which allow detailed molecular conversion mechanisms to be elucidated. Mechanistic insight leads to insight, understanding and ultimately, control of complex industrial processes. All the weapons of chemistry, from fundamental research techniques to industrial field trials, are being used to attack this challenging group of problems.

Surface Properties of Materials

Scientists can alter the bulk properties of materials to suit particular applications, as exemplified by the development of PSZ. Although surface properties are the focus of research into zeolite catalysts, it is still changes to the bulk structure of a zeolite that underly its altered surface properties. With some other materials, however, applications may only require changes to surface rather than bulk properties.

To produce wear-resistant steel, only the surface needs to be hard (and as a consequence, brittle) while the remainder of the object may exhibit toughness, magnetism or other properties. Surface-hardening techniques have been known to Japanese sword-makers for centuries.

More recently, ion implantation techniques have been evolved for controlled modification of the surface properties of materials. A cloud of atoms, usually generated by evaporation from a solid source, is converted to positive ions by removal of electrons. These ions are then accelerated by a large electrical potential, of the order of 50.000 volts, to form an ion beam. The depth of ion penetration into the surface layers of the chosen solid is regulated by the energy or voltage of the beam, and the ions can be targeted with great precision. The type of ion implanted is determined by its source, and can be changed as required.

CSIRO has recently set up an implantation facility to exploit the many opportunities which ion implantation offers. It has already been used to implant nitrogen ions in the surface of a bearing steel, substantially improving its hardness. Small tools such as cutting wheels could be treated in this way to increase their durability or versatility. Ion implantation has also been used experimentally in solar cell development. Studies are concentrated on the nature, position and density of ions in the host material, and the influence of these factors on the electrical properties of the solar cell.

Surface science is still in its infancy and many of its techniques are still being developed. Progress in this field, like progress in any other aspect of research, is based on a fundamental understanding of the instruments used, and the data they provide. From this, scientists derive explanations for the behaviour of materials, and develop ways of changing the material to achieve particular ends. Without understanding why zirconia is brittle, scientists could not have evolved a method of toughening it. Without a knowledge of the structure of zeolites, and the chemical reactions they catalyse, catalysts for specific reactions could not be developed.

The impetus for materials research comes from many sources. Curiosity about a material and its properties, or the need to adapt it to different applications, have both led to modification of existing materials or the development of new ones. Underpinning these advances is the strategic or long term research that provides explanations and enables predictions to be made about a material's properties. In CSIRO, these strategic studies are carried out in parallel with tactical research that has more immediate goals, to the mutual benefit of both types of research.

18. Improved minerals and coal processing

After mining, almost all mineral ores and coal are processed in various ways to upgrade their content of valuable material and to remove unwanted impurities. These operations reduce the tonnage of material to be handled in later stages and increase the export revenue earned.

Major improvements have taken place in mineral and coal processing in the last decade. Two important areas of advance are the development of nuclear on-line sensors that continuously analyse the material being processed, and the improved understanding industry has gained of the fundamental scientific principles that apply in these processes. These advances have led to better control of processing operations and better recoveries from them. CSIRO has contributed to such improvements in several ways.

Accurate Analysis

Australia is a world leader in the use of nuclear techniques for analysing ores and coal. The techniques are based on the use of penetrating radiation, such as gamma rays and neutrons, for analysing large volumes of material. The analyses can be made directly on material in the plant process stream—for example, on a conveyor belt or in mineral slurries.

This 'on-line' analysis overcomes the principal disadvantage of conventional techniques, which depend on taking a representative sample from the process line and analysing it in a chemical laboratory. The delays involved mean that the analysis is obtained long after the ore has passed through the plant.

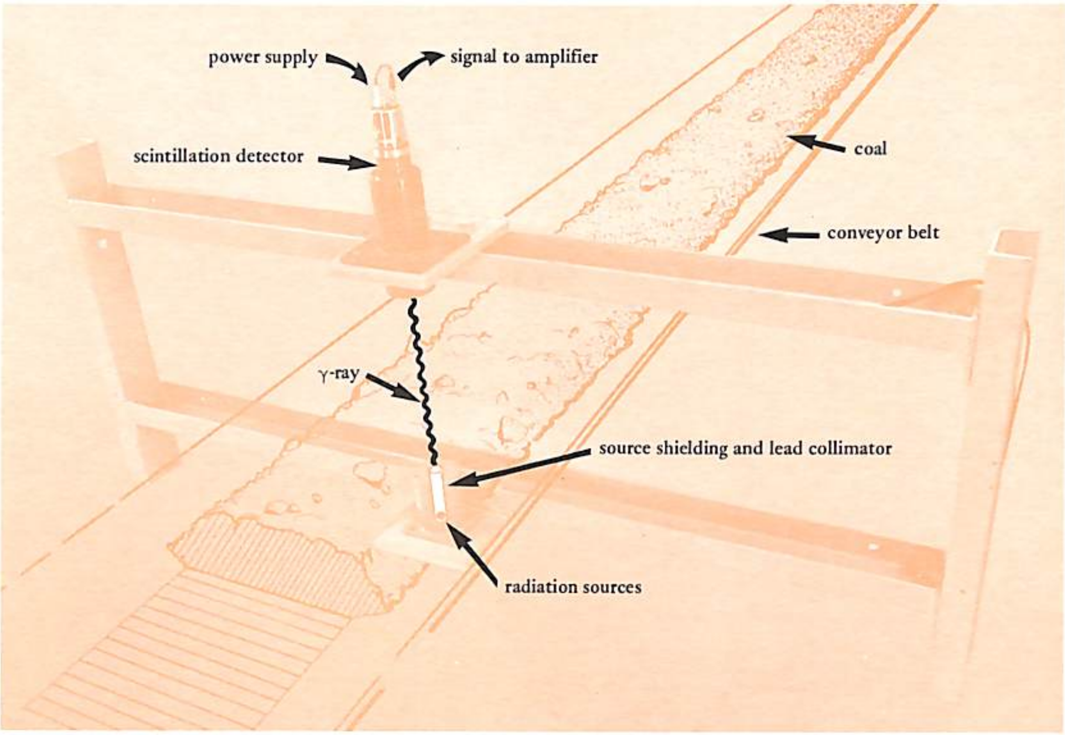
Continuous on-line analysis leads to better control of processing operations because plant operators know the concentrations of valuable materials in the various plant process streams. The operators can react quickly to changes in, for example, ore grade, adjusting operating conditions to maximize recovery of valuable mineral. Ultimately, the computer can be used to aid operators in this task.

In CSIRO, nuclear techniques are being developed to determine the concentrations of ash in coal and, within the ash itself, the levels of the elements aluminium, silicon and iron. The technique has been extended to measurement of the amount of solids and the ash content of coal in coal/water slurries, and the moisture content and calorific value of coal. Analysis techniques have been tested for iron in iron ores; aluminium and silicon in iron and aluminium ores, and manganese and aluminium in manganese ores. CSIRO is also developing on-stream analysis techniques for mineral slurries using high resolution X-ray detectors, and techniques to determine concentrations of sulphur, lead, zinc and iron in ore concentrate streams in smelting operations.

The project for determination of the ash content of coal illustrates the nature of the research procedure. The study was initiated within the Australian Atomic Energy Commission (AAEC) which has also been active in developing nuclear analysis techniques for the minerals industry. Such work has been continued by CSIRO since the transfer of AAEC staff to the Institute of Energy and Earth Resources last year.

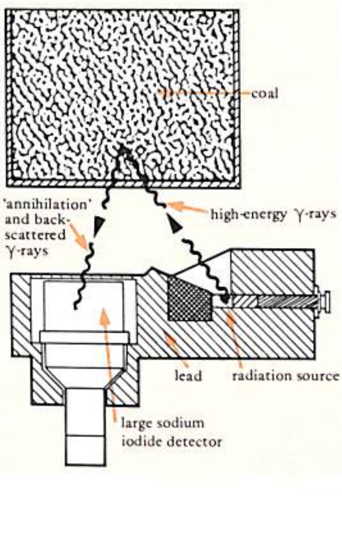
Ash is the residue left after the burning of coal and consists mainly of silica and alumina and some iron oxide. For control and usage purposes it is important to know the ash content during processing and coal cleaning. Two nuclear techniques, called SIROASH, have been developed to make these measurements. They depend on the differences between the nuclear interactions in the ash and the combustible part of the the coal. One technique involves measuring the absorption of low-energy gamma rays per unit weight of coal, and is recommended for use on product lines from coal washeries. The other depends on a high-energy gamma ray interaction called 'pair production' and is recommended for use with coals containing more ash, such as those going into coal washeries.

Both techniques were first tested in the laboratory on large coal samples. The low-energy gamma-ray technique was then tested at the coal washery of BHP Minerals Pty Ltd at Emerald, Queensland. Measurements were made directly on coal on the product line conveyor, demons-



Two technologies for determining the ash content of coal 'on line'. Above is the low-energy gamma ray (LEGR) SIROASH gauge, which measures ash content in a stream of moving coal by measuring the absorption of low-energy gamma rays passed through it. It is most suited to low-ash coals. For high ash coals, the pair production gauge, illustrated in the diagram at right, is preferred. In this device, high-energy gamma rays interact with atoms in the coal, producing two types of gamma rays whose intensities yield a measure of the ash content. Both devices are accurate to less than 0.5% by weight of ash.

Cross-sectional view of the Pair Production gauge



trating that the ash content could be determined accurately in the harsh environment of a coal washery. CSIRO and BHP are now testing the techniques on a coal washery conveyor in Newcastle, New South Wales with the support of grants under the National Energy Research, Development and Demonstration Program.

Mineral Control Instrumentation Pty Ltd (MCI) of Adelaide, South Australia, has been licensed to manufacture and market the two SIROASH instruments. Two instruments using the 'pair production' principle have been installed at coal washeries and CSIRO, BHP and MCI are soon to install an advanced prototype of the low-energy gamma-ray gauge on a product line conveyor belt at Newcastle.

The experience gained in development of on-line analysers is to be put to use in an Australian aid project being undertaken within the United Nations Development Program's Regional Project on Industrial Applications of Isotopes and Radiation Technology. The project, extending over the period 1983-86, involves:

- training courses both in Australia and in the Philippines relating to on-stream analysis and control of mineral concentrators
- installation of an Australian on-stream analysis system in a concentrator in the Philippines
- work to improve control of this concentrator
- in-plant training for Asian metallurgists and control engineers.

The four Australian organizations involved are CSIRO, The Australian Atomic Energy Commission, the University of Queensland and the Australian Mineral Development Laboratories. The overall project will cost about $1 million. The Australian Development and Assistance Bureau will supply $655 000, with the rest being provided by the United Nations and the various organizations involved.

Mathematical Modelling

Simulating a processing system mathematically is one way of establishing the fundamental principles that operate in mineral processing. Mathematical descriptions are developed to describe the fundamental physical and chemical phenomena involved in the various stages of a process. A model is built up using these and other descriptions representing the larger-scale phenomena.

Predictions from the model are then compared with actual measurements from the process. If the predictions are correct, then the assumptions as to the underlying scientific principles are proved to be reasonable. If predictions are not accurate, the model is altered until it matches the observed conditions, a process called 'validating'.

CSIRO has considerable experience in the mathematical modelling and computer control of a number of different mineral processes involving iron ore. This work started in the early 1970s and has been undertaken in collaboration with various Australian companies. The processes and the ores treated are quite different from each other, so research and application of results must be tailored to individual plants and there must be close involvement of the personnel who operate the plants.

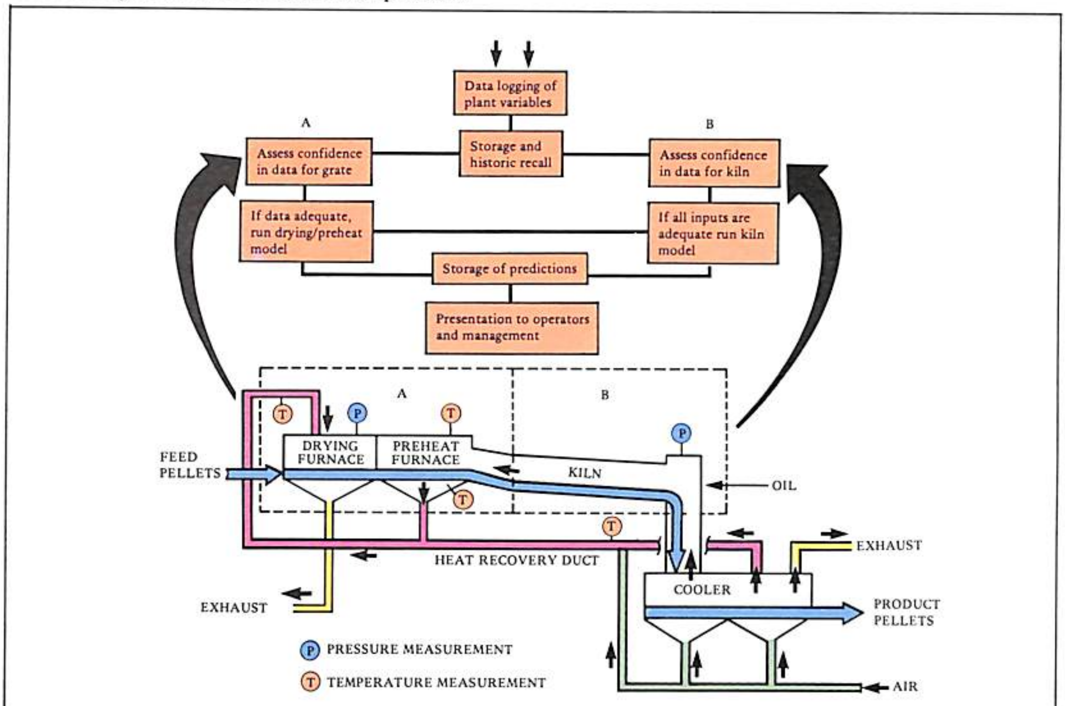
The drying and heat-hardening of iron ore pellets in grate-kiln furnaces provides an example of development, validation and use of models in processing. The research was done at a time when a substantial quantity of Australia's iron ore was exported in the form of pellets. Most pellet-making plants are now closed temporarily because of lack of demand for pelletized iron, but the research is still applicable to remaining and future pelletizing operations.

In pelletizing plants, the moist pellets are first placed in a deep layer, or bed, on a supporting grate that moves slowly through drying and preheating furnaces while hot gases are drawn down through the bed. The dried and partially-hardened pellets then travel the length of a kiln and are raised to approximately 1300°C by exposure to a large flame. The pellets are then laid as a bed on a travelling grate where they are cooled by a flow of fresh air. This air, heated from contact with the pellets, is fed back to the kiln and the initial drying furnace. Similarly, the gases from the kiln are used in the initial preheating furnace.

Because of the interactions between various furnace zones, the optimum operating conditions are difficult to discern and the mineralogical and thermodynamic state of the pellets through the process cannot be measured directly. The constantly varying nature of the process, the interactions, the complexity and the impossibility of measuring the actual states of the pellets contrive to make direct experiments on full-scale operating plants difficult or inconclusive. Direct experiments are often costly and sometimes hazardous as they may force the whole process beyond acceptable operating conditions. The full-scale plant is not the ideal environment in which to establish cause and effect.

Early work to develop and improve the process utilized laboratory-scale versions of parts of the process. However, these have limited use because it is impossible to scale down simultaneously all the factors that describe the full-scale plant and some phenomena that occur on the full-scale plant are absent on the laboratory scale.

The CSIRO approach was to develop a mathematical model of the process, built on the relevant observations but which also used control theory and chemical engineering concepts to provide a quantitative description of the total process. After validation, such a model is capable of establishing cause and effect in the process.



How computerized process control works in an iron ore pelletizing plant. The dotted lines show how the furnace and kiln processes are modelled independently, and then integrated in a computer model. The model employs data relayed from pressure and temperature sensors strategically placed throughout the plant. Operators can use the model to predict the effects of altering particular steps of the process, before any alteration is actually made.

The process was divided into three main sections: the drying/preheat furnace, the kiln and the cooler. The kiln was treated as a number of 'finite elements' within which the fundamental physical and chemical mechanisms were described mathematically. This involved deriving equations for:

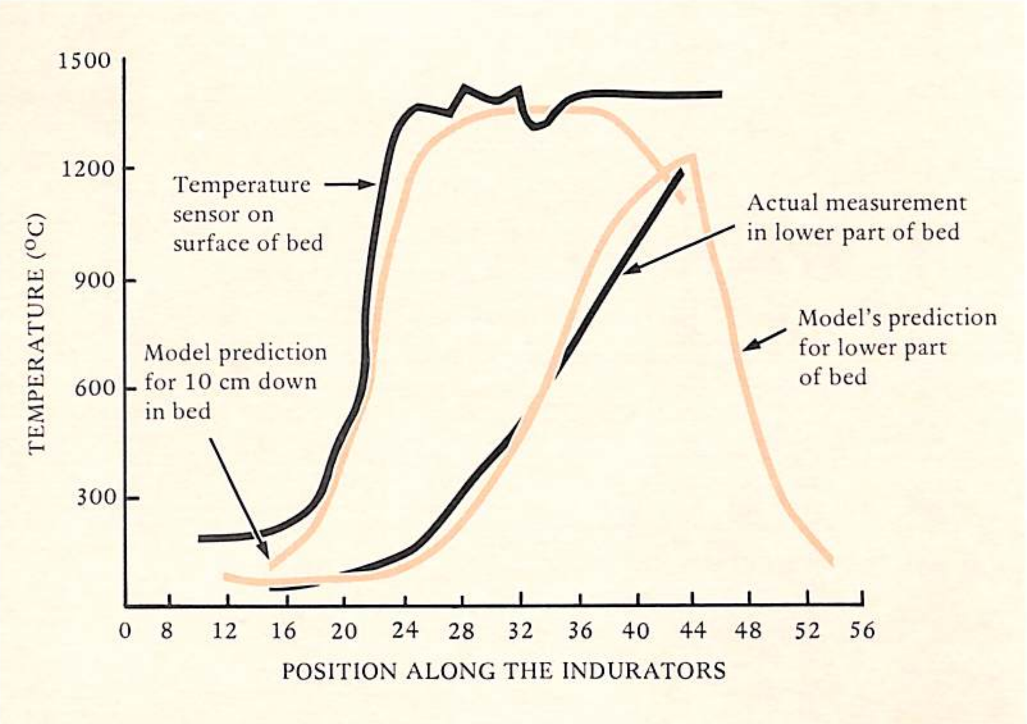
. combustion and mixing processes in the gas
. convective heat transfer from the gas to the wall of the kiln and to the pellets

- heat transfer and mineralogical changes within the pellets
- mixing and movement of pellets along the kiln, and
- conduction of heat through the wall and its loss to the surrounding air.

These equations, representing a set of assumptions about the physical and chemical mechanisms of each finite element in the full-scale kiln, were then solved simultaneously.

The other two main sections of the plant model involved gases flowing through beds of pellets, which meant that drying, heat transfer by convection, gas flow, chemical reactions and mixing phenomena had to be considered. Finite element models were formulated and solved in a similar manner to the kiln section.

The models for the three process sections, together with models of the process controllers and of the gas blending and pressure balance constraints, were then all solved simultaneously to yield a detailed mathematical simulation of the entire process.



During the validation of a model, its performance is compared with actual data from the process being modelled. Here, there is close agreement between the model's predictions and actual measurements obtained from sensors monitoring the pellet-firing process.

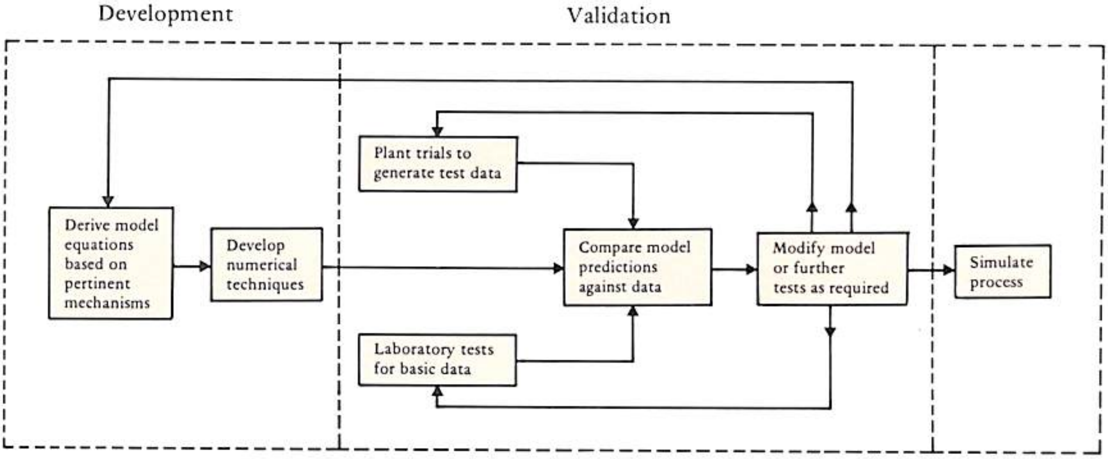
Validation was undertaken by comparing model predictions with measurements routinely available or taken during plant trials. Discrepancies between model predictions and plant measurements were taken to indicate that other fundamental physical and chemical mechanisms were at work, or that parts of the model were not correctly conceived. Revisions were made until the discrepancies were eliminated. The validation step highlighted some areas where basic information was lacking and appropriate research was undertaken in the CSIRO laboratories.

The validated model of iron ore pellet induration developed by this work is a powerful tool that has been used to simulate plant operations, to investigate process interactions, to establish the effect of equipment design changes, to investigate possible improvements to plant performance and to develop improved control strategies. This was achieved without costly or hazardous direct experiments on the plant. The CSIRO studies have led to a greatly improved fundamental understanding of the process, have demonstrated how its design could be improved, with resultant considerable savings, and have indicated the potential for improved process control. As a result, the consistency of product quality has improved and fuel consumption has been significantly reduced.

Computer Control

Sophisticated computer control schemes are feasible in large mineral processing plants in Australia because they have process control computers as integral parts of plant instrumentation.

A novel approach, pioneered by CSIRO, is to equip plant computers with appropriate versions of the type of mathematical model described earlier. These 'on-line' models can then be used to help plant operators and management predict the real but frequently unmeasurable states of the process, such as the maximum temperature of the pellets in the kiln and their resulting mineralogical state. While mineralogy can ultimately be determined from laboratory tests on sample pellets some hours later the immediacy of information from the on-line model allows direct control of process upsets. (The nuclear sensors being developed by CSIRO will also be of considerable use here.)



How mathematical models are developed. This diagram shows the role of laboratory and plant experiments, and the way in which the validation process requires a repeated 'looping' back to earlier steps until the model adequately matches the real process.

The models must be streamlined for on-line use by removing some of the exacting emphasis on detail or using more efficient numerical methods suited to smaller computers. They have other features peculiar to a computer control environment. The plant measurements must be converted, stored and recalled in a form suited to the mathematical assumptions of the model. The model predictions must also be in a form suitable for operators and management. These presentation tasks involve the obvious skills of ergonomics and communications as well as the art of diplomacy to handle cases where model predictions are correct but fly in the face of previous experience.

Any plant inevitably has periods of partial instrument failure, so the on-line models incorporate extensive checking of data. A measurement confidence scheme has been developed that weighs the importance of individual measurements on the basis of a 'Data Base Confidence Factor'. If at any moment the overall confidence factor for the data base is too low, control of the plant automatically passes to the operator.

The on-line models developed by CSIRO for advisory computer control have yielded direct advantages to Australian plants processing iron ore. They have given insight into otherwise unmeasurable conditions, provided predictions of product quality well in advance of laboratory analyses and served as consistent 'observers' of plant conditions that can be consulted by plant operators and management for unbiased estimates of plant performance.

19. Metals fabrication

In 1981-82 Australian industry's manufacturing sector provided 20% of the nation's Gross Domestic Product and 18% of its employment. Within this sector, industries involved in metals fabrication are conservatively estimated to have provided about 25% of turnover and 30% of employment. The contribution of metals fabrication to Australia's economic and social well-being is substantial and, in particular regions, vital, because of the way its industries are focused in major population centres.

Industry operates in an international marketplace and must be competitive to survive. Last decade the average 2.2% annual growth rate in Australia's exports of manufactured products fell well below the world average of 6.7%. The imbalance must be corrected urgently, principally through the development of new or specially-adapted manufacturing technologies offering improved products and increased manufacturing productivity. CSIRO is heavily involved in this process.

Metals fabrication involves the shaping of metals into components that are, in turn, assembled into products. Three basic processes are involved:

- Solidification from the molten state
- Plastic deformation of solid metal
- Removal of parts of a solid by cutting.

The selection of a particular shaping process depends on the properties of a material, the nature of the desired component, energy considerations, and economic constraints. Similar factors influence the choice, from the many techniques available, of methods for joining components and assembling them into finished products.

Fabricated metal products are designed to achieve a particular function within economic constraints. Before a design can proceed, a knowledge is required of available shaping processes and how they work, the bulk and surface properties of the metals to be shaped, procedures for changing the internal structure of metals, and special surface treatments.

Additionally, the designer must consider methods of planning and controlling production sequences, and how components are to be moved, stacked and assembled during manufacture.

Most importantly, the designer needs to consider what the component is required to do, and the conditions it will encounter during its working life.

Knowledge in all these areas has expanded greatly in the past few decades, and today reasonably satisfactory predictions can be made in many metals manufacturing processes. CSIRO has contributed to this knowledge, and in the past few years has expanded its studies of the materials, processes and procedures involved in shaping and assembling metal products. Such studies can lift manufacturing productivity, improve quality and lead to innovative new products.

Computers have enabled detailed knowledge to be marshalled for very effective planning of manufacture and product design, and are also being applied to the control and monitoring of manufacturing processes. These complementary functions are often referred to as CAD-CAM (Computer Aided Design and Computer Aided Manufacture). CAD-CAM is very much dependent on the basic understanding of materials and technology of the processes or procedures which the computer has been programmed to monitor. CSIRO research is directed to improving and applying basic knowledge in this field, and to identifying computer applications.

The diversity of technologies involved in fabricating metal products makes it difficult to review research in general terms, so examples are presented of specific CSIRO activities.

Diecasting

Diecasting involves the production of components by forcing molten metal into a shaped mould, and is widely used for mass-produced objects including car components, household appliances and builders' hardware. It is often the cheapest route from metal ingot to finished product, particularly for alloys of zinc or aluminium and, to a lesser extent, brass.

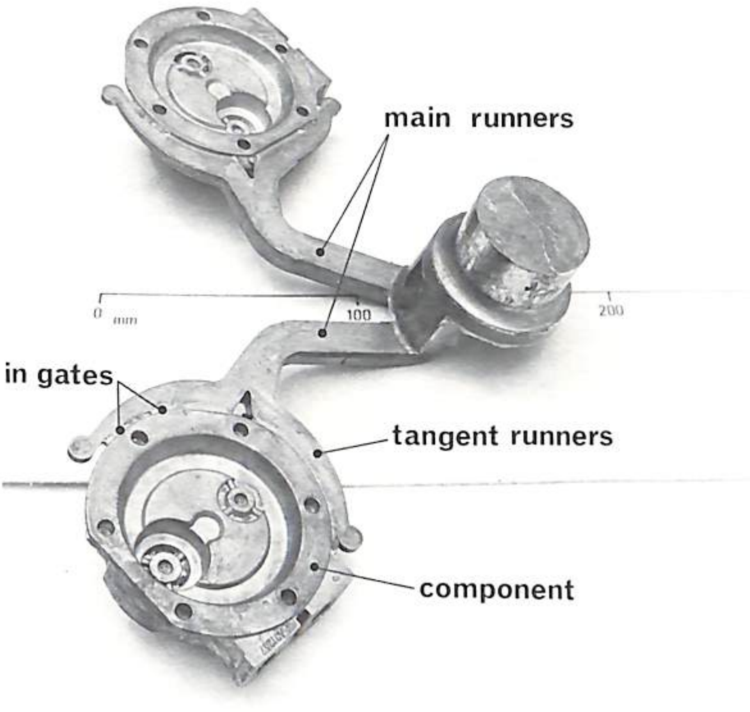
World competition in mass production highlighted the need for improvements in Australian diecasting, and in 1971 CSIRO established a small group to assist local industry to improve its efficiency. Outwardly simple, diecasting involves many complexities and variables, but the inevitable lengthy learning period for CSIRO was kept within bounds by the enthusiastic cooperation of key people in industry who recognized the potential benefits of research.

At an early stage it became clear that instrumentation and process control were poor and that there were deficiencies in the design of machines and dies. Castings varied in porosity, surface finish and mechanical properties, and there was little agreement in the industry about the causes. Die design frequently involved very expensive trial and error procedures.

The fluid mechanics of die filling had not been studied, and realizing this information would be required for later studies, the CSIRO team set out to make precise measurements of molten density and viscosity of the common casting alloys.

In 1973, using an old diecasting machine presented by industry, CSIRO produced Australia's first diecastings where the crucial manufacturing parameters of flow rate, pressure and temperature were measured and analysed in detail. The information assisted diecasting companies to achieve improved control of the process.

The zinc industry financed Australian Zinc Development Association encouraged the CSIRO studies and assisted in establishing close cooperation with diecasters. In the mid-1970s, financial support from the International Lead and Zinc Research Association saw further expansion, and extensive experimentation was performed in some 10 diecasting plants in New South Wales and Victoria.



CSIRO's studies of the fluid mechanics of metal die filling have led to an improved industrial diecasting. The two zinc components shown still attached to the solidified metal of the runner and gate systems, illustrate where improvements have been made in die design.

Studies were made of fluid flow, both in the runner system and in the casting cavity. Filling times are in the order of milliseconds and flow velocities are high—60 m per second is not uncommon. The flow problem is complicated by the shape of the runner and cavity. The stream of liquid metal in the runner expands into the air space of the cavity, permitting mixed flow of metal and air. Allowance must be made for excess metal to displace air, so voids are not formed in the casting. Dies must be protected from surface damage caused by the combined effects of thermal shock, chemical attack and erosion produced by the flowing metal when local velocities change rapidly. Erosion due to cavitation in the flow stream must be avoided. The process parameters must be controlled to produce adequate properties in the casting, and an acceptably low level of defects, and the highest possible production rate.

CSIRO's experiments in the laboratory and in diecasting plants have shown hydraulic theory can be applied to predict the performance of dies and diecasting machines, stimulating improvements in the design of machines and dies not only in Australia, but worldwide. Theoretical and experimental work into the flow characteristics of tangent runner systems now allow systems to be designed for a predictable fill pattern, improved venting, freedom from die erosion, and minimum remelt cost.

The technology has been incorporated in computer software to assist design. The software incorporates the analysis of die pressure requirements and their matching to machine capability, the balancing of multiple cavity dies, and the calculation of cooling channel size and location. The geometry of the metal feed system is generated and used to provide information for machining of the required channels.

Many companies in Australia, the USA, Asia and Europe have adopted this technology, with benefit to Australia as a major international supplier of diecasting metals, notably zinc and aluminium. To achieve this result, the CSIRO group had to devote substantial effort to technology transfer. Published material has been translated and republished in many European languages, as well as Chinese and Japanese. The group has gained major awards in recognition of the importance of its work, including the 1976 Award of Distinction of the Society of Diecasting Engineers (Australia), the 1980 Nyselius Award of the American Diecasting Institute, and the 1981 International Award of the Society of Diecasting Engineers (USA).

Work is continuing on the fundamentals of the process and on the application of computer aided design and manufacture of molten metal feed systems. Better ways of heating and cooling dies are being studied, and improved alloys are in prospect.

The project is significant for Australia, which supplies more than 20% of the world's zinc, and has the potential to capture significant world markets in aluminium products. Savings in energy and metal, through the use of thinner-walled castings, are important for a world with decreasing resources. Within Australia, a technically advanced local industry is now attracting major new investment in plant.

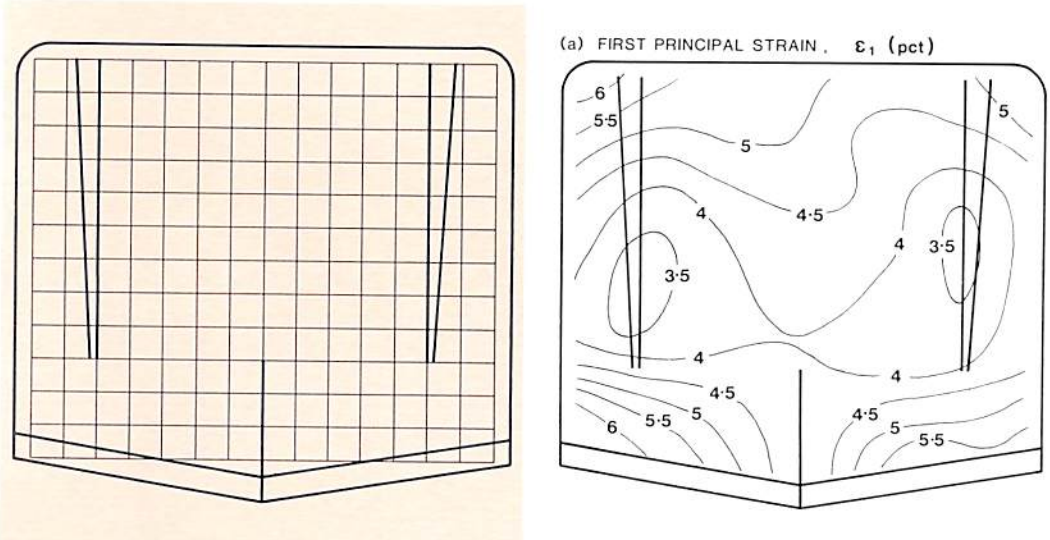
Sheet Metal Forming

Australian manufacturers use well over 1 000 tonnes of steel sheet per day to produce a vast array of press formed parts. The greatest portion of this tonnage is used by the automobile industry in the manufacture of shallow pressings such as engine hoods, doors, and roof and boot (or trunk) panels of cars.

The process of pressing involves placing a flat sheet of metal under a large hydraulically-operated press. The sheet is clamped at its periphery by a surrounding blankholder plate which closes with considerable force. The blankholder often has a mating bead and groove, the 'drawbead', to hold the sheet firmly—the bead presses the sheet into the groove as the surrounding jaws close. With the sheet firmly clamped, a central section of the press comes down to press the sheet into a die cavity forming the desired shape of the finished panel.

The process has many complexities, including plastic strain in the sheet, friction between metal and die, gripping at the drawbead, local buckling, elastic springback of the formed sheet, and local thinning or fracture. Exact analysis is not possible and, as a result, the making of a die to create a particular panel is still very much an art, based on experience.

Two decades ago, fracture of the sheet was a major problem and much research around the world was addressed to predicting the die and press conditions which gave risk of fracture. Today, energy shortages have produced a trend to thinner, higher strength steels and design emphasises very flat skin profiles for cars. This has increased difficulties in controlling the exact shape of the finished panel—a problem known as 'shape conformity' or 'shape fixability'. Elastic springback, buckles and poorly defined style lines, along with low panel stiffness, are causing major problems for the industry.

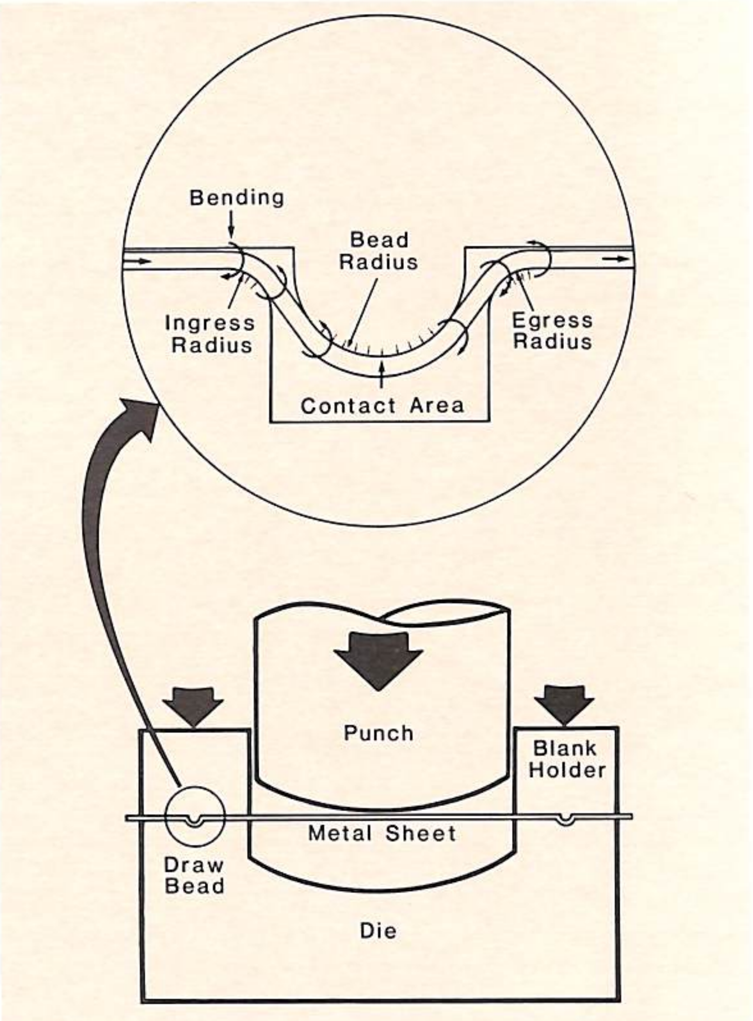


Analysis of the deformation of squares in the grid system inscribed on a metal sheet allows a computer to derive the strain contours that influence the shape of pressed metal sheets—in this case, a car hood.

CSIRO has developed a new technique for measuring the strain distribution in deforming sheet. The usual method involves measuring the deformation of a grid of circles marked onto the sheet prior to forming. Since the orientation of the deformed circles (ellipses) is difficult to determine at low strain levels, this procedure is slow, and does not provide information about the direction of the surface strains. The CSIRO method involves a reference grid of squares scribed on the sheet prior to pressing. Measurement of the grid after deformation enables strain directions and magnitudes to be depicted as 'strain maps' for the whole sheet. Computer software has been written for interactive strain analysis in the press shop and is being used both in production control and in tool development. When combined with high speed cine-photography and measurements of the rate at which metal moves at selected points, this procedure provides a very complete picture of the deformation process. To date the study of shape conformity has concentrated on the influence of five main parameters: geometry of the deformation, the material flow stress, the efficiency of lubrication applied to the sheet, the effect of blankholder pressure and the effect of sheet thickness.

Specific studies are in progress into the nature of wear of the die during press forming, and 'galling' of the sheet as it slides against the die. 'Galling' involves a local sticking of sheet to the die during pressing, causing a score mark on the surface which is quite unacceptable in production. The common sliding interface between the die and the sheet means that die wear and galling can be conveniently studied together as part of one physical system. Previous work has concentrated

The shape and position of a typical drawbead in a die. The drawbead produces a restraining force around the edge of the sheet metal in the die, and this force can be varied by changing the geometry of the drawbead. The restraining force can be predicted from the force required to bend and straighten the sheet around each radius, and the frictional effect between the sheet and die surfaces.



on the effect of the sheet surface in galling, while the present study is concerned with the contribution of tooling materials and their surface finish. Both are factors within the control of the sheet metal forming industry. Other studies centre on the drawbead and the way it controls flow in the sheet during pressing. Changes to blankholding force and drawbead geometry (see diagram) have major effects on the whole pressing process. Until now, the position and size of a drawbead have been determined by the experience of the die designer and practical testing in a tool try-out area. CSIRO studies of the metal flowing through the drawbead are showing how this control can be predicted.

Arc Welding

The electric arc is used extensively in fabricating metal structures and a huge variety of other metal components. The arc melts a portion of two metal parts which are to be joined, the molten pool unites the parts when it solidifies.

An arc is an intensely luminous bridge that forms between two separated electrodes when an electric current flows between them. Almost invariably the arc used for welding is struck between an electrode rod and the workpieces to be welded. In some cases the electrode is a refractory metal that is not consumed in the welding process; in others the electrode is melted and its metal is transferred to the weld pool, providing filler material in the gap between the parts being welded. Strong forces which arise in the arc zone can cause drops of molten electrode to be projected towards the workpiece, making it possible to weld with the workpiece above the electrode.

Various fluxing compounds are often used to aid the transfer of weld metal, to improve mixing of alloys in the weld pool, and to promote solidification without defects. The flux may be delivered as a material pasted on the outside of the welding electrode; as a granular core inside a tubular electrode; or as a free powder applied to the welding region. Tubular electrodes are often used in association with an auxiliary gas applied by a nozzle surrounding the electrode. This form of welding produces premium quality welds with high deposition rates, high strength and few defects. Because there is potential for expansion of this area of welding into a wide range of applications, CSIRO has established a cooperative research project with an industrial collaborator. The study aims to understand the fundamental processes occurring in the electric arc, and to develop methods for achieving high quality welds at a lower cost. The work has involved an extensive study of the electrode details, deposition rates and efficiencies, metal transfer behaviour, fillet weld dimensions, and the relative costs of welding consumables. Remarkable high speed photographs have shown that the composition of the gas surrounding a solid wire consumable electrode can significantly change the shape of the metal bridge between the wire and the drop being separated from it (see photographs). High-speed photography has also revealed that metal transferred from flux-cored electrodes tends to follow the alignment of the electrodes' core if the core projects through the metal drop. When the core does not project, the transfer follows a more random pattern usually associated with high carbon dioxide concentrations.

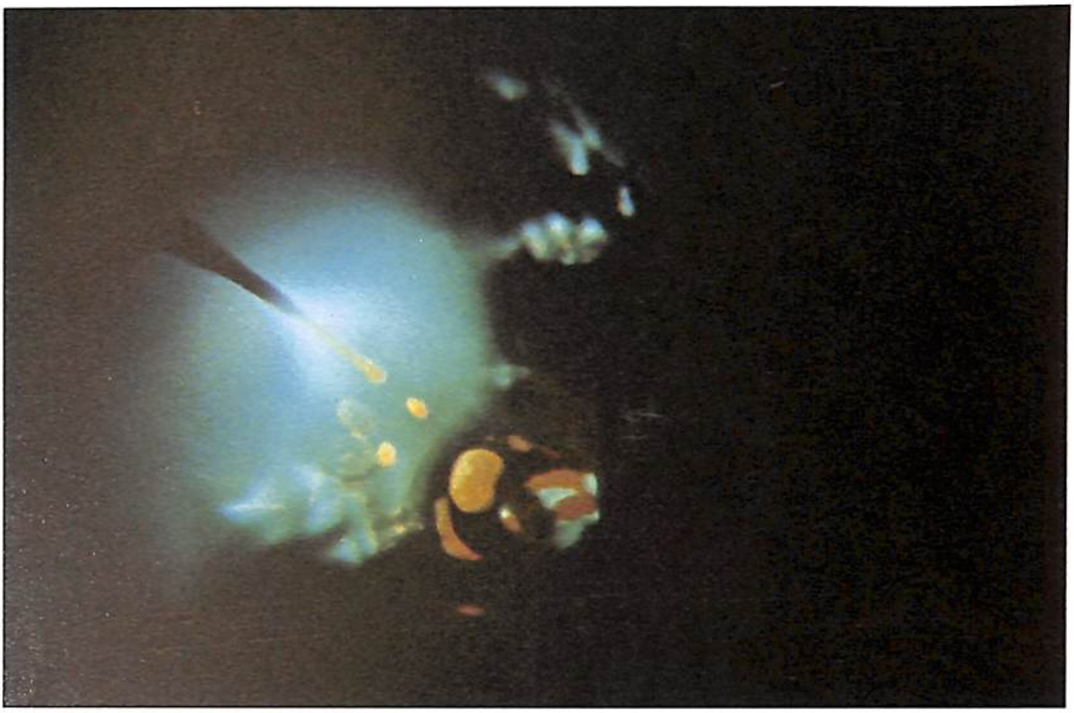
Quantitative studies of the deposition efficiency of cored electrodes has shown that although deposition varies almost directly with the current through the arc, nevertheless the power efficiency increases markedly with increase of current. The usefulness of this effect is ultimately limited by heating of the workpiece.

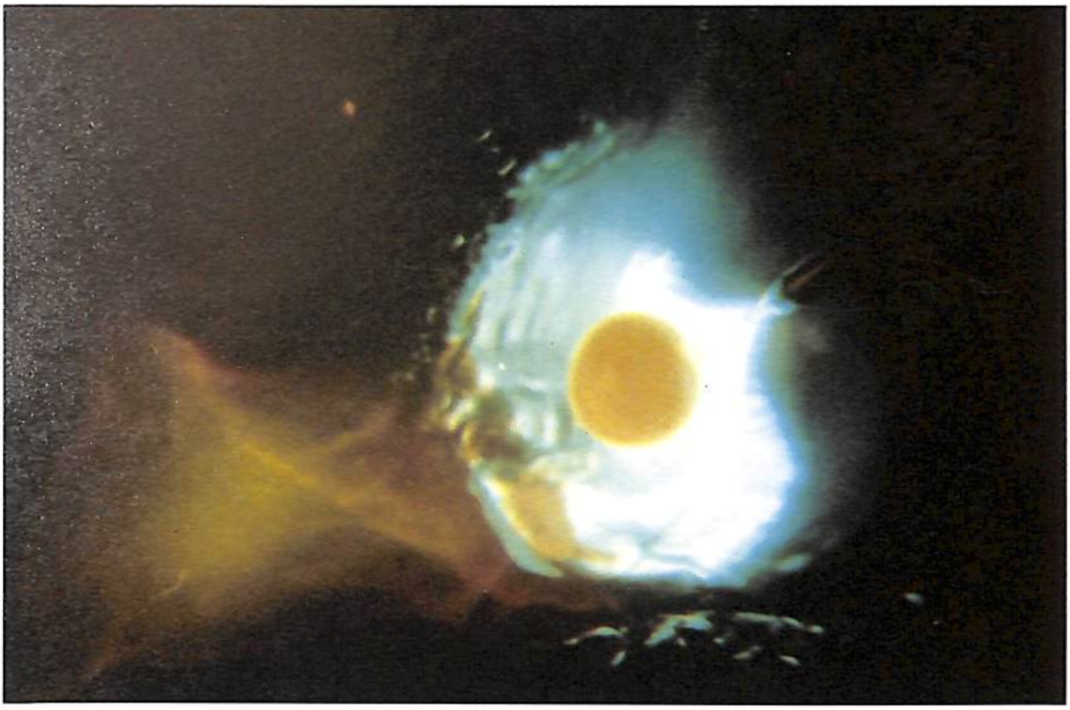
Pulsing of the electric current can provide better control of the weld pool and of the transfer of consumable electrode to the workpiece. Recognizing the practical advantages of a pulsed arc, CSIRO sought to develop a relatively low cost pulse generator. A circuit using thyristors (silicon controlled rectifiers) was developed, patented and tested in many practical welding situations. An industrial collaborator was sought and an agreement established with an Australian company. The collaboration has included work on the design of a commercial pulse generator, which is expected to be on the market during 1983.

The practical advantages of a pulsed arc current are numerous and dependent on the welding situation. In tungsten-inert gas (TIG) welding, a process with a non-consumable electrode, pulsing permits thinner materials to be welded than is otherwise possible. In this case, the size of the weld pool is controlled by adjusting the frequency of pulsation and the peak pulse current. Similar control of the weld pool size can be achieved with a continuously-fed consumable wire. The pulsating current can also be used to enhance the projection of droplets across the space from electrode tip to workpiece to make the process independent of gravity, making welding possible in any position without the excessive heat generated by continuous current welding. The pulsed current is particularly suited to welding heat-sensitive materials. Apart from these advantages, the simple way in which pulse frequency can be modulated by arc current or voltage offers advantages in the rapidly-expanding field of automated welding.

In approaching the development of improved welding consumables and of pulsed current arcs, CSIRO has had to study the basic nature of the welding arc and the physical and metallurgical processes occurring in the weld pool.

Although arc-welding is by no means a new technology, the complex physical processes occurring in a simple stable electric arc are not yet fully understood. Even less is known about the processes in which one electrode melts and transfers metal to the other electrode, a molten pool, processes which affect both the economics and efficiency of welding. CSIRO is investigating the





These remarkable pictures, single frames from a high speed cinefilm, reveal processes involved in metal transfer from a welding electrode. In the top photograph of an argon welding arc, two small hot metal droplets are in flight to the weld pool, which reflects their distorted images. When 18 per cent carbon dioxide is added to the argon, the electrode changes shape, as shown in the lower photograph. This photograph is dominated by a large metal bubble, probably caused by explosive boiling of oxide inclusions in the welding wire.

role of ionized metal vapours in the arc, and the nature of droplet transfer. To resolve conflict between theories attempting to account for the force causing separation of the metal drop a study has been made of the electrode end, using high speed colour cine-photography as pulses of current are passed through the arc. It has been discovered that the liquid metal bridge tends to be significantly cooler than the metal drop and that the metal drops can become much hotter as they pass from the electrode to the weld pool.

CSIRO is also measuring transient changes in the voltage and current through the arc as the metal drop separates from the electrode to help resolve the theoretical problem of drop separation from the electrode, the very basis of arc-welding.

The examples of research in the field of metal fabrication presented in this article show only a small part of CSIRO's activity in the field of materials fabrication.

20. Australia's plant and animal resources

Australia is an island continent, isolated from all other major land masses except Antarctica for more than 50 million years. An enduring marine barrier has maintained the biological boundaries of the Australasian region against the processes of invasion and exchange; no other continent has such a high percentage of endemic plant and animal species. The distinctiveness of the flora and fauna has been further enhanced by a unique geological and climatic history. Erosion and deep weathering have predominated over mountain building and volcanic renewal to produce landscapes of low relief and generally poor soil fertility, while the continent's gradual northward drift from the high latitudes of prehistoric times has changed the climate from warm and moist to a drier, markedly seasonal regime.

The unique Australian flora and fauna shaped by these elements are of paramount scientific interest and conservation value. They are a national resource of incalculable value for Australians, the basis of a lucrative tourist industry, and are central to the image that Australia projects overseas.

Many forces and interactions determine the patterns of plant and animal communities. Soil fertility, water availability, light and temperature are powerful natural influences on plant distribution and abundance, and upon the structure of plant communities. The productivity of a plant community in turn influences animal distribution and abundance, through its effects on food and habitat availability. Within this framework, complex interactions between plants, animals, and a diverse array of micro-organisms living in the soil or in association with plants and animals, further modify distribution patterns.

To a degree matched by no other continent, fire has been a powerful extra factor shaping plant and animal communities, both in an evolutionary sense, and over time scales measurable by the lifetimes of individual plant and animal species. Although Aborigines undoubtedly altered the fire regime in areas of Australia to a significant degree, and thus changed the patterns of plant and animal distribution, the impact of European settlement has been much more drastic and Europeans introduced yet another major force to change plant and animal distribution—agriculture, and especially, grazing.

The future conservation of Australia's unique flora and fauna, and the future productivity of agriculture, are mutually dependent on new, enlightened management strategies based upon sound research.

CSIRO contributes to the conservation of plant and animal communities by describing their geographical distribution and the species they contain, and by analysing their dynamics under both natural and disturbed conditions.

Survey Techniques

Aboriginal Australians appreciated better than early European settlers the influence of the land and its water upon the distribution of plant and animal communities. CSIRO's surveys of land systems in the 1940s were a first attempt to acknowledge this interdependence, and to make use of it. Basing their surveys on air photos, scientific teams representing several disciplines spent months in the field collecting data and describing study areas in terms of land systems—consistent patterns of landforms, soils, vegetation and climate, with hydrology and land use often being included. Unfortunately, no assessment was made of fauna. The surveys advanced scientific survey techniques, increased knowledge of large areas of northern Australia and Papua New Guinea and their vegetation, and provided a basis for assessing the agricultural and pastoral capability of the country.

The assembling of information about plant and animal communities and their environment has benefited from major advances in technique since surveys of this type began. Air photo interpretation is still used for small areas, but rapid methods of ground survey have been developed to record changes in vegetation over distance or with altitude. The steady improvement in the interpretation of satellite data, notably from LANDSAT, is also opening up new possibilities in rapid survey and monitoring of very large areas of vegetation at a fraction of the cost of air photo-based techniques. CSIRO has worked with the Great Barrier Reef Marine Park Authority to carry out resource surveys of areas of the reef, using LANDSAT. Such studies led to a further collaborative project with the Australian Survey Office to develop more accurate methods of reef location.

Once inventory data has been collected on biological communities and their environments, they can be organized and presented in numerous ways. With integrated surveys, for example, the data are interpreted into land systems and units with the vegetation of each land type described in terms of its plant communities. In this manner, the vegetation of large areas of northern Australia, Papua New Guinea and all of South Australia have been mapped as mosaics of identified plant communities.

Developments in computing in the past decade have seen major improvements in the storage and manipulation of data. The digitized data for a single LANDSAT image can be reorganized rapidly into a number of classes representing different light and heat 'signatures', each signifying a different type of land cover. Once the spectral signature of a particular plant community is known, its occurrence throughout the entire region covered by the LANDSAT image, and in other regions, can be mapped almost instantly by searching for areas of corresponding signature, without further recourse to ground survey. If the plant-animal associations within a particular community are known, broad inferences may also be made about animal distribution. This capacity to manipulate satellite imagery by computer ensures remote sensing will play an increasingly important role in monitoring natural resources.

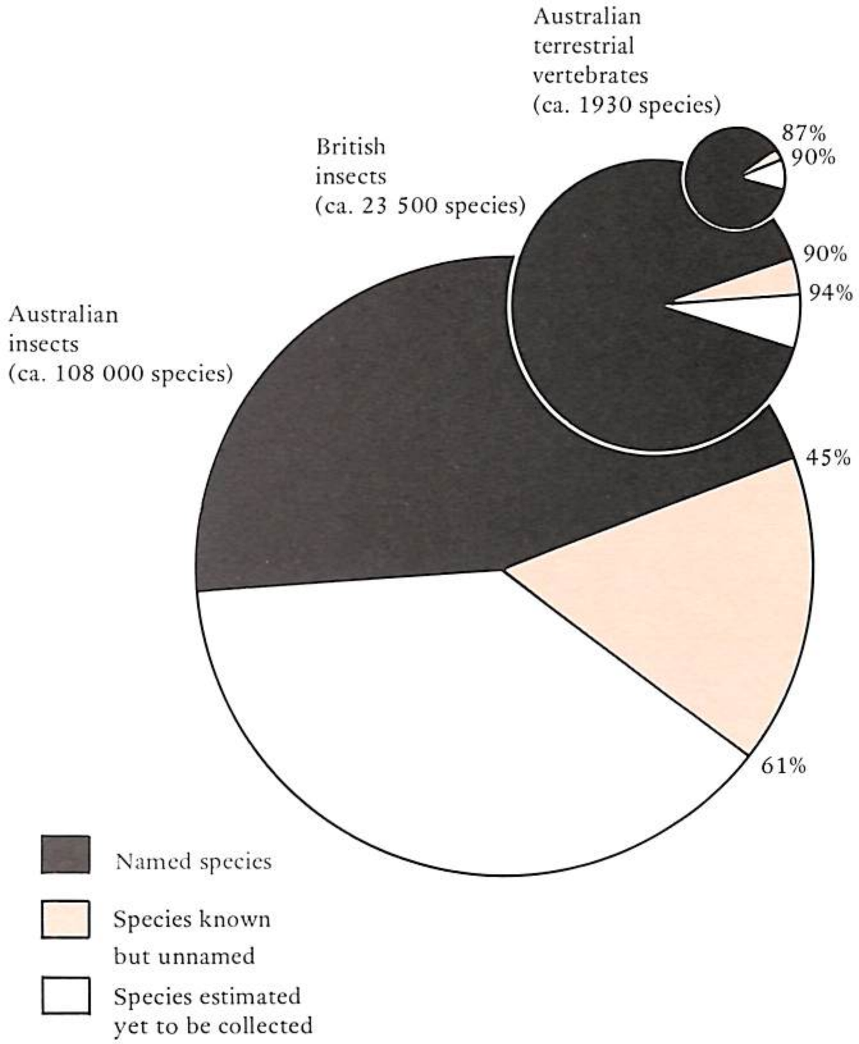
National Biological Collections

Once ground surveys have been completed, the plant and animal species collected must be identified. CSIRO administers the major national reference collections for invertebrates, plants and animals—the Australian National Insect Collection, the Herbarium Australiense, and the Australian National Wildlife Collection.

Australian National Insect Collection. A recent and perhaps conservative estimate suggests there are at least 108 000 insect species in Australia, more than 50 times the number of terrestrial vertebrates (estimated at 1 930 species). The insect total can only be roughly estimated, because of the incomplete census of the fauna. In the two centuries since Joseph Banks collected the first insects taken on the continent, representative specimens of about 66 000 species (61%) have been gathered into the research collections of the Australian National Insect Collection and the State museums, while about 48 000 species (45%) have been formally described and given scientific names. Impressive progress has been made in taxonomic inventory of Australia's insects in two centuries but much work remains to be done (see diagram—comparison of Australian, North American and British insect taxonomic progress).

Herbarium Australiense. The Herbarium Australiense is housed in two locations—in Canberra, and at Atherton in northern Queensland—and contains a total of about 360 000 specimens. About 18 000 Australian plant species have been formally described, and an unknown but certainly large number of species remain to be either collected or described.

There is growing recognition of the importance of the Australian flora as a national resource. It is of prime importance, therefore, that an accurate census of the flora be made. An essential



Progress in Australian insect taxonomy, compared with Australian vertebrate taxonomy and British insect taxonomy. A large proportion of Australia's insect species still remain to be collected and described.

aspect of utilization of the resource is a sound taxonomic base so the identity and relationships of the species are known. Knowledge of the reproductive biology of the species is also important, both as a guide to gene flow and sound taxonomy, and as a guide to possible use for economic purposes.

Australian National Wildlife Collection. The Australian National Wildlife Collection contains 44 000 specimens, comprising 169 species of mammal (72% of the known fauna), 623 bird species (83%), 338 reptile species (66%) and 102 amphibian species (66%).

When potential new species are discovered in these biological groups, the Australian National Wildlife Collection and other collections serve as a basis for their recognition by survey biologists and, later, for their formal scientific description. For example, a fauna survey in Kakadu National Park in the Northern Territory has found three new reptile species and one new mammal in the past two years.

A new skink, **Ctenotus** *sp., found by CSIRO during a fauna survey of Kakadu National Park in the Northern Territory. The park contains a diverse reptile fauna.*

Australian wild relatives of crop plants are a potential source of new genes for cultivated species. CSIRO has successfully produced a cross between the commercial soybean variety 'Lincoln' and a hybrid between the two Australian **Glycine** *species,* **G. tomentella** *and* **G. canescens.**

As the main or often sole custodian of many of the world's significant animal groups, such as monotremes, marsupials, parrots and cockatoos, Australia has an obligation to study and conserve them. CSIRO's wildlife research aims to understand the biology of both native and introduced vertebrates in relation to their conservation, management and pest status. Each of these areas is potentially controversial, and rational decision-making must be based on an understanding of the biology, behaviour and ecology of the species. The separation and naming of species, and an accurate catalogue of where they live, is fundamental to any understanding of the dynamics of plant and animal communities.

Impact of Grazing upon Plant Communities

Grazing is a major factor affecting many plant and animal communities in Australia. CSIRO is investigating the stability of plant and animal communities in grazing regions, to assist both the pastoral industry and conservation.

The native woodlands and grasslands of northern Australia are an important natural grazing resource, and the most productive native pastures in Australia. Much of the Top End of the Northern Territory and Cape York is covered by a tall grass savannah of open eucalypt woodlands with a dense perennial grass understorey dominated by kangaroo grass (*Themeda australis*). In eastern Queensland there is a similar community dominated by black speargrass (*Heteropogon contortus*).

The majority of these lands have retained remarkable vegetational stability. They are protected from overgrazing because the low quality of the herbage during the prolonged dry season limits carrying capacity and animal production. Feed supplements such as urea and molasses, or the incorporation into pasture of productive legumes, can enhance the nutritive quality of the herbage. The more complete utilization of the herbage and higher stocking rates lead to increased grazing stress.

The kangaroo grass savannahs of the north rapidly disintegrate under this stress. On the other hand, the sub-tropical black speargrass lands remain remarkably stable—although with considerable change in associated species. The differential stability of these two savannah communities has far-reaching implications for the management strategies needed to increase pastoral production in these areas.

The semi-arid woodlands of south-eastern Australia occupy about a sixth of the continent's area, and have been been severely affected by grazing. The woodlands are used mainly for grazing, an activity which has been linked with increases in woody weeds, massive soil losses and gradual reduction in productivity and plant diversity. The woody weed problem is particularly acute in south-west Queensland, where CSIRO has been studying the ecological consequences of grazing Poplar box (*Eucalyptus populneum*) woodlands. The key questions addressed are how water and nutrients are shared by trees, shrubs and grasses, and how these resources are modified by land clearing or grazing.

Larger trees have been found to affect the distribution and quantities of shrubs and grasses around them by generating litter and modifying water infiltration and the availability of water and nutrients. Removing trees and shrubs releases water and nutrients to herbs and grasses, and herbage production is increased—most of Australia's woodlands have been ringbarked for this reason. Tree, shrub and grass roots tend to occupy different soil strata, and thus exploit different reserves of water and nutrients. When trees are removed, nutrient cycling from depth is changed, and salinity of the upper soil layers is often increased.

With grazing, the surface characteristics of the soil are changed, mainly because of the removal of organic material and the top 50-100 mm of soil. The most important change is a reduction in water infiltration rates and increased soil surface hardness, both of which encourage shrub invasion. The number of invading shrubs depends on weather patterns—wet years after drought are most favourable for invasion--and on the surface characteristics of various soils—shrubs favour sandy soils over clay soils. Fire can be used to reduce shrub numbers in most situations, but native grasses suffer, particularly if heavily grazed during the recovery period after a fire. With this knowledge, areas can be defined that are best left intact and only lightly grazed.

Effect of Agriculture and Forestry upon Native Animals

CSIRO continues to conduct laboratory research and studies of captive animals, but increasing emphasis is placed upon studies of species in the wild. The interaction of a species with its environment may be subtle, yet crucial to its management.

It has been found, for example, that soil fertility strongly influences the species diversity of tree-living marsupials in eucalypt forest being clear-felled for woodpulp in south-eastern New South Wales. A CSIRO study, conducted with the assistance of logging crews, found that five species of glider and three species of possum were concentrated in relatively small areas of undulating country on soils derived from Devonian intrusive materials. The relatively higher availability in these soils of major nutrients such as nitrogen, phosphorus, and potassium is reflected in the nutrient levels in the leaves of the eucalypt species which grow in them, notably the peppermints *Eucalyptus radiata*, *E.dives* and *E.elata*, and is ultimately expressed in a larger, more diverse animal population. In all, 63% of the total number of animals of all species occurred in only about 9% of the felled area. After clear-felling, such higher-fertility areas are preferred for replanting with *Pinus radiata* rather than allowing natural regrowth, a practice which has important implications for wildlife conservation.

In northern Queensland, where logging operations have begun in the rainforest of the Windsor Tableland, CSIRO has recently begun an integrated study in a reserved area of upland rainforest, to determine the preference of groups of birds and mammals for microhabitats in a single forest type. The study aims to identify which species may be at risk from logging operations. Birds and mammals, via their activities in dispersing seeds and pollen, contribute to an unknown extent to the direction of succession and regeneration of rainforest. CSIRO is studying these influences, using selected tree species.

The extensive clearance of native woodland for agriculture in both eastern and western Australia has had variable impacts on different bird species, according to individual species behaviour, reproduction and habitat requirements. CSIRO has found that the Major Mitchell cockatoo (*Cacatua leadbeteri*) is a more prolific breeder than its close relative the galah (*C.roseicapilla*), but is considerably less abundant because breeding pairs will not nest within 2 km of each other. In a 450 km^2 area only 16 breeding pairs were found, and 100 non-breeding individuals which could not find a nesting site in the small patches of remnant woodland. The galah is a communal species and, in an equivalent area, one could expect to find 350 breeding pairs of galahs and 3000 non-breeding individuals.

In Western Australia, the white-tailed black cockatoo (*Calyptorhynchus baudinii*) is similarly at risk from land clearance because it nests in the hollow limbs of mature eucalypts. The longevity of the species has masked the sharp decline in its breeding caused by loss of mature trees. Grazing animals are preventing replacement of ageing stands by natural seedling regrowth.

Fire and Plant Communities

Fire is a key factor in Australian plant and animal communities, and several CSIRO studies illustrate its diverse effects. The tall, open forest and woodland of the Northern Territory is adapted to fire, but high intensity fires which have resulted from European habitation can damage them.

In the past, Aborigines used fire at the beginning of the dry season when they were moving from their wet season camps. The vegetation is much less flammable at this time of year, so fires were not as intense. Since European settlement of the Northern Territory, the fire regime has been altered. High intensity fires late in the dry season occur as frequently as once a year. They are

typically clearing fires set by pastoralists, or by buffalo shooters who want to open up the bush for better access. The practice has halted the recruitment of young eucalypts into the overstorey or tall tree canopy. If the trend continues most of the old trees will have died within 50 years and will not be replaced, so the area will change from woodland to scrub. By burning early in the dry season once every four years juveniles could be allowed to grow and replace lost canopy trees.

Fire is also an important factor influencing plant communities in the arid zone. More than half of Australian land use is based on the use of native pastures for sheep and cattle production. There is a need to balance meat and wool production with conservation, rather than regarding the two activities as antagonistic. Fire in the arid zone, coming irregularly at intervals from 5-20 years, may have a profound influence on populations of long-lived perennial plants. Some plants such as mulga (*Acacia aneura*), hop-bushes (*Dodonea* spp.) and *Cassia* species are particularly susceptible to fire, and in natural communities the establishment of young plants and the death of older specimens by fire are both linked with above-average rainfall. Fire also stimulates the establishment of replacement populations by cracking hard seeds. In contrast, species such as turpentine bush (*Eremophila sturtii*) and budda (*E.mitchellii*) resprout from dormant buds in older wood, and do not have fire-stimulated germination. These have more stable, long-lived populations, but are influenced by fire through the higher death rate of younger plants. If a fire regime is adopted which removes seedlings when they occur and is more frequent than the interval between germination and maturity, when the seed store will be replenished, shrubs and trees can be reduced to low densities–a desirable management objective in pastoral regions where such shrubs compete with and reduce the edible herbage layer.

As shown in the Northern Territory, the season of fire may also be important. CSIRO research in mallee communities has shown that regeneration after a spring fire is nearly total, whereas it is relatively low after an autumn fire, particularly if the fire is repeated two or three years later. Fire is a natural feature of mallee vegetation and cannot be suppressed, but timing and frequency can be organized so the fires can be controlled and the vegetation manipulated to advantage. An open mallee community may be desired in pastoral country, while a diversity of fire ages is considered desirable for wildlife conservation in national parks to maintain a balance between the high cover of mature trees and the greater feed supply of young, more open stands. In Uluru National Park in central Australia, CSIRO has developed a plan for a sequence of small prescribed burns to produce and maintain this diversity. Through the strategic use of natural fire barriers and a knowledge of diurnal changes in fire behaviour, it has been possible to run a series of self-extinguishing fires, so that no fire-breaks are required. These small burnt areas now form barriers that will break up an uncontrolled wildfire. This gives rise to a mosaic of fire ages, or diversity, and prevents the more devastating widespread fires that occur at intervals when efforts are made to exclude fire totally.

Fire can also affect the boundary of plant and animal communities. Australia's rainforests are of particular ecological interest because of their limited area (1% of Australia) and their high plant and animal diversity. CSIRO's rainforest studies at Atherton in Queensland have been concerned with the effects of fire on the boundaries between rainforest communities and grassland or eucalypt forest, and the factors and processes involved in rainforest regeneration. Abrupt changes in the floristics and vegetation structure are usually found at these boundaries, which have

The usefulness of LANDSAT imagery is demonstrated by this false-colour image of a grassland region in central Australia, where natural wildfires are a frequent occurrence. The image not only highlights the areas which have been fired, but yields information about fire frequency and direction. At least four years of fires are involved, and the effect of wind direction and speed is clearly visible–rounded fire fronts result from relatively calm conditions, elongated fronts indicate high winds.

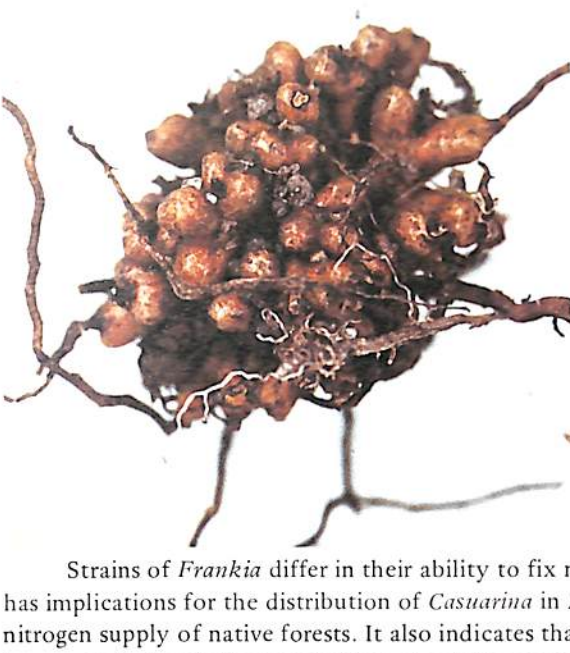
been of interest to ecologists for many years. Past theories have suggested the transition is due to changes in soil chemistry, soil water balance or to the effects of fire. CSIRO's work at Atherton suggests that fire is the primary influence on boundary position, with soil factors playing a secondary role.

Soil Organisms

Not all the important components of biological communities are readily visible. Soil micro-organisms are as important a part of plant communities as the more obvious above-ground components. A number of the fungi infect roots (forming mycorrhizal associations) and stimulate nutrient uptake and growth of both native and introduced plants.

CSIRO has been studying the particular microbial-plant association between native she-oaks (*Casuarina* spp.) and nitrogen-fixing fungi of the actinomycete genus *Frankia*. Casuarinas are important plants of Australian woodlands and are primary colonizers of coastal dunes and other inhospitable soils. Their success as colonizers and soil stabilizers, and their wide use as a fuel crop in many developing countries, is due largely to their nitrogen-fixing ability. As the great majority of the 83 species of *Casuarina* are endemic to Australia, their associated *Frankia* fungi are a biological resource almost wholly confined to Australia.

Nitrogen-fixing nodules on the roots of a casuarina. The organism responsible for casuarina nodulation is a fungus, ***Frankia****. Below: The growth response, after three months, of a casuarina seedling inoculated with a strain of* ***Frankia****.*



Strains of *Frankia* differ in their ability to fix nitrogen with different *Casuarina* species. This has implications for the distribution of *Casuarina* in Australia, and for their contribution to the nitrogen supply of native forests. It also indicates that productivity of *Casuarina* plantings in warm temperate to tropical countries throughout the world may be increased markedly by selection of the most effective *Frankia* strains.

Soil animal communities can also be important in terrestrial ecosystems through their role in decomposition of organic matter. CSIRO has undertaken studies in forests in northern Queensland and South Australia to develop a basic understanding of Australian soils as biological systems.

The studies provide an opportunity to investigate the effect on soils and their biological communities of disturbance by fire, cultivation and the introduction of exotic trees such as pines.

The animal groups that have received the most attention are micro-arthropods, termites and ants, which are the most significant groups and most widespread Australian soil animals. Micro-arthropods are particularly important in the initial stages of degradation and incorporation into the soil of plant litter and dead roots, and have been studied in eucalypt forests, tropical rainforests and pine plantations.

Termites are the dominant macro-faunal group in Australian soils and are usually present in large numbers. Their social organisation, which involves removal of dead plant material to central nests and mounds, where it is intensely degraded, results in a pattern of organic matter distribution that is peculiar to Australia and other regions of the world where termites are common. Mound-building species physically reorganize soil profiles, moving selected fine soil particles to the surface, and many Australian soils, particularly in the north, owe their present morphology to termite activity. Ants are also significant in soil profile modification owing to their burrowing and removal of soil to the surface, and some widespread species that harvest seeds have been shown to have a strong influence on the species composition of native and improved grasslands.

Nematodes are another significant component of soil animal communities. In natural communities, the soil contains small numbers of many different species, including parasites of native vegetation, predators on other micro-fauna, and forms which feed on fungi and bacteria. Most of these nematodes are closely related to species found in other countries, but some, including several types that parasitise plants, are endemic or found only in Australia and neighbouring regions. Some are rare, others occur throughout the continent.

When the land is used for agriculture, a dramatic change occurs in the nematode fauna. Most naturally-occurring species disappear relatively quickly when the land is cultivated, although some groups of predators and bacterial feeders seem to adapt and survive. In land cleared for irrigated horticulture in the Murray Valley, CSIRO has found that most native plant parasitic nematodes disappear within three to five years of the establishment of a farm. Few native species parasitize cultivated crop plants, although certain species may attack planted eucalypt forests.

With time, agriculture usually introduces a range of cosmopolitan plant parasitic nematodes associated with particular crops. Cultivated soils often contain larger numbers of nematodes than soil in its natural state, but diversity is low and biased towards crop-specific species. The cotton root nematode and the golden nematode of potatoes are among problem species which have not yet been found in Australia.

Summary

CSIRO's role in assisting with the conservation of animal and plant communities takes numerous forms. It may involve assisting a State or Commonwealth body with a specific project or a technique—for example, the Organization recently helped the Australia Heritage Commission determine its criteria for selecting natural areas for inclusion on the Register of the National Estate. Another project has involved the application of a land use planning method called SIRO-PLAN to the Cairns section of the Great Barrier Reef Marine Park, in collaboration with the Marine Park Authority. SIRO-PLAN, with its systematic and objective approach—unusual in land planning—will, it is hoped, make it easier to involve the public in decision-making.

Some of the most vigorously fought and hotly disputed public issues in recent years have been planning issues centred on the conservation of plant and animal communities and their supporting environments. In late 1982, the first steps were taken to make SIRO-PLAN more available to the community, and it is hoped that as the method gains acceptance, rural land use planning in Australia will become better able to anticipate and deal with such controversial conservation problems.

Appendices

Appendix I

Executive Members and senior staff

The following is a list of Members of the Executive, Directors of Institutes, Chiefs of Divisions and Officers-in-Charge of Units, together with senior staff of Central Administration and Regional Administrative Offices. This information reflects the position as at 30 June 1983.

EXECUTIVE

Chairman and Chief Executive	**Term of Office**
J.P. Wild, CBE, ScD, FTS, FAA, FRS	14.12.78 - 24.9.85
Full-time Members	**Terms of Office**
N.K. Boardman, ScD, FAA, FRS	14.12.78 - 24.9.85
G.H. Taylor, DSc, DrRerNat, FTS	1.5.82 - 30.4.89
Part-time Members	**Terms of Office**
D.P. Craig, DSc, FAA, FRS	26.3.80 - 25.3.83; 26.3.83 - 22.12.84
H.M. Morgan, LLB, BCom	14.12.78 - 13.12.81; 14.12.81 - 13.12.84
S.B. Myer, MA	14.12.81 - 13.12.84
G.G. Spurling, BTech, MAE, ED	9.9.82 - 8.9.85
P.D.A. Wright	1.12.79 - 30.11.82; 4.2.83 - 3.2.86

INSTITUTE OF ANIMAL AND FOOD SCIENCES

Director	K.A. Ferguson, PhD, FTS
Divisions	**Chiefs**
Animal Health	A.D. Donald, PhD (*Acting*)
Animal Production	T.W. Scott, PhD, FTS
Fisheries Research	S.W. Jeffrey, PhD (*Acting*)
Food Research	J.H.B. Christian, PhD, FTS
Human Nutrition	B.S. Hetzel, MD, FTS
Tropical Animal Science	D.F. Mahoney, DSc
Units	**Officers-in-Charge**
Molecular and Cellular Biology	B.R. McAuslan, PhD (*Acting*)
Wheat Research	C.W. Wrigley, PhD

INSTITUTE OF BIOLOGICAL RESOURCES

Director	M.V. Tracey, AO, MA, FTS
Divisions	**Chiefs**
Entomology	M.J. Whitten, PhD
Forest Research	J.J. Landsberg, PhD
Horticultural Research	J.V. Possingham, DSc, FTS
Plant Industry	W.J. Peacock, PhD, FAA, FRS
Soils	D.E. Smiles, DScAgr
Tropical Crops and Pastures	E.F. Henzell, AO, DPhil, FTS
Water and Land Resources	R.J. Millington, PhD, FTS

Wildlife and Rangelands Research	C.J. Krebs, PhD, FRS (Can)
Units	**Officers-in-Charge**
Centre for Irrigation Research	D.S. Mitchell, PhD
Laboratory for Rural Research (Perth)	F.J. Hingston, PhD

INSTITUTE OF ENERGY AND EARTH RESOURCES

Director	I.E. Newnham, AO, MBE, MSc, FTS
Divisions	**Chiefs**
Energy Chemistry	P.G. Alfredson, PhD
Energy Technology	D.C. Gibson, PhD
Fossil Fuels	Professor A.V. Bradshaw, BSc, FTS
Geomechanics	B.H.G. Brady, PhD
Groundwater Research	R.A. Perry, MSc, FTS
Mineral Chemistry	D.F.A. Koch, PhD, FTS
Mineral Engineering	A.F. Reid, DSc, FAA
Mineral Physics	K.G. McCracken, DSc, FTS
Mineralogy	A.J. Gaskin, MSc, FTS
Unit	**Officer-in-Charge**
Physical Technology	E.G. Bendit, PhD

INSTITUTE OF INDUSTRIAL TECHNOLOGY

Director	W.I. Whitton, PhD, FTS
Divisions	**Chiefs**
Applied Organic Chemistry	D.H. Solomon, DSc, FTS, FAA
Building Research	F.A. Blakey, PhD, FTS
Chemical and Wood Technology	W. Hewertson, PhD
Manufacturing Technology	R.H. Brown, BMechE, SM
Protein Chemistry	W.G. Crewther, DSc
Textile Industry	D.S. Taylor, PhD, FTS
Textile Physics	A.R. Haly, DSc

INSTITUTE OF PHYSICAL SCIENCES

Director	N.F. Fletcher, DSc, FAA
Divisions	**Chiefs**
Applied Physics	J.J. Lowke, PhD
Atmospheric Research	G.B. Tucker, PhD
Chemical Physics	L.T. Chadderton, DSc
Computing Research	P.J. Claringbold, PhD
Environmental Mechanics	J.R. Philip, DSc, FAA, FRS
Materials Science	J.R. Anderson, ScD, FAA
Mathematics and Statistics	T.P. Speed, PhD
Oceanography	A.D. McEwan, PhD, FAA
Radiophysics	R.H. Frater, DScEng, FTS
Unit	**Officer-in-Charge**
Australian Numerical Meteorology Research Centre	W.P. Bourke, PhD (*Acting*)

BUREAU OF SCIENTIFIC SERVICES

Director	S. Lattimore, BSc, ARCS
Units	**Officers-in-Charge**
Central Information, Library and Editorial Section	P.J. Judge, MA
Centre for International Research Cooperation	B.K. Filshie, PhD
Commercial Group	P.A. Grant. FRMIT
Science Communication Unit	B.J. Woodruff, BSc(For) (*Acting*)

PLANNING AND EVALUATION ADVISORY UNIT

Director	D.E. Weiss, OBE, DSc, FTS, FAA

OFFICE OF THE EXECUTIVE

Executive Secretary	L.G. Wilson, AO, MSc
Deputy Executive Secretary	J. Coombe, OBE

FINANCE AND ADMINISTRATION

Secretary	H.C. Crozier, BA
Deputy Secretary	K.T. Smith, BCom, AASA

PERSONNEL

Secretary	K.J. Thrift, BA
Deputy Secretary	I.D. Whiting, BA

REGIONAL ADMINISTRATIVE OFFICES

Brisbane	D.B. Thomas, BA
Canberra	G.A. Cave, BCom, AASA
Melbourne	W.C. Hosking, AASA, ACIS
Perth	J.P. Brophy, MBE
Sydney	T.C. Clark, AASA, ACIS

Appendix II

Advisory Council and State and Territory Committee Members

ADVISORY COUNCIL

Chairman

Sir Peter Derham, BSc, FAIM, LPIA, FInstD, former Managing Director, Nylex Corporation Ltd.

Chairmen of State/Northern Territory Committees

G.I. Alexander, BVSc, MSc, PhD, FACVSc, Director-General, Queensland Department of Primary Industries (*Queensland*).

R.A. Footner, AM, Chairman and Joint Managing Director, Bridgestone Australia Pty Ltd (*South Australia*).

D.B. Horgan, FSA, Company Director (*Western Australia*) (until April 1983).

J.E. Kolm, AO, IngChemEng, Consultant and Company Director (*Victoria*).

G.A. Letts, CBE, DVSc, Director, Conservation Commission of the Northern Territory (*Northern Territory*).

K. Satchwell, BSc, MSc, Managing Director, AFL Holdings Ltd (*New South Wales*).

Professor P. Scott, OBE, PhD, LLD, former Pro-Vice-Chancellor, University of Tasmania (*Tasmania*).

Other Members

S.C. Bambrick, OBE, BEcon, PhD, Senior Lecturer, Faculty of Economics, Australian National University.

F.N. Bennett, BEc, former Deputy Secretary, Department of Industry and Commerce (until July 1982).

Professor L.M. Birt, CBE, DPhil, Vice-Chancellor, University of New South Wales.

V.A. Brown, MSc, PhD, Lecturer, Centre for Adult Teaching, Canberra College of Advanced Education.

L.P. Duthie, BCom, Secretary, Department of Primary Industry.

H.R. Edwards, BA, DPhil (Oxon), FAIM, FASSA, MP, Member for Berowra (from May 1983).

Professor P.T. Fink, CB, CBE, BE, FTS, Chief Defence Scientist, Department of Defence.

A.M. Godfrey, BEcon, Deputy Secretary, Department of Industry and Commerce (from August 1982).

R.K. Gosper, BA, Chairman and Chief Executive Officer, Shell Company of Australia Ltd.

D. Hartley, BE, Hartley Computer Applications Pty Ltd from 1 September 1981.

J.H.S. Heussler, Grazier.

D.J. Ives, BSc, BEcon, Deputy Secretary, Department of Resources and Energy.

B.O. Jones, MA, LLB, ACTT, MP, Member for Lalor (until March 1983).

R.J. Kirby, AO, BE, Managing Director, James N. Kirby Holdings Pty Ltd (from August 1982).

P.R. Marsh, BEcon, Industrial Officer, Victorian Trades Hall Council.

B.W. Scott, DBusAdm, Managing Director, W. D. Scott & Co Pty Ltd.

M.S. Shanahan, Member of Australian Wheat Board.

P.R. Staples, BAplSc, MP, Member for Diamond Valley (from May 1983).

W.J.McG. Tegart, PhD, FTS, Secretary, Department of Science and Technology.

Senator A.M. Thomas, Western Australia (until March 1983).

Observers

Professor Sir Geoffrey Badger, AO, DSc, FTS, FAA, Chairman, Australian Science and Technology Council (until November 1982).

I. Castles, OBE, BCom, Secretary, Department of Finance.

Professor R.O. Slatyer, AO, FAA, FRS, Chairman, Australian Science and Technology Council from January 1983).

J.P. Wild, CBE, ScD, FTS, FAA, FRS, Chairman, CSIRO.

Secretariat

G.D. McLennan, B.Com, Secretary.

I.D. Gordon, Assistant Secretary.

Mrs B. Magi, Administrative Assistant.

STATE AND TERRITORY COMMITTEES

New South Wales

K. Satchwell, BSc, MSc (*Chairman*), Managing Director, AFL Holdings Ltd.

C.S. Barnes, PhD, Manager, Research, Biotechnology Pty Ltd.

C.G. Coulter, BE, ME, FIE, Officer-in-Charge, Power Development Division, NSW Electricity Commission.

K.P. Farthing, ASTC, Executive Director, Manufacturing, Metal Manufactures Ltd.

W.J. Hucker, OBE, Chairman, Air Programs International Pty Ltd.

R.A.K. Long, BSc, PhD, Assistant Director, NSW Department of Industrial Development and Decentralisation.

D.J. McGarry, BSc, Managing Director, Australian Oil and Gas Corporation.

D.R.H. MacIntyre, Grazier.

G.R. Peart, MRurSc, Agricultural Consultant.

D.A.J. Swinkels, PhD, Minerals Process Research Manager, BHP Central Research Laboratories.

Professor A.R. Toakley, PhD, Professor of Building and Head of School of Building, University of NSW.

R.A. Williams, BSc, Cotton Farmer.

T.C. Clark, AASA, ACIS (*Secretary*), Regional Administrative Officer, CSIRO, Sydney.

Northern Territory

G.A. Letts, CBE, DVSc (*Chairman*), Director, Conservation Commission of the Northern Territory.

B.J. Cameron, BAgSc, Chairman, Agricultural Development and Marketing Authority.

D.P. Drover, BSc, PhD, Chief Scientist, Department of Primary Production.

W.J. Fisher, Mining Consultant.

G.J. Hunt, BArch, Principal of Gary Hunt & Associates.

W.M. Kirke, Research Writer.

R.M. Morrison, DipArch, FRAIA, ARIBA, Architect.

J.V. Quinn, MD, Assistant Secretary, Environmental Health Division, Northern Territory Department of Health.

C. Rioli, Member of Executive, Tiwi Land Council.

J.W. Suiter, BSc, MSc, PhD, FRMIT, Vice Principal, Darwin Community College.

M.J. Tilley, Company Director and Farmer.

W.J. Waudby, Pastoralist.

M.G. Ridpath, BSc, PhD (*Secretary*), Officer-in-Charge, CSIRO Darwin Laboratories.

Queensland

G.I. Alexander, BVSc, MSc, PhD, FACVSc (*Chairman*), Director-General, Queensland Department of Primary Industries.

J.A. Allen, PhD, FTS, Chairman, Board of Advanced Education.

A.J. Allingham, Grazier.

G.L. Baker, MSc, Deputy Director (Technical), Department of Commercial and Industrial Development, Queensland.

D.W. Beattie, BE, FIE, Commissioner of Water Resources, Queensland.

J.M. Hudson, Grazier.

B.J. Meynink, BSc, Lecturer.

J.C. Rivett, ME, FAIM, Chairman, Gutteridge, Haskins & Davey.

D.M. Traves, OBE, BSc, Consultant, Peat, Marwick & Mitchell.

Professor D.H. Trollope, PhD, DEng, Deputy Vice-Chancellor, James Cook University of North Queensland.

R.J. White, FASA, DipCom, Managing Director, Consolidated Fertilizers Ltd.

C.D. Williams, MAIMM, Research Manager, MIM Holdings Limited.

D.B. Thomas, BA (*Secretary*), Regional Administrative Officer, CSIRO, Brisbane.

South Australia

R.A. Footner, AM (*Chairman*), Chairman and Joint Managing Director, Bridgestone Australia Pty Ltd.

F.E. Acton, General Manager, South Australian Co-operative Bulk Handling Ltd.

D. Andary, OBE, FAIM, Chairman, Berri Co-op Packing Union Ltd.

J.E. Harris, BEng, Managing Director, Adelaide and Wallaroo Fertilizers Ltd.

I.J. Kowalick, BSc, BEc, Deputy Director-General, Department of Trade and Industry.

J.C. McColl, MAgrSc, Director-General, Department of Agriculture.

R.J. Mierisch, ME(Civil), Managing Director, A. W. Baulderstone Pty Ltd (until September 1982).

Professor J.P. Quirk, DSc, FAA, Director, Waite Agricultural Research Institute.

K.J. Shepherd, ME, Director of Planning, Engineering and Water Supply Department, South Australia (until April 1983).

P.M. South, BSc, DipFor, Director, Woods & Forests Department, South Australia.

G.G. Spurling, B. Tech, MAE, ED, Managing Director, Mitsubishi Motors Australia Limited (until August 1982).

R. Woodall, AO, BSc, MSc, Director of Exploration, Western Mining Corporation Ltd.

B.W. Bartlett, AASA (*Secretary*), Divisional Secretary, CSIRO Division of Human Nutrition (until February 1983).

J.H. Martel, MSc, PhD, Technical Secretary, Division of Manufacturing Technology (from March 1983).

Tasmania

Professor P. Scott, OBE, PhD, LLD (*Chairman*) former Pro-Vice-Chancellor, University of Tasmania.

J.R. Ashton, BCivilEng, Commissioner, Hydro-Electric Commission, Tasmania.

R.D. Barker, Dip Metallurgy, Dip ChemEng, General Manager, Electrolytic Zinc Co.

E.C. Best, BSc, BE, Manufacturing Manager, Cadbury-Schweppes Ltd.

A.S. Bickford, AASA, ACISA, Mill Controller, Sheridan Domestic Textiles (until January 1983).

M.C.P. Courtney, Editor, Launceston 'Examiner'.

T.M. Cunningham, BSc, BFor, PhD, Commissioner (Management), Tasmanian Forestry Commission.

R.J. Downie, Grazier.

P.J. Fountain, BSc, Director, Tasmanian Department of Agriculture.

Professor J.N. Lickiss, MD, FRACP, FRCP, Professor of Community Health, University of Tasmania.

Captain D.M. Waters, MSc, Principal, Australian Maritime College.

B. Wilson, MSc, Research Manager, Goliath Portland Cement Co.

G.B. Stirk, BSc (*Secretary*), Officer-in-Charge, CSIRO Tasmanian Regional Laboratory (until February 1983).

A.C. Woods, BSc, MSc (*Secretary*), CSIRO Division of Oceanography (from March 1983).

Victoria

J.E. Kolm, AO, IngChemEng (*Chairman*), Consultant and Company Director.

J.D. Brookes, MC, MSc, Director of Conservation, Ministry for Conservation, Victoria.

I.W. Cameron, BMechE, Group Managing Director, Repco Corporation Ltd (from September 1982).

D.J. Constable, BE(Civil), Commissioner, State Rivers and Water Supply Commission, Victoria.

A.J. Farnworth, MBE, PhD, Chief General Manager, Australian Wool Corporation.

R.N. Gottliebsen, Editor, Business Review Weekly (until August 1982).

Professor K.H. Hunt, FTS, MA, Professor of Mechanical Engineering, Monash University.

F.C. James, MSc, Dean, Faculty of Applied Science, RMIT.

J.A. Kelly, Executive Member, Cattle Council of Australia.

Sir Laurence Muir, VRD, LLB, former Senior Partner, Potter Partners.

R.D.E. Parry-Okeden, BE, Managing Director, Vickers Ruwolt.

E.F. Sandbach, BA, BSc, Director Research, Telecom Australia.

E.J.L. Turnbull, Managing Editor, The Herald & Weekly Times Ltd (from September 1982).

S.D.M. Wallis, BCom, AASA, ACIS, Managing Director, Australian Paper Manufacturers Ltd (until August 1982).

J.A. Pattison, MBE, AASA (*Secretary*), Divisional Secretary, CSIRO Division of Building Research.

Western Australia

D.B. Horgan, FSA (*Chairman*), Company Director (until April 1983).

E.N. Fitzpatrick, MAgSc, Director, Department of Agriculture.

E.R. Gorham, BE, Coordinator of Industrial Development, Department of Industrial Development.

R.M. Hillman, BEng, Director of Engineering, Public Works Department.

W.J. Hughes, Chairman, Westwools Group.

J.B. Kirkwood, FInstEngsA, FTS, Commissioner, State Energy Commission.

J.R. de Laeter, PhD, Chairman of the Division of Manufacturing and Science, Western Australian Institute of Technology.

S.L.G. Morgan, BE, Director, Westfi Manufacturing Ltd.

J. Shepherd, BSc, Farmer and Agricultural Scientist.

Professor R. Street, DSc, FAA, Vice-Chancellor, University of Western Australia.

J.P. Brophy, MBE (*Secretary*), Regional Administrative Officer, CSIRO, Perth.

Appendix III

Fields of research and functions

Institute of Animal and Food Sciences

The Institute comprises the following Divisions and Units:

Division of Animal Health
Division of Animal Production
Division of Fisheries Research
Division of Food Research
Division of Human Nutrition
Division of Tropical Animal Science
Molecular and Cellular Biology Unit
Wheat Research Unit
Australian National Animal Health Laboratory.

The Institute conducts scientific and technological research aimed at improving the efficiency of livestock production, the management and productivity of Australia's fisheries resources, the conservation of its marine ecosystems, and the quality and safety of human foods; and at obtaining a better understanding of the relationships between human diet and health.

The Institute's activities include research on:

- control of indigenous and exotic animal diseases;
- nutrition, reproduction, genetics and management of livestock;
- marine ecosystems and the ecology and population dynamics of the ocean's harvestable resources;
- methods of processing, handling and storing meat, fish, dairy foods, fruit, vegetables and grain;
- identification of nutritive imbalances and deficiencies in the diets of Australians and investigation of their effects on human health;
- molecular and cellular biology and its application in the livestock and pharmaceutical industries.

Division of Animal Health

The Division directs its main research effort towards alleviating the major disease problems of the grazing sheep and cattle industries, with emphasis on the immunological approach. Research is also conducted into pig and poultry diseases.

Division of Animal Production

The Division aims to assist the animal industries by providing new and improved technologies offering significant gains in efficiency of livestock production. Its research is mainly in the fields of nutrition, reproduction, genetics, and livestock management.

Division of Fisheries Research

The Division undertakes strategic and resource-oriented research on marine biology and ecology, ocean productivity, and the population dynamics of commercial and potentially commercial species.

Division of Food Research

The Division's research is related to maintenance of the quality of meat, fish, dairy, fruit and vegetable foods throughout the chain of events from production to consumption. Microbiological safety, nutritional value, flavour and appearance are among the aspects of quality involved. Research on methods of processing and storage is aimed not only at improving final quality, but also at avoiding or utilizing wastes and reducing the energy and labour costs of processing and handling.

Division of Human Nutrition

The Division studies nutritional processes with a view to identifying the existence and health consequences of nutritive imbalances and deficiencies in Australian diets. Its research includes experimental studies in developmental neurobiology and in metabolism and digestion, and epidemiological and behavioural studies with emphasis on the relations between nutrition, lifestyle and human health.

Division of Tropical Animal Science

The Division carries out research to help the animal industries of northern Australia, particularly the extensive beef cattle industry, to improve their productivity. Its research is mainly directed towards studying the linked problems of adaptation, nutrition, reproduction and disease control.

Molecular and Cellular Biology Unit

The Unit's research is concerned with gene technology, tissue differentiation and development in animal cells, and with DNA repair and mutagenesis, DNA methylation and chromatic structure. Applications include the production of reagents and the development of techniques useful for diagnosis and therapy in man and animals.

Wheat Research Unit

The Unit's primary objective is to improve understanding of grain quality, with particular reference to wheat. It is also studying the chemical modification of wheat proteins for new industrial uses.

Australian National Animal Health Laboratory

The functions of the Laboratory are to provide diagnostic, research, training, and vaccine production and testing services in support of exotic livestock disease control and eradication programs in Australia, to ensure that livestock imported through animal quarantine stations are free from diseases exotic to Australia, and to certify that livestock exported from Australia are free from specified diseases.

Institute of Biological Resources

The Institute comprises the following Divisions and Unit:

Division of Entomology
Division of Forest Research
Division of Horticultural Research
Division of Plant Industry
Division of Soils
Division of Tropical Crops and Pastures
Division of Water and Land Resources
Division of Wildlife and Rangelands Research
Centre for Irrigation Research

The Institute conducts scientific and technological research aimed at improving the management and productivity of Australia's land, soil, water, agricultural, pastoral and forestry resources, and the management and conservation of Australian ecosystems.

The Institute's activities include research on:

- application of the plant sciences to the management and utilization of crops, pastures, forests and native ecosystems;
- introduction, selection and breeding of plant material as a basis for developing new and improved varieties of crop and pasture plants and forest trees;
- control of insect pests of plants and animals, and of weeds and plant diseases, with particular emphasis on research aimed at reducing dependence on chemical control;
- biology of native and introduced animals in the context of conservation and pest control;
- assessment and management of land, soil and water resources in agricultural, pastoral, forested and near-urban areas.

Division of Entomology

The main aim of the Division is to undertake biological rsearch on insects and related arthropods so as to acquire knowledge relevant to the solution of problems of economic and social significance. The research involves the study of the identity, abundance and distribution of insects; and of their behaviour, pathology and genetics. Major activities of the Division are the development of methods of control of arthropod pests by biological, physical and chemical means and by variation of conditions of crop culture, with the aim of integration of these methods into management systems; control of weeds by biological agents; the modification of existing control practices where these have undesirable attributes. The Division further seeks to understand the role of insects in environmental balance. A current specific responsibility of the Division is to maintain and foster the Australian National Insect Collection as part of the national heritage.

Division of Forest Research

The Division's research programs on forest resource characterization, forest management, forest ecology, tree breeding and genetics, and harvesting are designed to supply a scientific basis for the balanced management of Australia's forests in relation to wood production, water supply and ecosystem preservation.

Division of Horticultural Research

The aim of the Division's research is the improvement of woody perennial horticultural crops in Australia. These include a range of grapevines and subtropical and tropical fruit and nut species. Emphasis is placed upon the development of new techniques for the selection and breeding of improved plant types and on understanding the complex interaction between plant performance and the environment.

Division of Plant Industry
The Division is concerned with improving agricultural production through research in the plant sciences, including molecular biology, plant breeding and plant introduction, biochemistry and physiology, nutrition, and microbiology, and with developing new and existing crops, pastures and agricultural practices to meet both current and future requirements in Australia. The Division is also a major centre for research on the Australian flora and vegetation, its taxonomy, ecology and management.

Division of Soils
The Division studies the physics, chemistry and biology of soils and other porous media, together with the integrative disciplines of pedology and geomorphology. It also seeks to establish principles for the application of soil science to agriculture, forestry, hydrology, engineering and conservation.

Division of Tropical Crops and Pastures
The Division conducts research on field crops and pastures in tropical and subtropical Australia, excluding the arid zone. In pasture research, the emphasis is on beef production. The main aims are to develop new legume-based pastures, and to define the effects of environment and management on their growth and productivity. Some studies are done on the ecology of native grasslands. The Division's irrigated and dryland crop research is mainly concerned with developing crops that are new to Australian agriculture, and improving the performance of grain sorghum and soybeans at lower latitudes.

Division of Water and Land Resources
The Division has the broad aim of promoting better use of water and land resources in Australia. Its water research is particularly concerned with catchment hydrology, and with salinity and other aspects of water quality, with a view to improving conservation and management practices. The Division provides Commonwealth, State and local authorities responsible for water and land use decisions with improved methods of gathering, processing and using information on resources. To this end, the work is concerned with techniques for management and survey of natural resources, for their evaluation for a range of possible uses, and for decision-making about the use of resources.

Division of Wildlife and Rangelands Research
The Division aims to understand the nature of ecological systems in relation to the management and conservation of Australia's wildlife and land resources. The general aim of the Division's research is to study the ecology of animal and plant populations and to provide information concerning the processes controlling their stability, diversity, productivity and value to Australia. Specific areas of concern are the management of pests, and the management of rangelands for sustained productivity.

Centre for Irrigation Research
The Centre is concerned with improving productivity of irrigated crops and the efficiency of water use management. Its main research programs are concentrated on physical, chemical and biological processes in the soil/water/root zone system in irrigated, fine-textured soils, and on management of the water resources. Other research is concerned with energy-conserving methods for greenhouse crop production and with oilseed breeding.

Institute of Energy and Earth Resources

The Institute comprises the following Divisions and Units:

Division of Energy Chemistry
Division of Energy Technology
Division of Fossil Fuels
Division of Geomechanics
Division of Groundwater Research
Division of Mineral Chemistry
Division of Mineral Engineering
Division of Mineral Physics
Division of Mineralogy
Physical Technology Unit.

The Institute conducts and fosters scientific and technological research aimed at contributing to the better definition, utilization and management of Australia's mineral, energy and groundwater resources, with due recognition of the environmental consequences of these activities.

The Institute's activities include research on:

- locating, evaluating, defining and characterizing Australia's energy and earth resources; and
- planning their recovery, development and effective use, consistent with the minimization of environmental stresses.

Division of Energy Chemistry

The Division concentrates on chemical research directed towards the development of energy resources particularly relevant to Australia, such as the extraction of oil from shale, conversion of coal to oil, and the conversion of the sun's rays into readily usable energy.

Division of Energy Technology

The Division undertakes engineering research directed towards the balanced use of Australia's energy resources; its activities cover industrial thermodynamics, fluids engineering, transportation research and numerical modelling of energy systems.

Division of Fossil Fuels

The Division undertakes basic and applied research in order to develop and improve methods for discovering and characterizing fossil fuels and methods for the beneficiation and treatment of fossil fuels and certain minerals; to achieve a better understanding of the chemical and physical processes involved in the utilization of coal and other fossil fuels, especially in the conversion of coal to liquid fuels and coal combustion; and to elucidate and, where possible, ameliorate any adverse environmental consequences resulting from the production, treatment or use of fossil fuels.

Division of Geomechanics

The Division conducts basic and applied research that improves the capacity for prediction and control of the behaviour of rock masses in which mining and other engineering activities are performed.

Division of Groundwater Research

The Division investigates the physical and chemical processes affecting the quality and quantity of groundwater, including natural interactions between surface water, groundwater, soils and rocks, and responses to man-made factors such as mining, waste disposal, agriculture, artificial recharge and pumpage.

Division of Mineral Chemistry

The Division's research is directed to assisting the development of new methods and the improvement of existing methods of mineral processing through the application of its continually developing expertise in physical and inorganic chemistry related to minerals. This scientific base also enables it to advance technology in areas such as the environment and energy, which affect the community as a whole.

Division of Mineral Engineering

The Division conducts theoretical, experimental and application studies aimed at developing, improving and controlling industrial processes. Particular emphasis is placed on the treatment and handling of ores and mineral products.

Division of Mineral Physics

The Division applies fundamental principles of physics, engineering, mathematics and geology to the identification and solution of problems in the mineral industry.

Division of Mineralogy

The Division develops its expertise in the geological sciences—particularly in geochemistry, mineralogy and petrology—with the aim of solving problems encountered, or expected, in exploration for ore bodies and economic minerals.

Physical Technology Unit

The Unit's research is aimed at solving specific problems associated with the recovery and utilization of coals, the processing of minerals, and the transport in inland waters of trace metals arising from mining activities.

Institute of Industrial Technology

The Institute comprises the following Divisions:

Division of Applied Organic Chemistry
Division of Building Research
Division of Chemical and Wood Technology
Division of Manufacturing Technology
Division of Protein Chemistry
Division of Textile Industry
Division of Textile Physics

The Institute conducts scientific and technological research and development aimed at increasing the efficiency, competitiveness and scope of Australian industry in relation to both national and international markets.

In the resource-based industries, the Institute's activities include research on:

- properties, processing and use of wool and leather;
- protein science;
- preservation and properties of wood;
- forest products, pulp and paper;
- utilization of lignocellulose resources;
- agricultural engineering;
- chemicals from coal;
- substitute liquid fuels.

In the technology-based industries, activities include research on:

- industrial microbiology;
- biologically active materials;
- specialty polymers and resins;
- building materials;
- metals fabrication;
- automated production technology;
- building and construction;
- safety and comfort in domestic, industrial and commercial buildings;
- purification of water and waste-water.

Division of Applied Organic Chemistry

The Division's particular expertise is in organic chemistry, physical chemistry and polymer science. Its activities are directed to developing alternative sources of energy, fuels and chemicals, to studying the action of organic chemicals on biological systems in order to synthesize new pesticides and veterinary drugs, and to the design, synthesis and use of plastics materials with special structures for specific end-uses in industry and commerce.

Division of Building Research

The aims of the Division are, through research and development, to increase efficiency and effectiveness in the building and construction sector of the economy; to enhance the potential standard of accommodation in Australia for living, work and leisure; and to contribute to urban development and improved environment.

Division of Chemical and Wood Technology

The Division is concerned with the application of chemical technology, engineering and biotechnology. Research areas include wood science, forest conversion engineering, wood preservation, fibre separation and pulping, development of pulp-wood resources and cellulose-based composite materials, the use of chemical and biological systems for converting lignocellulose to animal feed, chemicals and energy, the development of agro-industrial systems, and technologies for purifying and recycling water. In the field of agricultural engineering, the main interests are in grain storage and de-infestation of stored grain by physical processes.

Division of Manufacturing Technology

The Division's research is directed to improvements in the manufacture of fabricated components. The main activities include welding, diecasting and metal sheeting. The research covers the study of processes for manufacture, the integration and control of processes through microelectronics devices, and the engineering analysis and synthesis of product design for manufacture.

Division of Protein Chemistry

Research in the Division is concerned with the structure, science and biological activity of proteins. The knowledge gained and the techniques developed are used to assist industries based on protein products such as wool, leather and seeds. The Division collaborates with other research laboratories, including other CSIRO Divisions, on problems of a biochemical or biophysical nature relating to a wide variety of proteins.

Division of Textile Industry

This Division's main objective is to improve the utilization of Australian wool in the world textile industry. The work includes studying the relationship between the properties of fibres and their performance in textile processing, improving the operations carried out to convert raw wool into a clean fibre ready for mill processing, developing improved techniques and equipment for the manufacture of tops, yarns, fabrics and garments, devising procedures that reduce the environmental impact of textile processing, and improving the performance of the final product.

Division of Textile Physics

The principal task of this Division is research and development associated with the physical properties and performance of wool for the Australian wool industry. Major efforts are directed towards research on the measurement, specification and handling of raw wool to achieve economies in packaging, transport, marketing and processing, and also to improvements in processing and end-use arising from new techniques and studies of the physical properties of textile fibres, yarns and fabrics. Non-wool work is confined at present to the use of textiles for filtration, especially of industrial particulates from air and flue gases.

Institute of Physical Sciences

The Institute comprises the following Divisions and Units:

Division of Applied Physics
Division of Atmospheric Research
Division of Chemical Physics
Division of Computing Research
Division of Environmental Mechanics
Division of Materials Science
Division of Mathematics and Statistics
Division of Oceanography
Division of Radiophysics
Australian Numerical Meteorology Research Centre.

The Institute conducts scientific and technological research in the physical, chemical and mathematical sciences aimed at meeting the needs of Australian industry and the community generally. The research includes work directed to increasing understanding of the physical environment, and undertaken both in the national interest and in accord with the Organization's obligation to contribute to the discharge of Australia's international scientific responsibilities in areas such as astronomy, oceanography and the atmospheric sciences.

The Institute's activities include research on:

- application of the physical sciences to industrial problems;
- maintenance of the national standards of measurement;
- development of scientific and industrial instrument techniques;
- properties of industrial materials and development of improved materials and chemical and physical processes;
- climate, weather and atmospheric transport of pollutants and other entities;
- physics of interactions between soil, water, plants and atmosphere;
- radiophysics and its application to astronomy, navigation and communication;
- the physical and chemical oceanography of the Australian marine environment, including air-sea interaction;
- application of mathematics and statistics to problems in industry and science; and
- development of advanced computer operating systems and the provision of a central computing service.

Division of Applied Physics

The Division undertakes research in applied physics related to problems in industry and the community, and collaborates with industry in exploiting promising developments. An important part of its work is the maintenance of the Australian standards of measurement of physical quantities. The Division conducts research on the properties of materials and on the physics of the sun. It takes part in international scientific activities in cooperation with national laboratories of other countries under the Metric Treaty, and with countries establishing their own standards.

Division of Atmospheric Research

The objectives of the Division are to conduct research into physical and chemical aspects of atmospheric processes and phenomena, including both basic studies and investigations directed towards the solution of environmental, industrial and community problems.

Division of Chemical Physics

The Division conducts research directed broadly towards the understanding of chemico-physical phenomena, and encompassing spectroscopy, diffraction studies, radiation interactions, and solid-state investigations. It seeks to exploit the results of this research in solving scientific and technological problems and promoting technological innovation, particularly in the area of scientific instrumentation and techniques.

Division of Computing Research
The Division provides advanced scientific and technical computing services for CSIRO Divisions, government departments and some universities through the CSIRONET computing network. This links the central computers in Canberra with smaller computers in all State capitals and other centres in various parts of Australia. The Division also conducts research concerned with the development and application of advanced computer operating systems, picture processing and graphics, simulation languages and simulation techniques, data-base management systems, and the design of Very Large Scale Integrated (VLSI) circuits.

Division of Environmental Mechanics
The Division conducts physical investigations of energy exchange, heat and momentum transfer, and the movement of natural and introduced substances (for example, water, carbon dioxide, salts and fertilizers) in the environment, with special reference to plants, soils and the lower layers of the atmosphere. It applies the results of these investigations to problems in agriculture, ecology, hydrology, meteorology and industrial processes. Investigations of mathematical aspects of ecology and geophysics are also carried out.

Division of Materials Science
The Division studies the properties, behaviour and utilization of industrially important materials based on metals, alloys, refractory oxides and ceramics. Its work covers the development of catalysts for the synthesis and processing of liquid and gaseous fuels, the development of materials of very high strength and resistance to severe environments, and the study and development of various industrial processes.

Division of Mathematics and Statistics
The objectives of the Division are to apply statistics and other appropriate mathematics in support of research throughout CSIRO and to conduct research related to such application. In pursuing these objectives, the staff of the Division collaborate in research projects with other Divisions, pursue appropriate statistical and mathematical research, and provide consulting services.

Division of Oceanography
The Division carries out investigations of the physical and chemical structure, processes and dynamics of the Australian coastal and oceanic waters with the aim of describing and predicting currents, meteorological and climatic influences, biological production, and the effects of human activity.

Division of Radiophysics
The Division conducts research in radiophysics and its application to community and industrial problems. In its radio astronomy programs, the fields of research include galactic, extra-galactic and solar system astrophysics. As progress in these fields requires advanced observing instruments and techniques, substantial effort is devoted to research in antennas, electronics and signal processing. In the Division's applied programs, promising applications of this expertise to community problems in general are developed in collaboration with industry.

Australian Numerical Meteorology Research Centre
The Centre is a joint unit of CSIRO and the Department of Science and Technology. It develops

numerical models of the atmosphere and oceans, and uses these to study the possible causes and nature of natural and man-induced climate changes and to improve the accuracy of Australian weather forecasts and extend the period for which they apply.

Bureau of Scientific Services

The Bureau aims to facilitate and promote the transfer and utilization of technology and scientific and technical information for the benefit of Australian science, industry and the community at large, and to foster technical development projects with other nations.

The Bureau consists of the following four units:

Central Information, Library and Editorial Section (CILES)
Centre for International Research Cooperation (CIRC)
Commercial Group
Science Communication Unit.

The Bureau's activities include:

- providing scientific and technical information and publishing, library and data-base services for CSIRO and the community;
- communicating information about CSIRO and its research to a variety of audiences, both technical and non-technical, and liaising with industry;
- encouraging the adoption of CSIRO technical know-how, inventions and technology in industry by collaborative research and development agreements, by licensing, and by contracting-out research and development;
- coordinating CSIRO's involvement in international relations and its involvement in technical assistance programs in developing countries; and
- providing advice to the Executive, Institutes and Divisions on matters of policy related to the Bureau's areas of activity.

Central Information, Library and Editorial Section (CILES)

The Section provides scientific and technical information, library, and publishing services for CSIRO and, where practicable, makes information services available to the wider Australian scientific and technical community, to industry, and to the public. It also participates in a range of activities related to information services in Australia and overseas, and seeks to increase awareness of the importance of scientific and technical information resources and, coincidentally, to assist in the development of an information industry in Australia. An important part of its functions is the development of new computer methods for applications in its areas of activity.

Centre for International Research Cooperation (CIRC)

CIRC is responsible both for the formulation, for Executive approval, of policy and procedures for the Organization's participation in international activities, and for their implementation as appropriate. It coordinates the Organization's activities in relation to international science and technology agreements, and is also the focal point for formal arrangements which CSIRO makes with overseas research institutions and with the United Nations and other international agencies.

CIRC is responsible for coordinating the Organization's efforts to assist developing countries, for evaluating and implementing project proposals, and for training scientists from developing countries.

Commercial Group

The Group provides specialist advice and administrative assistance within CSIRO on commercial matters relating to patents, know-how, trade marks and other industrial property rights; licences, collaborative R&D and secrecy agreements; and joint ventures and the use of CSIRO's corporate powers.

It is responsible for the administration of the Organization's industrial property portfolio, including the payment of fees to attorneys and others, the provision of regular status reports to the Executive and the Minister, and the maintenance of complete records, and for advising on proposed agreements for the sale, licensing or exchange of CSIRO technology.

The Group also administers the Executive's Central Development Funds, which are allocated by a Committee of Directors for the support of short-term development projects with strong commercial prospects.

Science Communication Unit

The Unit facilitates the communication of information about CSIRO and its research, and of any other scientific and technical information considered appropriate, to a variety of audiences, both technical and non-technical; provides assistance in a range of cooperative communication projects; and evaluates the effectiveness of communication programs.

Planning and Evaluation Unit

A Planning and Evaluation Advisory Unit, headed by a Director, assists the Executive in the development of policies and priorities for the conduct of research.

The functions of the Unit are to:

- provide advice to the Executive, based on analyses of scientific, economic and social data from both within and outside CSIRO, which will assist the Executive in the discharge of its strategic planning responsibilities;
- provide specialist input to committees of review;
- advise the Executive, Institute Directors and Chiefs on planning, review and evaluation methodology;
- undertake special studies in industrial and economic areas as required by the Executive for strategic planning purposes; and
- advise the Executive on trends in research planning in other countries.

Appendix IV

Freedom of information

The Freedom of Information Act 1982 came into effect on 1 December 1982.

Requests made to CSIRO 1 December 1982-30 June 1983

CSIRO received a total of eight requests for documents under the Freedom of Information Act and was involved in inter-agency consultations on a number of requests of primary concern to other agencies.

Requests were handled in the following manner:

(i)	access granted	2
(ii)	transferred to other agencies	1
(iii)	access granted in part only	3
(iv)	awaiting decision	2

Reasons for decisions to refuse access or make deletions in respect to (iii) above were made under one or more of the following provisions of the FOI Act:

.	Internal working documents	(S.36)
.	Documents affecting the staff management interests of an agency	(S.40(c))
.	Documents affecting personal privacy	(S.41)
.	Documents containing material obtained in confidence	(S.45)

Initial decisions on whether or not access was granted were notified to applicants within the following intervals of time:

.	0 to 15 days	2
.	31 to 45 days	1
.	46 to 60 days	3

The numbers of requests on various subjects were as follows:

	Subject matter of requests	No. of requests
.	Documents relating to personal affairs	4
.	Documents relating to the use of non-human primates for research purposes	2
.	Documents relating to the review of CSIRO Divisional research activities	1
.	Documents relating to tests on fire extinguishing agents	1

Two applications were received for internal review of documents relating to personal affairs. Decisions were varied in both cases on review, and access granted with fewer deletions.

Handling of Rejections

During the reporting period there were no cases involving action by the Ombudsman or the Administrative Appeals Tribunal.

Costs of Freedom of Information

In three cases CSIRO had a discretionary power to charge fees. However, as the information and documents supplied were of a type CSIRO customarily makes available to the public free of charge, no charges were levied.

Four extra positions were approved for FOI purposes. Activities relating to requests are handled by three officers (Administrative Officer Class 4, Administrative Officer Class 3 [two positions]) who were progressively appointed during the reporting period. These officers were principally engaged in preparing the Organization for the introduction of FOI legislation and the production of associated documentation in addition to the handling of specific requests.

Manpower costs for these officers, including overheads, were $54 361.

Manpower costs for authorized decision-makers and their advisers, including overheads, were approximately $1405.

The approximate total manpower costs for CSIRO, including those of support staff, were $55 766.

Other FOI costs incurred were estimated to be:

	$
Communications (postage, telex, telephones)	634
Training (fares, accommodation, visual displays)	7545
Inspection facilities and fittings	1237
Copies of the FOI Act, Regulations and Guidelines	230
Printing and photocopying	1414
Office equipment	249
Total	11 309

Internal Procedures

CSIRO has a central FOI Unit, established within the Headquarters of the Organization, which is responsible for the receipt of requests, for identifying the documents subject to requests, for referring these to senior officers for decision, for giving access to those documents as appropriate, and for maintaining statistics on the operations of FOI.

All CSIRO Registries have been alerted to the need to ensure that FOI requests are given priority treatment and sent promptly to the FOI Coordination Unit. Requests are registered and indexed on receipt and a file created within a special FOI file series. An instruction sheet and a form for the calculation of charges and the obtaining of statistical data for statutory reporting purposes accompanies each file which has its own distinctive cover. Cost category codes established within the CSIRO accounting sytem account for all expenditure incurred by the FOI Unit.

All responses to applicants are monitored through the FOI Unit to ensure that the requirements of the legislation are fully observed.

CSIRO is operating on a centralized decision-making basis. The following officers in the functional areas of Headquarters are authorized to make decisions on requests:

Designation	**Classification**	**Scope of Authority**
OIC FOI Coordination Unit	Administrative Officer Class 3	Grant access. Charge a fee—remit a fee.
Personnel Operations Manager	Administrative Officer Class 7	Grant or deny access. Amend documents—personal affairs.
Assistant Secretary (Administrative Systems and Services)	Assistant Secretary	Grant or deny access. Charge a fee—remit a fee.
Deputy Secretary (Personnel)	Assistant Secretary	Grant or deny access. Amend documents—personal affairs.
Secretary (Personnel)	Senior Assistant Secretary	Review decisions.
Deputy Secretary (Finance and Administration)	Senior Assistant Secretary	Review decisions.

All CSIRO Divisions and Units have nominated FOI contact officers for the handling of inquiries and providing advice and assistance to the general public.

Staff Training

The following internal FOI training activities were undertaken during the reporting period. In all, 12 seminars were held over 15 consecutive working days and were conducted by a representative of the Personnel Branch and the officer-in-charge of the FOI Unit.

Aim of Activity	Duration	No. of Staff in Attendance	Venue and Target Audience
Briefing session on the major features of the FOI Act.	½ hour	30	Headquarters ACT, Personnel Branch and senior staff
Briefing session on the major features of the FOI Act.	1 hour	30	Black Mountain ACT, Divisional administrative staff
Briefing seminars on provisions and implications of the FOI Act including the proposed amendments, plus related aspects of personnel decision-making.	3 hours	22	Perth
	3 hours	16	Adelaide
	3 hours	48	Melbourne
	3 hours	10	Hobart
	3 hours	26	Sydney
	3 hours	20	Brisbane
	3 hours	12	Townsville
	3 hours	5	Rockhampton
	3 hours	7	Darwin
	3 hours	6	Alice Springs
	3 hours	28	Black Mountain ACT
	3 hours	30	Headquarters ACT
	5 hours	7	Headquarters ACT (Trial presentation)
			FOI Divisional contact officers and senior Divisional staff including representatives of Staff Associations

A total of nine officers attended FOI seminars and forums conducted by the Attorney-General's Department and the Public Service Board.

Appendix V
Reporting requirements

Statutory Reporting Requirements

Section 57 of the Science and Industry Research Act 1949 requires that certain items be included, together with a general account of the operations of the Organization, in each annual report. These items are listed in the table below in the order in which they appear in section 57, together with responses or cross-references to other parts of the report.

Financial statements in respect of that year in such form as the Minister for Finance approves.	See Chapter 14.
Copies of all determinations of the Minister made under sub-paragraph 9(a)(iv).	No determination was made.
Copies of all directions of the Minister given under section 13.	A direction was given in 1978 and has continued in force since that date. The text appears on page 50 of the CSIRO Annual Report 1978/79.
All advice furnished by the Advisory Council under section 34 during that year.	See Chapter 15.
A statement of the policies of the Organization in relation to the carrying out of the scientific research of the Organization that were current at the beginning of the relevant year, together with a description of any developments in those policies that occurred during that year.	The response developed by the Organization to meet this requirement has two main components. These are: . a comprehensive statement each year of the research objectives being pursued by the Organization and the level of resources devoted to each objective; and . an initial statement of general policies relating to research, followed by statements of policies relating to specific areas of research, as these policies are developed. The statement of research objectives and resources is presented in Chapter 2. The initial statement of general policies relating to research appeared in the CSIRO Annual Report 1978/79. Policies relating to specific areas of research which were developed during 1982/83 appear in Chapters 3-6.
Comments of the Executive on advice furnished to it by the Advisory Council during that year.	See Chapter 15.
Auditor-General's report	See Chapter 14.

Additional Reporting Requirements

In November 1982 the Government announced decisions on general information to be provided to Parliament in the annual reports of statutory authorities (see Senate Hansard pages 2258-2261). These items are listed in the table below in the order in which they appear in the Government's announcement, together with responses or with cross-references to other parts of the report.

Enabling legislation	Science and Industry Research Act 1949.
Responsible Minister	Minister for Science and Technology. The Minister's statutory powers of direction are mentioned in the preceding table.
Powers, functions and objects	See page iv.
Membership and staff	See page v and Appendices I and II. CSIRO staff are employed under Section 32 of the Science and Industry Research Act 1949. Information about CSIRO may be obtained from the sources listed below. **Scientific and technical inquiries:** Central Information Service, CSIRO, P.O. Box 89, East Melbourne, Vic. 3002. Tel. (03) 418 7333. The Librarian, CSIRO, P.O. Box 225, Dickson, A.C.T. 2602. Tel. (062) 48 4228. Regional Information Office, CSIRO, P.O. Box 218, Lindfield, N.S.W. 2070. Tel. (02) 467 6211. **Inquiries in Western Australia:** Regional Information Office, CSIRO, P.O. Box 374, West Perth, W.A. 6005. Tel. (09) 322 2111. **Freedom of Information inquiries:** Freedom of Information Unit, CSIRO, P.O. Box 225, Dickson, A.C.T. 2602. Tel. (062) 48 4123. **Media inquiries:** Media Office, CSIRO, P.O. Box 225, Dickson, A.C.T. 2602. Tel. (062) 48 4484.

	Publications inquiries:
	Central Information, Library and Editorial Section, CSIRO, P.O. Box 89, East Melbourne, Vic. 3002. Tel. (03) 418 7333.
Financial statements	See Chapter 14.
Activities and reports	See Chapters 1-20.
CSIRO publications	See page 110.
Operational problems	See Chapters 1-11 and 14.
Subsidiaries	CSIRO has no subsidiaries as such. However, it holds a one-third equity shareholding in Siromath Pty Limited, a private company established to provide high level mathematical consultancy services, primarily to Australian industry. CSIRO's participation in the formation of the company was an exercise of its powers under paragraph 9AA(b) of its Act. The other shareholders in the company are the Australian Mineral Development Laboratories and Knight Actuaries Pty Limited. In 1982/83 Siromath quadrupled its turnover and staff, and became essentially self-supporting. A company report for 1982/83 is expected to be available by the end of 1983.

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