Commonwealth Scientific and Industrial Research Organization, Australia

CSIRO Twenty-seventh Annual Report 1974/75

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This report of the work of CSIRO for the year ending 30 June 1975 has been prepared as required by Section 30 of the Science and Industry Research Act 1949–1973.

The Executive gratefully acknowledges the valuable help received from Australian and State government departments and instrumentalities, universities and other research bodies, members of primary and secondary industries, private individuals, and overseas institutions.

The Executive also wishes to thank those who have made their knowledge and experience freely available to the Organization by serving on its Committees or by personal advice.

J. R. Price (*Chairman*)
V. D. Burgmann
M. F. C. Day
V. E. Jennings
L. Lewis
A. E. Pierce
E. J. Underwood
W. J. Vines
F. M. Wiltshire

CSIRO was established by the Science and Industry Research Act of 1949. Under the Act, CSIRO replaced the former Council for Scientific and Industrial Research established in 1926.

The powers and functions of CSIRO are:

the carrying out of scientific research in connection with Australian primary and secondary industries or any other matter referred to it by the Minister

the training of scientific research workers and the awarding of studentships

the making of grants in aid of scientific research

the recognition of support of research associations

the maintenance of the national standards of measurement

the dissemination of scientific and technical information

the publication of scientific and technical reports

liaison with other countries in matters of scientific research.

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Cover
Processing passionfruit juice in the pilot plant of the DIVISION OF FOOD RESEARCH at North Ryde, Sydney, by means of a centrifugal film evaporator and essence recovery equipment. The Division has used this plant to develop a process for concentrating passionfruit juice without interfering with the fruit's characteristic flavour. The evaporator is also used to study aroma losses and quality changes during the concentration of various fruit juices and liquid foods.

Photograph: Will Rushton

Research

Introduction

Two centuries ago Edmund Burke declared that the public interest requires doing today those things that men of intelligence and goodwill would wish, five or ten years hence, had been done. This dictum represents an essential element in the philosophy of any research organization, and it has a special relevance for CSIRO, concerned as it is with the conduct of research directly related to the future needs of Australian industry and the Australian people.

Matching research objectives and priorities to national needs is not an easy task. In some instances, where a particular line of research requires a time scale of say 10–15 years, the community interest may be only dimly perceived. In others, the community interest may be expressed in terms of national goals formulated after widespread community debate.

Even when there is general agreement, however, national goals are usually expressed in quite broad terms. Frequently they are more easily sensed than defined, and most countries have found it difficult to describe their national goals with any degree of precision. Nevertheless, it is usually possible to arrive at broad areas of agreement about national priorities, and it is expected that in Australia the newly formed Australian Science and Technology Council will help to bring to sharper focus these areas of agreement.

The expectations of society for science and technology have been clearly described by the Government in its White Paper, 'Science and Technology in the Service of Society—The Framework of Australian Government Planning', in the following words:

> 'Society's requirements of science and technology will not diminish. On the contrary, there will be growing but changing patterns of needs. The individual scientist, pursuing his own speciality remote from day-to-day pressures, will still enjoy a respected and important place in the general scheme of things. The technologist or engineer will still be as involved as he is at present in devising new products or providing skilled services for a demanding public. Fundamental research and creativity wherever they flourish will always be precious features of humanity, requiring nurture and tangible support. However the mistakes of the past and the great problems of the times, to the solutions of which science and technology promise so much, will necessitate new approaches characterized by the co-ordinated multi-disciplinary application of various skills and types of specialized knowledge. In particular, the social sciences will be required—and encouraged—to provide their proper contribution to the processes of matching scientific and technological considerations to government policy.'

One of the principal tasks facing CSIRO is to identify the needs of the Australian community or sections of it. This requires a continuing, free and active flow of information at various levels. It is essential that CSIRO maintain effective communication with a wide cross-section of the public so that it can be confident of its perception of priorities and national goals.

Within CSIRO this process of identifying community needs and determining research priorities involves active and continuing debate among the Executive, Chiefs of Divisions and research staff. Having defined the problems and priorities, however, in the final analysis it is the individual research scientist who is best able to determine the most appropriate approach to these problems.

The need for effective communication between scientists and the community was also emphasized in the introduction to the Government's White Paper on 'Science and Technology in the Service of Society':

> 'The Government believes that the early perception and definition of national goals and of new and fruitful opportunities for achieving them can best take place in a climate of informed awareness engendered by a continuing and active interchange of information and a more articulated expression of attitudes within society. It is important that scientists and technologists contribute to this debate and that they address themselves not only to their peers but also to the public.'

CSIRO contributes to the debate in a number of ways in order to ensure an adequate feedback that will assist in directing its research effort into the most appropriate channels. One avenue of communication is the Organization's Annual Report. Although it is not possible in a publication of this size to deal in any detail with the overall research activities of the Organization, the Report is nevertheless an important means of informing Parliament, in particular, and the community, in general, about what the Organization is doing.

This year the research chapter of the Annual Report presents the research programs in a wider perspective and places less emphasis on individual research projects. Descriptions of these projects are published in Divisional Reports.

The Annual Report is, however, only one of the means by which CSIRO communicates its work to the public. The part-time members of the Executive, the members of the Advisory Council and the various State Committees provide valuable links between CSIRO and other sectors of the community. Similar links have been established as a result of CSIRO officers serving on numerous bodies

either as representatives of CSIRO or as experts in a particular field of knowledge, or both. Publications are an important medium of communication and CSIRO produces a wide variety of periodicals, technical reports and brochures intended for lay audiences. A new publication appearing this year is ECOS, a periodical dealing with research relevant to environmental issues. There are many other channels of communication, some formal, some informal, some relying on the printed word, some on personal contact. The aim of all of these, however, is not only to communicate information but to generate feedback that will help CSIRO identify the specific research requirements of various groups within the community.

Never in its history has CSIRO been involved internally and externally in so intensive an examination of its present and future role as in the past two years. The preparation of CSIRO submissions for the Coombs Task Force, the OECD Examiners' review of science and technology, the Green Paper studies on rural policy and manufacturing industry, the various inquiries of the Industries Assistance Commission, dominated by that on 'Financing Rural Research', the Royal Commission on Australian Government Administration, and the Senate Standing Committee on Finance and Government Operations has provided a stimulus leading to critical self-examination.

These reviews are an important element in the total communication process through which CSIRO identifies the needs of the community and makes judgments on how its research can best contribute to meeting these needs.

J. R. Price

Chairman

General

Administrative arrangements

In June 1975 the portfolio of Minister for Science was changed to Minister for Science and Consumer Affairs, and Mr Clyde Cameron was appointed to the new portfolio succeeding Mr W. L. Morrison. Details of this and other changes in the Ministry were announced in a press statement issued by the Prime Minister, Mr E. G. Whitlam, on 5 June. The final sentence of the press statement said: 'The Department of Minerals and Energy will take over responsibility for the Minerals Research Laboratories and the Solar Energy Studies Unit.'

On 6 June the Administrative Arrangements Order was published in the Australian Government Gazette No. S104. This restricted the responsibilities of the Minister for Science and Consumer Affairs in relation to the administration of the Science and Industry Research Act 1949–73 by inclusion of the words 'except in so far as it relates to mineral and solar energy research'. The responsibility for these matters was allocated to the Minister for Minerals and Energy.

These announcements caused considerable speculation and public controversy about the possible transfer of those staff concerned with mineral and solar energy research from CSIRO to the Australian Public Service.

The situation was subsequently clarified by the publication of revised Administrative Arrangements Orders and the issue of a press statement by the Prime Minister. The latter document made it clear that staff were not to be transferred from CSIRO. It also indicated that the administration of the Science and Industry Research Act 1949–73 was to be the joint responsibility of the Minister for Science and Consumer Affairs and the Minister for Minerals and Energy—the responsibility of the latter Minister being defined as administration of the Act 'in so far as that Act relates to mineral and solar energy research'.

Appointment to Executive

Mr F. M. Wiltshire was appointed a part-time member of the Executive in December 1974. He has been Managing Director of Wiltshire File Co. Pty Ltd since 1938 and Managing Director of Wiltshire Cutlery Pty Ltd since 1959. He is also a director of Australian Paper Manufacturers Ltd and Repco Ltd.

In recent years he has served as President of the Australian Industry Development Association, Chairman of the Committee of Enquiry into Awards for Colleges of Advanced Education, Deputy Chairman of the Manufacturing Industry Advisory Council, Vice-Chairman of the Aircraft and Guided Weapons Industry Advisory Committee, and a member of the Science and Industry Forum of the Australian Academy of Science.

Mr Wiltshire succeeded Dr D. L. Ford, Chief Research Chemist for Union Carbide Aust. Ltd, who served on the Executive for the previous three years.

As a part-time member of the Executive, Dr Ford contributed his extensive experience in the organization and conduct of industrial research and development. He also took a particular interest in CSIRO's safety program.

Senior appointments

Professor B. Rawlings was appointed Chief of the DIVISION OF MECHANICAL ENGINEERING in November 1974. He was formerly Deputy Dean of the Faculty of Engineering and Head of

the Department of Civil and Structural Engineering at the University of Sheffield. Professor Rawlings succeeds Mr R. N. Morse who is now Director of the SOLAR ENERGY STUDIES UNIT.

Mr R. H. Clarke was appointed Officer-in-Charge of the AUSTRALIAN NUMERICAL METEOROLOGY RESEARCH CENTRE, formerly the COMMONWEALTH METEOROLOGY RESEARCH CENTRE, in December 1974. Mr Clarke, who was previously with the DIVISION OF ATMOSPHERIC PHYSICS, succeeds Dr G. B. Tucker who is now Chief of that Division.

Dr T. W. Scott was appointed Chief of the DIVISION OF ANIMAL PHYSIOLOGY in February 1975 following the retirement of Dr I. W. McDonald.

Human nutrition

In November 1973, the Advisory Council received a report from Professor F. J. Fenner, formerly Director of the John Curtin School of Medical Research at the Australian National University, on the involvement of CSIRO in fields related to medical research. One of the recommendations in the report was that CSIRO should establish a DIVISION OF HUMAN NUTRITION. Following consideration of the proposal, the Executive agreed to the establishment of such a Division using buildings, research facilities and a number of the staff of the DIVISION OF NUTRITIONAL BIOCHEMISTRY in Adelaide. The new Division came into being on 1 January 1975, and the Chief of the former DIVISION OF NUTRITIONAL BIOCHEMISTRY, Dr A. T. Dick, was made Interim Chief of the DIVISION OF HUMAN NUTRITION until Professor B. S. Hetzel takes up his appointment as Chief in February 1976.

In general, the Division's research will encompass the study of human nutritional processes, including biochemical aspects of nutrition in relation to growth and development. The actual programs to be undertaken cannot be completely finalized until the Executive confers with the Chief, after he takes up his appointment. However, areas of research which could be appropriate for the new Division include:

- trace elements, minerals, and vitamins;
- assessment of nutritional status and energy metabolism under varying environmental and socio-economic conditions;
- impact of technological and social developments on dietary patterns and nutrient intakes, including alcohol;
- nutritional values of foods;
- biochemical aspects of nutrition in relation to growth and development.

Forest research

In March 1975, the Minister for Agriculture, Senator K. S. Wriedt, and the Minister for Science, Mr W. L. Morrison, released a joint statement announcing that agreement had been reached on the establishment of a CSIRO DIVISION OF FOREST RESEARCH with headquarters in Canberra. The new Division, which would come into being on 1 July 1975, would include the research activities previously carried out by the Forest Research Institute and the harvesting and mensuration research groups of the Forestry and Timber Bureau. The change, which affected about 200 officers of the Forestry and Timber Bureau located in Canberra and at field stations in the States and the Northern Territory, was aimed at achieving better coordination of Australian Government scientific research into forestry.

The Ministers said that CSIRO's role would be to concentrate on long-

term strategic research to complement the research undertaken by State forestry authorities. The move had the support of the Standing Committee of the Australian Forestry Council and industry.

Discussions with the States have suggested areas of research for the new Division, including ecology, management and harvesting of forests, forest pests, and tree physiology, health and nutrition. The Division will be concerned with the whole forest ecosystem in relation to timber production and other uses of forests. Its program will be complemented by research in other CSIRO Divisions on such matters as forest hydrology and the multiple use of forests. Close links will also be maintained with CSIRO Divisions carrying out research on forest products.

The Executive is planning to establish a Forest Research Advisory Committee to provide a formal communication link between CSIRO, State forest services and industry.

Dr M. F. C. Day of the CSIRO Executive will be acting Chief of the new Division until a permanent Chief is appointed.

CILES

The former Editorial and Publications Section and the Central Library and Information Services were brought together last year to form a branch of the Secretariat known as CILES, the Central Information, Library and Editorial Section. Mr P. J. Judge, formerly head of the OECD Science and Technology Information Section, was appointed Officer-in-Charge of the new section.

The publications held by CSIRO constitute the largest single collection of literature on science and technology in Australia and a considerable effort is being put into making this material available, not only to other scientific institutions and to industry, but to all sections of the Australian community.

Between them, the various Divisions of CSIRO handle many thousands of requests for information each year. In addition, CILES deals with some 4000 inquiries a month from other libraries, from industry, and from the public. To help cope with the growing number of inquiries, a regional information officer has been appointed in Sydney.

CILES is also increasing its contacts with other Australian libraries and is collaborating with the National Library to determine how CSIRO might participate in ALBIS, the Australian Library-based Information System now being developed by the National Library.

Two-thirds of all journals received by CSIRO's Central Library are obtained in exchange for CSIRO publications. In the last year CILES has increased its overseas exchanges, particularly with South-east Asian countries, by 200. It has also increased its exchanges within Australia by the same amount.

Access to all scientific and technical journals held in Australia not only by CSIRO but by outside libraries as well, is made possible through *Scientific Serials in Australian Libraries*, a major catalogue compiled by CILES. *Scientific Serials* has been updated. Some 8000 new titles have been catalogued and the entire work of over 5000 pages is being prepared for publication. All new holdings and amendments up to June 1975 have been included. Future versions will be produced in machine-readable form to facilitate the updating of the catalogue in microfiches and other appropriate formats.

CILES provides the main indexing effort for Australian scientific

publications. *Australian Science Index*, a classified monthly index to the Australian scientific and technical literature, indexed some 5315 papers from 271 journals during the year.

In January 1975, CILES introduced a new series, *CSIRO Index*, which documents published reports by officers of the Organization. *CSIRO Index* continues the functions of the former *CSIRO Abstracts*, but the abstract content has been replaced by enrichment terms intended to amplify or clarify the title of each paper. The format is designed to facilitate quick scanning of both subject and bibliographic details. Titles of recent CSIRO translations of scientific papers are also listed with enrichment terms.

The computerized information services offered by CILES have continued to develop. Some 248 scientists, both inside and outside CSIRO, are using the SDI service on data-bases in fields of chemistry, physics, biology, food science and technology, water resources, and agriculture. A data-base in the earth sciences, GEOARCHIVES, will be available towards the end of 1975 and others are being tested.

Arrangements have been made to install an on-line computer terminal in the Australian Embassy, Washington. The terminal is connected to the Systems Development Corporation Service in Washington and provides access to a number of data-bases for retrospective searches through several years of the literature in such fields as the earth sciences, agriculture, chemistry, communications, ecology, urban planning, engineering and pollution. It also provides access to U.S. Government research reports.

CILES has been providing input to the FAO International Information System for the Agricultural Sciences and Technology, AGRIS, since early in 1975. The State Departments of Agriculture are working with CSIRO in this program. CILES is also responsible for providing abstracts of relevant papers published in Australian journals for *Selected Water Resources Abstracts*, a data-base compiled in Washington for world-wide use.

CILES has also been able to extend the use of its software in aid to the Republic of Korea. Korean information officers have been trained in computer programming and profile construction and have now installed the CSIRO SDI system in the Korean Scientific and Technical Information Centre with the assistance of a member of CILES staff. As a result, an SDI service in chemistry is now available in the Republic of Korea.

In conjunction with the Australian Academy of Science, CILES publishes the nine Australian Journals of Scientific Research. It also publishes the journal, *Australian Wildlife Research*, which replaces the former *CSIRO Wildlife Research*.

Considerable effort has gone into improving the marketing of the Australian Journals of Scientific Research both in Australia and overseas to ensure their more effective distribution. Local scientific societies have been given special subscription rates for their members and overseas agents have been offered realistic discounts so that they can obtain new accounts.

During the year the Executive revised its policy with respect to the sale of CSIRO publications in order to make them available on an unrestricted basis to the general public. This has been achieved by putting CSIRO publications on sale through booksellers and the Australian Government Printing Service, and by active promotion through the Organization's extensive mailing lists.

Research

In a report of this size it is not possible to give a full account of all of CSIRO's current investigations. The items in this section have been chosen, therefore, to show something of the wide range of CSIRO's activities and their relevance to the needs of the Australian community. The items also illustrate that many research programs involve the collaboration of scientists from different disciplines and different Divisions. More comprehensive information on the Organization's current research activities can be obtained from the separate annual reports published by each Division. A brief description of the fields of research engaged in by each Division is given on pages 67–71 of this report.

Studying Australia's woodlands

Man's impact on the ecology of Australia's woodlands and forests is being assessed.

Australia's woodlands and forests are subject to many disturbances by men and machines, for example, thinning, clear felling, grazing, burning, competition from introduced pasture species, addition of nutrients and fertilizers, and compaction by machines and livestock. The Woodland Ecology Unit of the DIVISION OF LAND USE RESEARCH is concerned with studying the ecological consequences of such disturbances. The Unit is also an adviser to the Australian Army on restoring and conserving the vegetation of various areas that have been reserved for military training.

The main vegetation types being investigated and the areas in which they are located are:

* Poplar box shrub woodlands—Wycanna (near Talwood) and Shoalwater Bay, Qld.; Cobar, N.S.W.
* Narrow-leafed ironbark woodlands—High Range, Charters Towers and Shoalwater Bay, Qld.
* Grey box woodlands—Puckapunyal, Vic.; Raymond Terrace and Bungonia, N.S.W.; Shoalwater Bay and Mareeba, Qld.
* Spotted gum–white stringybark forests—Shoalwater Bay and Mundubbera, Qld.
* Subtropical eucalypt and rain forests—Canungra, Qld.
* Tropical rain forests—Tully, Qld.

These communities are extensive and are important for agriculture and forestry.

In those cases where an area has been subject to known interference in the past, such as ringbarking or clear felling, the Unit is monitoring the regeneration of the natural vegetation. In other cases, the Unit manipulates woodlands experimentally and studies the response. At Wycanna in southern Queensland, for example, the positions of all trees and shrubs on experimental areas were plotted, and changes in the herbaceous layer were monitored before and after applying different disturbances.

The experiments at Wycanna have led to improved methods for thinning trees on semi-arid and subtropical grazing lands, and for controlling regeneration of unwanted trees and shrubs by competition, fire and grazing. Chemical techniques developed for thinning woodlands to enhance grass production have also provided an ecological tool for manipulating the composition of tree and shrub communities in experimental woodlands.

Recently an intensive study of disturbed forest ecosystems was started at Shoalwater Bay, Qld. Here disturbances, including clear felling for wood chips, are being applied to sets of paired catchments, and the resultant effects on regeneration of vegetation and on nutrient and water balances are being monitored. Regeneration following clear felling for wood chips is also being studied in forests near Triabunna, Tas.

Other major investigations are concerned with the repair and stabilization of damaged and eroding landscapes, and the restoration of woodland communities destroyed by agricultural, military, or other activities.

In two large projects at Puckapunyal, Vic., and Canungra, Qld., attempts are being made to restore woodland and forest communities destroyed by agricultural and other activities. The Puckapunyal project, one of the largest revegetation projects in Australia, is scheduled for completion in 1977. This scheme involves establishing a self-regenerating community of plants on areas subjected to continual disturbance by army tanks. Attempts are being made to re-establish forests and woodlands on upper slopes and ridges. The aim is to restore the hydrologic balance in order to prevent the waterlogging and salting of lower slopes and flats and the deposition of silt in the adjacent river. The DIVISION OF PLANT INDUSTRY, the Soil Conservation Authority of Victoria, the Forests Commission of Victoria, and the Australian Army are helping with the project.

At Canungra, attempts are being made to restore sclerophyll forest and subtropical rain forest on land cleared earlier for dairying. The Canungra project is based at CSIRO's Long Pocket Laboratories in Brisbane where the Unit works in close association with the Rain Forest Ecology Unit of the DIVISION OF PLANT INDUSTRY.

Smaller projects involving the revegetation of landscapes are in progress at Swanbourne, W.A., where, in conjunction with the State Department of Agriculture, studies are being made on ways of stabilizing coastal dunes, and at Murray Bridge, S.A., where experiments on stabilizing mallee sandhills are being conducted with the DIVISION OF SOILS. The DIVISION OF CHEMICAL ENGINEERING is collaborating in studies on revegetating damaged landscapes by devising methods of coating and pelleting seeds for aerial sowing.

Because of the importance of fire in the management of some native grasslands, studies of fire behaviour and of the ecological consequences of different types of burning are receiving special attention, particularly in western New South Wales and at Shoalwater Bay, Qld.

At the request of the Department of Urban and Regional Development the Woodlands Ecology Unit is conducting surveys in the western environs of Sydney and Melbourne to obtain information on vegetation, soils, climate, and other environmental factors. This information will help town planners and landscape architects to plan future urban developments, and will indicate the best tree and shrub species to improve and beautify these two regions. It will also draw attention to features of scientific, historical, or scenic interest that are valuable for conservation.

New initiatives in soil science

The DIVISION OF SOILS *is placing increased emphasis in its research on conservational aspects of land use.*

In 1973 several CSIRO research units were regrouped to form the LAND RESOURCES LABORATORIES as part of a move to coordinate and intensify research on the definition, evaluation, and management of Australia's land resources. The Laboratories comprise the DIVISION OF LAND RESOURCES MANAGEMENT, the DIVISION OF LAND USE RESEARCH, and the DIVISION OF SOILS. Following this reorganization the DIVISION OF SOILS has continued to undertake tactical and strategic research to complement the work of its sister Divisions.

Although this is a traditional role for the DIVISION OF SOILS there has been a restructuring of research programs to place greater emphasis on the conservational aspects of land use. The Division's research is aimed at helping solve important problems in land use such as the maintenance of stable agricultural systems, the conservation of water supplies for plants, animals and man, the control of soil erosion, and the identification and reduction of environmental pollution.

From its establishment in 1926 until the early 1950s, much of the Division's research was directed to providing maps showing the distribution of different soil and landscape types, such information being regarded as essential for land use planning. However, these soil maps proved to be of limited use in determining the fertilizer requirements of crops and pastures, and the Division's work in soil surveys and pedology became overshadowed by its other research. In recent years interest in the findings of the early surveys has revived, probably because the system of classifying soils was based largely on the relatively permanent physical properties of soil such as structure, permeability, and erodibility, which are now regarded as more important than their more ephemeral chemical properties. Although intermediate glasshouse and laboratory experiments are often desirable, soil and landscape problems occur in the field and ultimately must be solved there. Accordingly, the Division is augmenting its present work with more regional studies in soil physics, and with further field studies of soils and landscapes.

Soil erosion has always been recognized as important, but its scientific study has been somewhat neglected in Australia because of the lack of detailed information on rainfall intensity and distribution, the physics of soil particle disruption, and the susceptibility of different soil types to erosion under various conditions. Suitable instruments for recording information of this sort in both natural and artificial environments are now being developed and basic studies on landscape erosion are being extended to field situations.

The expansion of the Division's efforts in pedology and soil physics, which is expected to provide useful information, not only for agriculture and soil conservation, but also for urban planning, is being accompanied by a limited reduction in research on soil chemistry. In addition, some chemical research is being redirected into matters involving environmental pollution.

Much of the Division's research will continue to be oriented towards agriculture, since a substantial part of Australia's export income still comes from cereal grains, wool and meat. To a large extent these products are produced from broad-acre agricultural systems requiring relatively low inputs of capital, labour, and energy—both directly in the form of fuel for cultivation and

harvesting and indirectly in the form of such things as fertilizers and pesticides. There is still a considerable lack of information on how these extensive, low input systems work and, more importantly, on how much they can be manipulated without causing a decline in soil resources or an increase in consumption of energy. The Division is therefore revising its attitude to soil fertility and is moving away from research on responses to large applications of fertilizer and towards the conservation of soil nutrients, for example, the fate of nitrogen and phosphorus in typical wheat rotations.

Soil biology is also receiving attention. Research on controlling certain soil-borne diseases by biological rather than chemical means, and on using soil organisms to make nutrients more available to plants in deficient soils is having some success.

In addition, work on soil zoology is being integrated with projects on the microbiological decomposition of fresh organic matter. The Division's soil zoology group has been expanded and will be investigating the turnover of organic matter and the re-cycling of plant nutrients in agricultural and forest systems.

Better plants for Australian agriculture

An active program of plant introduction and breeding is being undertaken to provide new and improved plants for Australian agriculture.

Australia's native flora is notably deficient in plants suited to commercial agriculture. The first Australian settlers therefore relied on the introduction of those cereal, vegetable, and horticultural crops that they were used to in England and Europe, and deliberate plant introduction has continued to play an important role in the growth and development of Australian agriculture.

The trend toward pasture improvement did not commence until the turn of the century and was retarded for some time by widespread phosphorus deficiency. Early introductions of pasture species were random and often accidental. Subterranean clover (*Trifolium subterraneum*), the annual medics (*Medicago* species), and Townsville stylo (*Stylosanthes humilis*) were all chance introductions. On the other hand, some other useful species such as kikuyu grass (*Pennisetum clandestinum*) and *Sorghum almum* were introduced intentionally. But direct introduction often represents only the first stage in developing a productive plant species. A second step is tailoring the best of the introductions by plant breeding to improve their adaptation to local environments and to overcome specific problems such as toxicity and susceptibility to disease.

Breeding programs for cereals commenced at the turn of the century under the guidance of men like William Farrer. Since that time the breeding of cereal crops has remained largely in the hands of State Departments of Agriculture and the universities.

Interest in breeding improved pasture species did not occur until the 1930s with CSIR entering the field around 1935. These early efforts were limited, however, by an inadequate range of parent material.

Today four CSIRO Divisions, the DIVISIONS OF PLANT INDUSTRY, TROPICAL AGRONOMY, HORTICULTURAL RESEARCH and IRRIGATION RESEARCH, are involved in plant introduction and breeding.

Through international seed exchange and special collecting missions these Divisions obtain genetic stocks of a wide

range of crop and pasture species. The DIVISION OF PLANT INDUSTRY, in addition to its own program, acts as a central procurement, registration, and quarantine clearing agency for Australian plant introductions. Species introduced by CSIRO scientists are distributed to other CSIRO Divisions and cooperating organizations. An annotated list of introductions (Plant Introduction Review) and a seed exchange list are issued periodically to foster closer liaison with scientists in Australia and overseas.

The plant introduction program has made a considerable impact on our agriculture, particularly with pasture species. The success is due to the joint efforts of the four CSIRO Divisions, State Departments, Universities and the seed trade. These groups have formed Herbage Plant Liaison Committees in each State which release new cultivars for commercial use.

Until recently, the DIVISION OF PLANT INDUSTRY has concentrated mainly on introducing pasture species. Now that the prospects for further advance through direct introduction may be limited for much of south-eastern Australia, the Division is putting increasing emphasis on crop research. Extensive cereal and coarse grain collections have been introduced from overseas and more limited introductions of rice, peanuts and other crops have also been made. In addition, a program for the long-term preservation of genetic stocks of plant species of special interest to Australia has been initiated. Wild relatives of important Australian crop plants will be included in the introduction program as time and facilities permit.

The Division also undertakes basic research on crop and pasture species and their wild relatives to determine the kinds and amounts of genetic variation in plant populations, the factors maintaining this variation, and the role of variation in the adaptability of plants to different environments. This work, together with fundamental studies in genetics and molecular biology, provides the Division with information that is valuable in developing more effective programs for collecting and conserving genetic resources and for exploiting these resources by plant breeding.

For a long time the Division's plant breeding program has been directed to pasture plant breeding, and its successes include Sirocco and Seedmaster phalaris, Cancreep lucerne, and Howard subterranean clover. A phalaris cultivar equal to Sirocco in seedling vigour, winter productivity, and drought tolerance, but with higher seed yield and lower content of toxic alkaloid is now being developed. Studies of self compatibility and hybrid vigour in lucerne have shown that it should be possible to select lines that give a high proportion of hybrid seed under field conditions.

In recent years increasing attention has been given to crop breeding. The Division has bred Sirogo and Sirone, the two main tobacco cultivars currently in use in Australia, and has developed improved genetic material for sorghum, millet and adzuki bean.

At its Cotton Research Unit at Narrabri, N.S.W., the Division is attempting, through breeding, to raise the yield of cotton varieties used in fine count spinning. Australia at present needs to import most of its fine cotton as the existing varieties are too low in yield to compete with the higher yielding medium staple cottons. The Unit is also examining the yield potential of hybrid varieties of cotton and is investigating varieties that have genetic characteristics, such as hairless leaves, which might help minimize pest attack. Work is also continuing on the

development of strains that are early-maturing and resistant to bacterial blight. This work was started originally at Griffith, in the Murrumbidgee Irrigation Area, and at Kununurra in the Ord Irrigation Area.

The DIVISION OF IRRIGATION RESEARCH has begun a program at Griffith to breed new sunflower and safflower cultivars suited to irrigation or to areas with soils of high moisture content. Among the aims of this breeding program is the production of varieties of both sunflower and safflower which are not only high-yielding and disease-resistant, but which also have a maximum ratio of linoleic (poly-unsaturated) to saturated fatty acids while retaining their existing protein levels.

Quarantine restrictions on the importation of seed, and the low genetic variability of present sunflower varieties, which are mainly of Russian origin, have so far limited sunflower breeding in Australia. The Division is giving top priority to improving genetic variability and in an important innovation, has begun importing sunflower pollen from overseas countries, including France, Holland, Rumania, Argentina and the United States. Further imports from Spain, France, Argentina and the USSR are planned. Pollen is much easier to obtain as plant breeders' rights impose more restrictions on the export of seeds. Additionally, pollen faces less severe quarantine restrictions, and breeding progress requires less glass-house space because several crosses can be made on a single plant. With new pollen culture techniques, the Division plans the rapid establishment of large inbred populations of sunflowers for its breeding program.

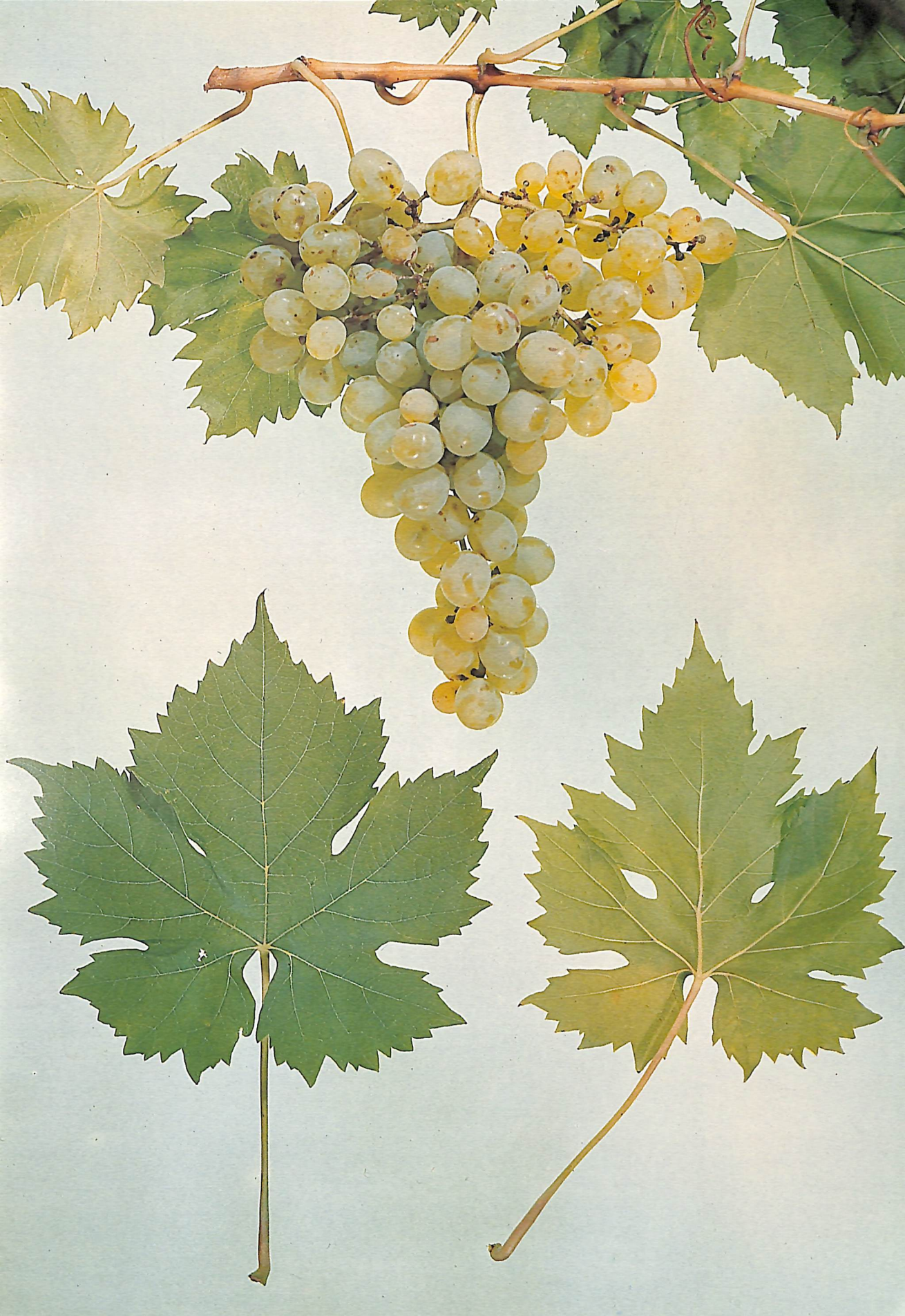
As a winter crop, safflowers are ideally suited to rotation with the summer-growing sunflower. Emphasis in the safflower breeding program will be on producing early-maturing cultivars to permit a year-round oilseed crop.

The introduction, breeding and selection of new varieties of tropical pasture and crop have always been a major part of the DIVISION OF TROPICAL AGRONOMY's research program. In addition, the Division is undertaking research on plant adaptation and plant geography, which is aimed at improving existing introduction and breeding procedures, as well as more basic studies of the genetics of pasture and crop plants.

Since its inception 15 years ago the Division has been instrumental in the release of nine pasture grasses and 13 pasture legumes (notably in the genera *Cenchrus*, *Panicum*, *Paspalum*, *Desmodium*, *Leucaena*, *Trifolium* and *Stylosanthes*). These have been developed for commercial usage as a result of plant introduction and evaluation. These varieties have laid the foundation for the expansion of tropical pastures in northern Australia. Moreover, the Division's plant breeders have produced the valuable frost-tolerant setaria Narok

Goyura, one of the new grape varieties bred specifically for Australian conditions by the DIVISION OF HORTICULTURAL RESEARCH. Goyura has been selected for making white wines suitable for early consumption and should produce wines that are fresh and crisp.

Photograph: Ted Lawton



(a grass), and what is probably Australia's outstanding example of pasture plant breeding—Siratro. Siratro, an entirely new legume bred after intensive selection from crosses between two central American introductions, is the most widely grown pasture legume in southern and central Queensland.

Breeding work is currently in progress on 12 pasture species. In most of these, emphasis is being placed on cool season growth, or frost tolerance, or both. With grasses, herbage quality is also important, and with legumes, persistence.

Plant introduction will continue to have a major impact on pasture development in the tropical north-east and north of Australia. For example, the Division holds stocks of over 500 introductions of *Stylosanthes*. This Australian collection has already yielded three new cultivars, Oxley, Cook and Verano, with several other promising lines still being evaluated.

The efficient use of such collections has been facilitated by the development of new data-handling methods which have made it possible to define the environmental adaptation of introductions. A computer-based information retrieval system is used to classify and index the Division's collection of 12 000 varieties of pasture and crop plants. This genetic resource centre includes not only the most comprehensive collection of tropical pasture plant seed in the world, but also the most comprehensive collection of information about each of the varieties represented.

A grain sorghum breeding program has been underway at the Kimberley Research Station in Western Australia since 1970. The Division is also considering breeding grain legumes when the large collections introduced in recent years have been evaluated.

The Division's introduction and breeding programs are supported by basic research in a number of areas ranging from studies of the breeding systems of major pasture genera, through statistical studies on inheritance and genetic relationships of important characters, to concepts of varietal structure and new breeding methods. All studies are aimed at improving the efficiency of breeding and introduction programs, and of evaluating the potential of plants for particular environments.

The DIVISION OF HORTICULTURAL RESEARCH is seeking to introduce and develop superior strains and varieties of vines and orchard trees to meet specific economic and environmental conditions. Over 200 new varieties of vines have been introduced to evaluate their performance and fruit not only in traditional grape-growing areas but in many other parts of Australia as well, ranging from Kununurra, in the far north-west of Western Australia, to Tasmania.

Both introduced and existing varieties are being crossed to develop hybrids for the production of wine, dried fruits, and table grapes. The project will take some years to complete since 10 to 12 years are needed to evaluate a new grapevine hybrid. Of the 30 000 seedlings produced since 1965, 90 of potential merit are now in the second stage of evaluation.

The success of the Division's vine selection program to date is indicated by the fact that all sultana rootlings used in Victoria and New South Wales are now the progeny of CSIRO selections. The Salt Creek rootstock imported in 1957 has shown high resistance to nematodes and sultanas on Salt Creek have produced up to twice the yield of ungrafted sultana vines.

Four new grape varieties were released last May for limited testing by State Departments of Agriculture and commercial interests. One variety,

Carina, is for the production of currants, while the others, Tarrango, Goyura, and Tulillah are for wine.

The Division is also working on the production of improved fruit varieties and new horticultural crops for inland areas through the introduction and breeding of plant material. Citrus root-stocks have been bred for tree-dwarfing, tolerance to salt, and resistance to phytophthora, Tristeza virus and nematodes. These are being evaluated in both the laboratory and the field.

Avocados and pistachios are currently being introduced from overseas. Both crops show considerable promise and field trials are under way to provide essential horticultural information and to determine the most suitable areas for their production. Other new and potentially valuable crops being introduced include mangoes, cherimoyas, custard apples, lychees and longans.

Heavy metals in the ocean

Recent concern about the amount of heavy metals ingested by man through eating various seafoods has highlighted the need for a far greater understanding of the movement of these metals in the marine environment.

The heavy metals antimony, arsenic, cadmium, copper, lead, mercury, silver and zinc are potential pollutants of sea-water. Since seafoods contaminated with any of these metals are a hazard to human health, scientists in a number of countries are turning their attention to how heavy metals get into our seas and oceans.

Because little is known about heavy metal concentrations in the marine environment before recent times, it is difficult to determine how much they are due to natural sources such as the weathering of the earth's crust, and how much to sources such as industrial waste, sewage and atmospheric contaminants.

Lead provides an example of a metal whose concentration has increased rapidly this century in the surface waters of the sea. Analyses of lead in ice formed in 800 B.C. and in 1966 in a Greenland glacier show a 500-fold increase, much of which probably occurred in recent years. Estuaries and inshore waters, commonly the receiving waters for contaminating outfalls, can suffer severe local pollution. For example, the average cadmium content of some contaminated waters has been up to 500 times that found in the ocean.

Once present in sea-water, some heavy metals can become incorporated in marine plants and animals and then transferred biologically through the links of the food chain. This can result in high concentrations within the species at the top of the chain, such as large predatory fish. High concentrations of heavy metals can also occur in oysters and other filter-feeding molluscs. Since man is a part of the total system and depends on marine processes for many things, including food, there is a need to understand these processes and to reduce or prevent the occurrence of undesirable imbalances.

In 1972 a proposal was made to dump a large quantity of refinery waste containing traces of heavy metals off the south-eastern coast of Tasmania. Existing knowledge was inadequate to predict the likely effects, and so the DIVISION OF FISHERIES AND OCEANOGRAPHY undertook to study the sea-water, currents, sediments and heavy-metal content of the fish at the site before, during, and after dumping.

Sampling prior to dumping was undertaken during cruises by HMAS *Diamantina* and HMAS *Kimbla* at a number of stations in the dumping area.

These samples provided information about water movements at various depths and on the metal contents of the water, the bottom sediments and the microscopic fauna. Since dumping began, samples of water have been taken from the dumping barge with a specially designed and patented sea-water sampler built by the Division. The Australian Government Analyst is assisting with the analyses.

This investigation is expected to provide information about the solubilities of heavy metals in sea-water, the dispersion and settling rates of heavy-metal compounds, seasonal changes in current movements, and the effects of heavy metals on the sea bottom and on the flora and fauna of the region. The investigation will also give valuable information on which to base a decision about continued dumping at the site or future dumping at comparable sites.

Rivers are a major route for the transfer of pollutants to coastal waters. Together with sewage and industrial wastes, they subject estuarine life to the most severe pollution in the marine environment. As for oceans, 'baseline' data are needed to assess the significance of changes in the amounts of substances such as heavy metals in the water.

The DIVISION OF FISHERIES AND OCEANOGRAPHY has embarked on a major research program at Port Hacking, south of Sydney. Among other things, the research aims to obtain 'baseline' data for an estuary that has suffered little or no change as a result of human activities.

The data can then be used to assess the condition of other Australian estuaries and should prove valuable to those responsible for managerial decisions affecting the state of these estuaries. Our coastal waters will, in turn, reflect the type and quantity of land-generated pollution that is received by the estuaries.

Surveying Australia's wildlife

Surveys of the numbers and kinds of animals living in different habitats provide much-needed biological information for those concerned with conserving and managing Australia's wildlife.

Although a number of surveys have been made by CSIRO and various government bodies, there is still much to be learnt about Australia's 1600 species of mammals, birds, reptiles, amphibians and freshwater fish. The geographical distribution of most of these species is known only vaguely and in some cases not at all. About one-fifth of Australia's mammals, for example, have been collected less than a dozen times this century.

Flooding along the Murrumbidgee. Australia's inland river systems provide many of the major wetland habitats that have been examined by the DIVISION OF WILDLIFE RESEARCH during the pilot study for the proposed survey of the nation's wetlands. Periodic flooding of these river systems is an important factor in the successful breeding of many species of Australian waterbirds. The Division has studied the ecology of a number of these species and is currently assessing some of the problems of waterfowl conservation in south-east Australia.

Photograph: Ed Slater

The DIVISION OF WILDLIFE RESEARCH has carried out fauna surveys in widely separated regions of Australia and Papua New Guinea and is now increasing its effort in this field. While the surveys have been conducted for a variety of reasons, in each instance the results have also been interpreted in relation to conservation. In addition, the Division has mapped the total distribution of several species under comprehensive study, such as the two species of grey kangaroo, the five crow and raven species, and the rabbit.

The methods used in fauna surveys are mainly modern refinements of old techniques. They include systematic trapping, searching with spotlights for nocturnal animals, and mist-netting for birds and bats. Data recorded for the captured specimens include measurements of anatomical features, body weight, breeding status, and a description of the habitat where the animal was caught. Some specimens are marked and released for subsequent observation, others are killed and their reproductive organs preserved for detailed examination to obtain further information about the reproductive capacity of the population. Rare animals may be taken alive to the headquarters laboratory for close and continuous scrutiny of their breeding habits and other aspects of their biology and behaviour. As data accumulate, a picture is gradually built up of the biology of individual species, their relative abundance, their relationship to particular habitats, their breeding patterns, and so on.

Last year's Annual Report referred to the part played by the DIVISIONS OF LAND USE RESEARCH, WILDLIFE RESEARCH, and ENTOMOLOGY in an environmental survey of the Alligator rivers region of Arnhem Land. Among other things, the survey team obtained information on the ecological relationships of animal and plant communities, and on the abundance and seasonal cycles of the animals. CSIRO's findings and recommendations were contained in a review report completed at the end of 1973.

More recently, the DIVISION OF WILDLIFE RESEARCH has published a report on an extensive fauna survey that it made of the Cobourg Peninsula north-east of Darwin. The Peninsula was declared a wildlife sanctuary in 1962.

The survey aimed at identifying the fauna in order to allow appropriate management plans to be formulated by the responsible authority. In addition, a good reference collection was established.

Despite some changes caused by feral stock, the range of animal habitats on the Peninsula was found to support a large and varied fauna which is a relatively rich segment of that typical of the 'Top-end' of the Northern Territory and much of northern Australia. In the course of the survey, 132 species of birds were collected and the taxonomy and biology of each were described. Another 21 were positively identified but not collected. The 25 indigenous mammals found included marsupials, bats, rodents, and a monotreme (an echidna).

At the request of the Department of the Environment, the Division has undertaken, in collaboration with the DIVISIONS OF LAND USE RESEARCH and FISHERIES AND OCEANOGRAPHY, a study for a survey of Australia's wetlands. The survey, which was proposed because of the considerable inroads being made into the habitats of many Australian birds by the reclamation of wetlands, will assess the situation and provide a basis for further action.

As a result of the preliminary study, CSIRO has proposed a longer term survey which will again involve the

above Divisions. During the first stage of the survey, an assessment will be made of Australia's wetland and estuarine resources and of the wildlife associated with them. The second stage will comprise integrated studies of various aspects of wetland ecology such as pollution and man's use of wetlands.

The DIVISION OF LAND USE RESEARCH is currently conducting an investigation for the Department of the Environment concerning the practicability of identifying, describing and mapping major plant communities, wildlife habitats, patterns of land use, ecosystems and landscapes with a view to expanding this preliminary enquiry into a national ecological survey. A trial survey of more than 400 000 km^2 will be undertaken in collaboration with appropriate State authorities and a detailed report is expected to be available during the first half of 1976. Information from a national ecological survey would enable the Department of the Environment to assess the extent to which existing parks and reserves are representative and indicate areas which could be suitable for additional national parks and reserves. From the data collected during the survey, it should be possible to identify long-term changes in the distribution and abundance of flora and fauna and to assess their importance.

Microbes and food

Research in microbiology is important in maintaining food quality for the consumer.

For thousands of years man has used the chemical action of bacteria and yeasts to produce wine, beer, bread and cheese. He has also devised techniques such as smoking and salting to protect food against the microbes that spoil it. The DIVISION OF FOOD RESEARCH is examining the role of both the useful and the deleterious micro-organisms to ensure that the consumer receives food free from undesirable microbes.

Some of the microbes which cause food spoilage and food poisoning are extremely hardy. Many survive treatment with disinfectants and the high temperatures used in baking and pasteurizing. Others grow at temperatures near freezing or are adapted to multiply in very dry or highly acid conditions. The Division is attempting to gain an understanding of how these microbes resist such adverse conditions in order that control methods may be developed.

For many years fundamental studies of bacterial spores have been undertaken at the Division's Food Research Laboratory in Sydney. The spore-forming genera *Bacillus* and *Clostridium* include many species which cause food spoilage or food poisoning. One species of *Clostridium* secretes the powerful toxin causing botulism, the most dangerous form of food poisoning. The spores of these bacteria are particularly resistant and are almost impossible to eliminate with disinfectants or by cooking. By studying the formation, germination, structure and composition of spores and the susceptibility of spores to pressure, the Division hopes to improve the current methods of destroying them in food.

Preliminary experiments to explain the ability of some bacteria to grow at chilling and freezing temperatures have implicated the cell granules or ribosomes which produce protein in the bacteria.

The germination and growth of food spoilage fungi over a wide range of moisture conditions are also being investigated. Information obtained from this study should help in the

identification of the fungi involved and suggest better ways of control.

The main microbial investigations at the Division's Meat Research Laboratory in Brisbane are concerned with overcoming the problem of contamination of meat with *Salmonella*, a genus of bacteria responsible for many intestinal diseases in man including both mild and serious forms of food poisoning. Studies at abattoirs have shown that carcasses become infected with *Salmonella* when stock are kept in infected yards for a long while before slaughter and when the carcasses remain warm and moist for long periods owing to poor circulation of air during chilling.

Another study concerns a certain group of food spoilage and food poisoning bacteria which are characterized by having a cell envelope consisting of several layers. This structure enables the bacterial cell to survive harsh environmental conditions. Previous studies examined the relationship of the layers of the cell envelope to the process of cell division, the effect of inhibition of protein synthesis on the cell envelope, and the properties of some temperature-sensitive mutants. The effects of thermal damage to both the inner and outer membranes of the cell are being investigated at present.

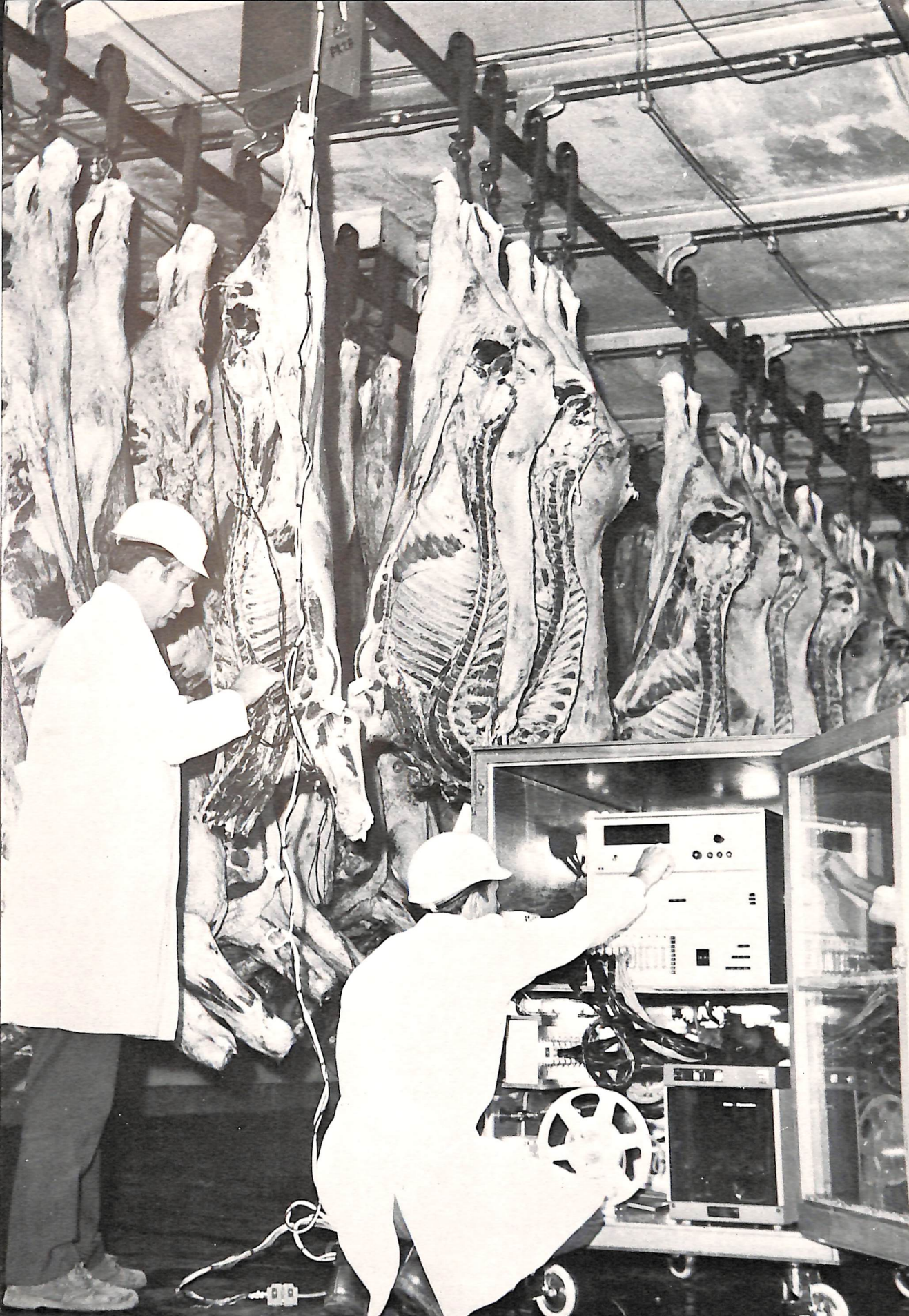
Research is also in progress to extend the shelf life of packed meats and frozen foods.

Among the microbes which can be put to constructive use are those that turn milk into cheese. In commercial cheese manufacture, 'starter' cultures of certain selected strains of bacteria are added to pasteurized milk to ensure that the preferred strains multiply in the milk and in the curd, and that the growth of undesirable strains is restricted. The Division's Dairy Research Laboratory in Melbourne is developing concentrated starter cultures for use in cheese manufacture to obviate the need to propagate the cultures in the factory. A pilot production plant has been installed at the Laboratory and has produced cheese starter cultures for trials in selected cheese factories. Initial results from one factory have shown that the quality of cheese produced is equal to or better than that of cheese manufactured with a conventional bulk starter.

The starters are vulnerable to attack by bacteriophages (bacterial viruses) and attempts are being made to develop resistant starters. Mutant strains of the bacterium *Streptococcus lactis* show promise, and their performance in cheese making is being followed. There is evidence that the production of bitter flavours in cheese can be avoided by selecting suitable starter cultures.

Scientists from the Meat Research Laboratory of the DIVISION OF FOOD RESEARCH studying weight changes in sides of beef during chilling. The investigation is part of a broader research program aimed at improving the design of chillers.

Photograph: Graham Muhl



Controlling worms in sheep

Ecological studies of sheep worms are leading to more emphasis on preventing re-infection from pastures and less on drenching.

Moderate infections of sheep by roundworm parasites can reduce wool production by 30%. More severe infections can cause heavy mortality, particularly in young sheep.

The life cycle of round worms involves development on the pasture of eggs deposited in the droppings, through two larval stages to an infective third larval stage. Infective larvae migrate to the herbage where they may be eaten by the sheep and continue their development to the fourth larval and adult egg-laying stages. Essentially, the numbers of infective larvae available on the pasture at any time determine the rate of infection among animals grazing it.

For many years research on internal worm parasites of livestock has tended to focus on the parasitic phase within the host. Much of this work throughout the world has aimed at developing more effective drenches to remove worms from the host. In recent years the DIVISION OF ANIMAL HEALTH has been examining more critically long-standing theories concerning the free-living larval stages of worm parasites on pastures. Intensive ecological studies of the free-living stages were begun with the aim of improving the efficiency of worm control by regulating rates of larval intake through changes in pasture management and in the frequency and timing of drenching.

The Division found that infective larvae could persist in pastures during the cooler months of the year for much longer than was previously thought. Thus, simple short-term spelling of pastures has little or no effect on the availability of infective larvae and re-infection of sheep can occur again immediately after drenching. The Division also found that in hot dry summers, eggs and larvae are rapidly destroyed.

Field trials in the winter rainfall areas of western Victoria, planned on the basis of this knowledge, established that a single treatment of sheep at the beginning of the long dry summer followed by another treatment in mid summer were more effective and profitable than the customary several drenchings during autumn and winter. Nevertheless, the improvement in profitability was less than that expected and possible reasons for this are being examined, particularly in relation to the effectiveness of the drenches used. Subsequent research with cattle has established that most commercially available drenches are only half as effective as claimed, even at double the recommended dose level. It is not known whether this is due to deficiencies of the drenches themselves or to the parasites becoming resistant to the drenches commonly used. Nevertheless, if a similar lack of effectiveness occurs with sheep worms, it could explain the limited effectiveness of the original trials.

While the above technique of drenching twice during summer is reasonably effective in areas with hot dry summers, different techniques are required in areas with wet or variable summers. In the non-seasonal and summer rainfall areas, larvae which develop from eggs deposited in late summer, autumn, and winter survive to constitute a major source of infection for ewes and lambs in the following spring. Eggs deposited in spring are the major source of infection during summer. Effective worm control in these areas therefore depends on minimizing this residual pasture infection by some form of pasture or stock management in association with strategic drenching.

Various management systems for the

control of worm infections in sheep are being examined at Canberra in collaboration with the DIVISION OF PLANT INDUSTRY and at Armidale, New South Wales, with the DIVISION OF ANIMAL PHYSIOLOGY. Since worms which infect sheep do not readily infect cattle, and vice versa, sheep and cattle are being grazed alternately with a single drench at the time of changeover. Preliminary observations reveal a distinct productivity advantage in favour of the sheep–cattle system as compared with continuous grazing by sheep. A somewhat similar alternate grazing principle has been applied to the continuous sheep system by using resistant adult sheep instead of cattle. This has shown that lambs reared on pastures previously grazed by adult sheep have fewer worms and make better weight gains than those reared on pastures previously grazed by young sheep.

Making war on flies

Novel approaches are being adopted to combat five major fly pests—the buffalo fly, bushfly, sheep blowfly, screw worm fly, and the Queensland fruit fly.

The more primitive flies such as mosquitoes and sandflies are important throughout the world in relation to human and animal health, but the more highly evolved forms such as the blowflies and related groups are also of considerable economic significance in horticulture and animal production. In general, the more highly evolved species show such superb adaptation to their environment and such versatility in relation to challenges from man that their control presents special problems of great complexity. For some reason—perhaps the superiority of their environmental adaptation over that of their parasites —they are poor targets for biological control. Chemical control is often complicated by the innate capacity of these insects to become resistant to pesticides, but collaborative studies between the DIVISION OF APPLIED ORGANIC CHEMISTRY and the DIVISION OF ENTOMOLOGY are pointing to possible new materials, with novel modes of action, that may circumvent the problem of resistance.

The DIVISION OF ENTOMOLOGY is working on five major fly pests: the buffalo fly, bushfly, sheep blowfly, screw worm fly, and Queensland fruit fly.

The buffalo fly, which sucks blood from cattle up to 40 times a day and occurs in numbers up to 10 000 per beast, is a source of great worry to the cattle industry in the tropics. Over the past 40 years intermittent attempts have been made to control it with imported or exotic parasites and predators, but without success. Chemical control was practicable in settled areas when it was permissible to use DDT. Since DDT was banned, however, substitute chemicals have proved either too expensive or ineffective.

Best hopes now centre on a program devised by the DIVISION OF ENTOMOLOGY which is introducing dung beetles that utilize the cattle droppings in which the flies breed. Research is also being directed towards enhancing this effect by supplementing the beetles with other components of the dung fauna which prey on the buffalo fly larvae. This work involves extensive ecological studies in Australia and Africa.

Introduced dung beetles also offer most hope against the pestiferous bushfly. The Division's work in this field has been described in previous Annual Reports.

The sheep blowfly lays eggs on moist, attractive places on live sheep, and

the maggots which hatch attack the living tissues. This pest costs Australia $30–$40 million a year. Mulesing and husbandry methods offer only partial solutions; some sorts of blowfly strike cannot be averted by these strategies and chemicals must still be employed. The sheep blowfly has become resistant to most available insecticides and seems likely to acquire resistance rapidly to any other chemicals that may be used. Alternative methods of control are urgently required.

An entirely new approach being explored by the Division involves manipulating the mechanisms of inheritance in the fly. By irradiation and selective breeding, it is possible to produce strains of sheep blowfly that are reproductively incompatible with wild flies, but which nevertheless mate with them and prevent them from propagating. The flies of the 'manufactured' strains are self-fertile and might persist in the environment in low numbers perpetuating their effects. They can be 'designed' to incorporate features which will nullify any noxious effects they might otherwise have, for example, by building into them insecticide susceptibility, which, combined with their inherently low fertility, minimizes their nuisance value to the industry.

Two such strains of sheep blowfly with modified chromosomes have already been produced and their reproductive performance in crosses with the wild-type flies has had the expected result. Relevant ecological information for the application of the new method has been amassed, and practical and economical methods of distributing large numbers of the synthetic strains have been worked out. Plans for pilot-scale field trials are now well advanced.

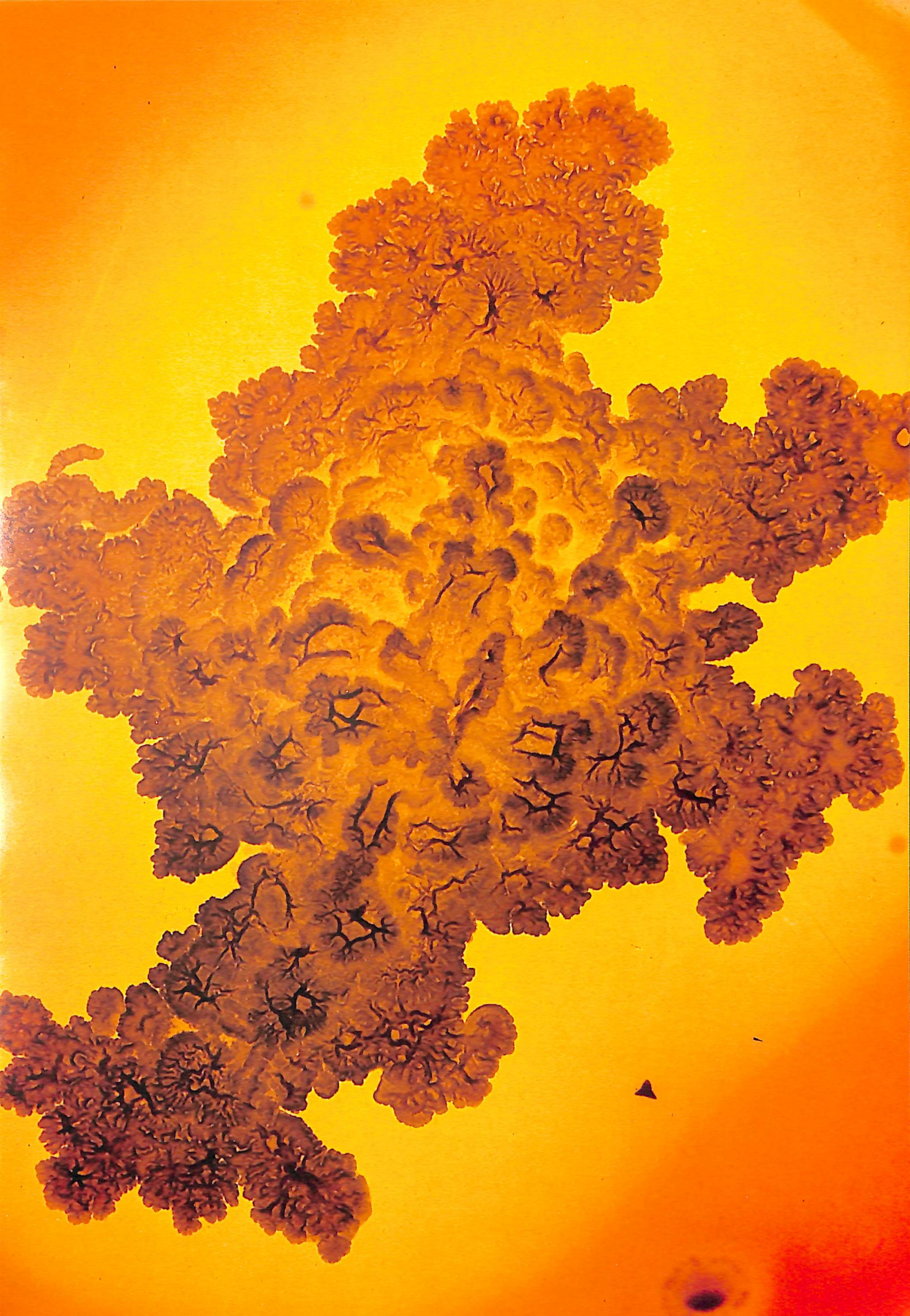
The screw worm fly of Papua New Guinea has gone a stage further than the sheep blowfly in its specialization: it is an obligate parasite of mammals and birds and cannot breed in carrion. The female flies lay their eggs on lesions of any size or body orifices, and the maggots invade and destroy the living tissues. Cattle are highly susceptible and if not treated may succumb to the effects of the attack, which is progressively aggravated by the arrival of more and more egg-laying flies at the wound.

Australia is separated by less than 100 miles of island-studded sea from the infested shores of Papua New Guinea, and concern is felt that the fly could cross this barrier and become established in northern Australia. If it did this it would wreak havoc among the extensively grazed herds, which are seldom mustered, and which usually offer abundant injuries, tick bites, and buffalo fly sores to attract attack by the screw worm fly.

To assess the risk of this fly invading Australia and to evaluate possible methods of controlling or eradicating it, the DIVISION OF ENTOMOLOGY has had a team stationed in Port Moresby since early 1973 to investigate the biology, ecology and control of the screw worm.

A culture of the bacterium *Bacillus licheniformis* on ox blood agar. This organism causes abortion in cattle and is being studied by the DIVISION OF ANIMAL HEALTH as part of an extensive research program on infectious infertility in cattle.

Photograph: Eric Smith



Much valuable information has been obtained during the brief period the team has been in operation. Techniques have been developed for the first time for breeding the fly without living animals—a vital preliminary to many studies on its habits and control. Moreover, evidence has been obtained that the fly can sustain a population on native animals and birds in the absence of domestic animals. This will be a highly important consideration in planning possible eradication campaigns.

The Queensland fruit fly is an Australian native insect which has found the horticultural activities of European man very much to its advantage. Stone, pome and citrus fruits are its main commercial targets, but many other fruits are infested as well. In addition to being a serious pest in the warm eastern coastal areas, the fly has shown a marked tendency to invade the cooler southern states, so posing a vexatious problem in interstate quarantine.

Research by the Division on the ecology and population dynamics of the fruit fly has revealed that it is a long-lived insect with a marked capacity for migration in relation to the degree of suitability of local areas. Its mating habits are highly specialized, being dependent on sounds and odours produced by the flies themselves and on certain light intensities at twilight.

The ecological and behavioural studies thus far have revealed a remarkably well-adapted insect and have led to a much better understanding of the factors that make it a potent pest. Although this work has not pointed the way to ecologically based control measures, it has assisted materially in maximizing the effect of chemical control measures. Accordingly, very small quantities of insecticides can be used with such effect that it is possible to eradicate the fly from comparatively isolated areas such as country towns or islands. For example, an infestation which had gained a footing on Easter Island was eradicated under the supervision of an officer of the DIVISION OF ENTOMOLOGY, thus relieving a threat posed by this Australian pest to huge areas in the warmer parts of the New World.

Objective measurement of wool

Improvement in techniques of wool sampling and measurement are leading to substantial economies in selling the Australian wool clip.

More than 15 years ago, the DIVISION OF TEXTILE PHYSICS saw that there was a developing need for the wool industry to base its handling and manufacturing operations on objective measurement of the characteristics of raw wool rather than on the traditional methods of subjective assessment. The Division realized that the need of the wool-processing industry to improve the efficiency and speed of its operations would lead to increasing demands for quantitative information about the raw material it used. The Division also realized that if the substantial and rising costs of wool handling and selling in Australia were to be contained, ways would have to be found of avoiding both the excessive fragmentation of the wool clip into about one million small lots and the multiple handling operations that were involved. Putting wools together and handling them on the basis of their measured characteristics was considered the best solution.

Accordingly, the Division has been increasing the proportion of its research concerned with wool measurement so that one-half of its resources of staff and finance are now devoted to this field. The development of the program

on objective measurement of raw wool has involved:

- identifying those characteristics of raw wool which can be shown to be of real significance during manufacture or for the end product;
- establishing the physical principles and measurement techniques needed for accurate sampling and testing of 5 million bales annually at a reasonable cost;
- designing and developing equipment from the experimental stage through to commercial versions; and
- developing methods for making optimum use of industrial equipment and measurement techniques.

The following characteristics in the raw material have been identified as important factors in processing: content of clean fibre (yield); expected loss of fibre in processing; amount and type of contamination by vegetable matter; mean diameter of fibre and, in some cases, diameter distribution; length and strength of fibre; colour after scouring; and the incidence of potentially troublesome contaminants such as stained pieces and burr clumps. With present technology only some of these characteristics can be measured objectively. Although suitable techniques are being sought for measuring such characteristics as length and strength, others such as the type of contamination will probably continue to be assessed subjectively for some time yet.

The Division is actively involved in developing new and improved equipment for handling and measuring wool. Fast, automatic equipment has been developed for washing samples for yield testing, and simpler, cheaper washing methods for situations where precision is less critical. New, improved instruments have been introduced to measure mean fibre diameter, and equipment will soon be released for rapid determination of diameter distribution. A new method of obtaining direct measurements of clean fibre yield is undergoing final evaluation and should eliminate some of the disadvantages of conventional methods. Automatic equipment has been developed for measuring staple length in greasy wool, and fast methods for measuring the length of individual fibres are being investigated. Procedures for using commercial instruments to measure 'scoured colour' in raw wool are being improved.

A considerable amount of work has been done by the Division to ensure that the Australian clip is reliably sampled for testing. Sampling schedules are now based on an intensive survey by the Division of the variability of the clip. Automatic machines have been developed for drawing cores and intact samples from the bales, and improved methods for blending samples before testing have been introduced.

Over the past two years there has been a dramatic change in wool handling and selling procedures, and tests for yield, mean diameter, and contamination by vegetable matter have become an integral part of the selling process. In 1974–75 about 40% of the clip was sold on the basis of display samples accompanied by test results rather than on the traditional subjective assessment of bales. Increasing use of the new procedures will mean substantial economic savings to the industry.

There is still a considerable need, however, for further research and development since new handling and selling methods bring fresh technical problems. Also, as processing becomes more measurement-oriented so the ability to measure additional characteristics, such as the length and strength of fibres, becomes more urgent.

To further the application of measurement methods by the wool industry the Division helps prepare the Australian and international measurement standards used in the industry and helps evaluate the degree of agreement between the testing laboratories. Sources of disagreements are investigated. The Division is collaborating with the Australian Wool Corporation on processing trials designed to establish and demonstrate the value of various characteristics of raw wool to wool users. The trials are taking place in wool-using countries under controlled industrial conditions with wool which was carefully prepared and measured in Australia.

In planning and conducting its research program the Division maintains close contact with the Australian Wool Corporation, and provides technical help for the Corporation's programs for improving wool handling and selling procedures. The Division also collaborates with the wool-growing, broking, buying, and processing sectors of the industry, and with the International Wool Secretariat.

Treating industrial wastes

The problem of industrial effluent is being tackled in a number of CSIRO Divisions.

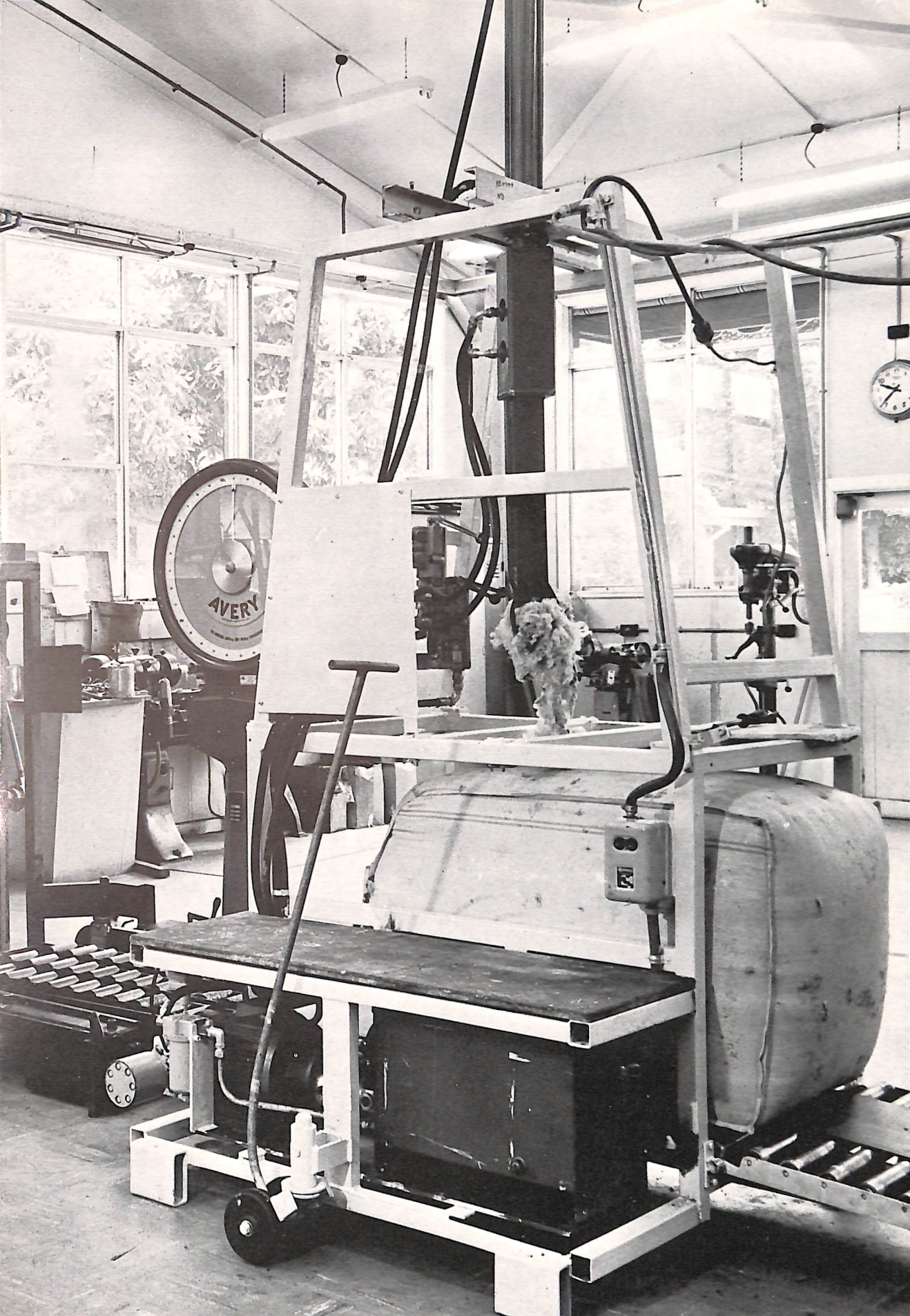
Most industries produce waste materials, the disposal of which can be a major problem. Regulations laid down by local government authorities and environmental protection agencies are imposing greater restraints on how industries dispose of their wastes. Treatment of industrial effluent can add considerably to the cost of production, and in some cases companies that have been unable to meet the demands for effluent quality have had to restrict their operations.

Work on treatment of industrial wastes has always been an important part of CSIRO's research for industry. In general, the most satisfactory way of approaching the problem of effluent is to investigate the process rather than the waste material. Accordingly, CSIRO's work in this area is pursued in whichever Division has the appropriate technical knowledge of the particular processes involved and is not concentrated in any one specific Division.

The objectives of this research include minimizing waste disposal costs and maximizing energy recovery. Ideally, the best way to solve an effluent problem is to replace the effluent-producing process with one that produces no effluent. This is extremely difficult and in many instances may result only in the production of a new type of effluent,

Grab-sampling machine Model A, developed by the DIVISION OF TEXTILE PHYSICS, is shown here with a typical sample drawn from a bale. In the operation of this machine a slit is first cut in the bale pack. The grab jaws, in the closed position, are thrust hydraulically into the interior of the bale. The jaws are then opened, thrust forward a short distance, closed again, and withdrawn from the bale. The jaws are then opened and the sample removed by hand. The position of the bale and the grab-head can be varied so that sampling positions can be randomly selected. The unit can be wheeled readily from point to point in the store.

Photograph: Douglass Baglin Pty Ltd


AVERY

which although perhaps less noxious, also presents its own set of disposal problems. Often the best that can be done is to reduce the quantity of effluent produced, by recycling for example, or by designing improved methods of treating the effluent. Perhaps the most satisfactory of all methods for dealing with industrial waste is to use it as the starting material for another product.

The scouring of greasy wool has been the subject of a considerable research effort over recent years, but the basis of the process is still treatment of the wool with an aqueous solution of detergent—a process that inevitably produces large quantities of liquid effluent. Typically, a mill will use about 16 litres of water per kilogram of greasy wool scoured and an average mill might produce about 250 000 litres of scour liquor a day. This liquor requires substantial treatment before it is acceptable for discharge to local sewers. The DIVISION OF TEXTILE INDUSTRY has an active program of investigation into the treatment of scour liquors. The aim of the research is to devise economical methods of treatment which will make the liquors conform to the standards laid down by municipal authorities in terms of suspended solids, grease content and biological oxygen demand.

A typical wool scour effluent might have a grease content of 4000 mg/l, a biological oxygen demand (BOD) of 7000 mg/l, and contain suspended solids of 6000 mg/l. Regulations may require the grease content to be lowered to about 200 mg/l, the BOD to 500 mg/l, and suspended solids to about 500 mg/l. The high grease content of scour liquors causes severe problems and makes the attainment of the required standard very difficult. Only about 40% of the total grease content can be economically removed by centrifugation. The Division has investigated a number of techniques including biological oxidation, chemical flocculation and ultra filtration. A process involving a rapid biological treatment followed by chemical flocculation has been developed and the flocculation efficiency is greatly enhanced by the preliminary biological treatment. Ultra filtration has also been established as a feasible method of removing all the suspended matter from the waste water. These methods, like many other effluent disposal processes, produce sludge, the disposal of which presents a completely different set of problems.

Only two methods are available at present for the complete disposal of wool scouring waste—land disposal, which costs about 18 cents per cubic metre of waste, and evaporation followed by incineration which costs about $5.50 per cubic metre. Experiments are being carried out to test the feasibility of simply spreading large quantities of scour liquor over grassed paddocks. The grease breaks down and does not build up in the soil; moreover, it appears to stimulate the growth of some plants. If the standards of effluent quality become more demanding, wool scouring works may need to be relocated in areas where adequately grassed land is available.

Two of the major problems facing the leather industry today are the satisfactory disposal of effluent and the shortage and increasing cost of the chemicals used. Stringent requirements for the quality of tannery effluent have led the Leather Research Section of the DIVISION OF PROTEIN CHEMISTRY to investigate methods of reducing the quantity of effluent produced and making more efficient use of the chemicals involved in processing. Tannery effluents contain particularly noxious components such as highly alkaline sulphide from the unhairing stage and chromium compounds from the tanning stage itself. Attempts to

devise processes which completely replace sulphides in unhairing with less noxious chemicals have never been completely successful commercially and no adequate routine tanning agent has been found to replace chromium.

In a conventional tannery operation the effluent from each stage of the processing is mixed and disposed of together, but by separating the liquors from the various stages they can be re-used after an appropriate topping-up with the particular reagent. Such procedures involve substantial changes in the operating procedures of the tannery, but the effects are very real and can make the difference between commercial success and failure. Experiments by the Division have shown that lime sulphide unhairing liquors can be recycled 20 times and perhaps indefinitely with appropriate replenishments. This gives at least a 20-fold reduction in water consumption and effluent sulphide, and a 7-fold reduction in effluent lime. These recycling procedures have no effect on the quality of the leather. A side benefit of this procedure is that the dissolved protein from the liming liquors (up to 10% by weight) may be recovered and used as an animal feedstock.

In the chrome tanning process it was discovered that exhaustion of the chrome was only of the order of 70–80%. Discharge of 20–30% of the chromium used therefore makes the limit of 1 part per million chromium in effluent, as set by some authorities, difficult to attain. Moreover, this wastage of chromium causes the industry a loss of around half a million dollars each year. Preliminary experiments showed that there was no selective uptake of particular chromium complexes from the tannery liquors and therefore one potential obstacle to recycling was eliminated. Chrome liquors have now been recycled successfully in commercial tanneries over several months representing over 50 re-uses, and there are indications that the liquors can be used indefinitely. A considerable easing of the effluent problem and a substantial saving in chromium compounds can therefore be achieved simultaneously. The leather produced in the recycling process is identical in all respects with that produced in a conventional process.

An alternative approach to treating waste materials is to consider ways in which they can be used productively.

The first step in the manufacture of aluminium from bauxite involves the digestion of crushed ore with caustic soda to produce alumina. This treatment results in the formation of an insoluble residue called red mud which is washed to recover the caustic soda, flocculated, and settled out. In Australia, nearly 5 million tonnes of red mud are dumped each year into specially constructed lakes and dams, and the problem of finding and constructing new dumps for the ever-increasing volume of red mud has become both difficult and costly. The DIVISION OF BUILDING RESEARCH is looking into ways of utilizing red mud for the production of building products and acoustic tiles. The Division has used a mixture of shale and red mud from Queensland to produce bricks of acceptable quality. The mechanical properties of these bricks were similar to those of conventional clay bricks. The Division has also used a mixture of red mud from the Kwinana refinery in Western Australia, and coarse sand to produce bricks of satisfactory strength, but which have a higher porosity than normal. Ways of overcoming the problems created by this high porosity are being examined.

Another possible use for red mud is in the production of acoustic tiles. This involves calcining and crushing red mud to give porous grains of the desired size. These grains are then mixed with

powdered glass and sodium silicate and pressed into a mould. The tiles are efficient sound absorbers, resistant to fire, and suitable for use outdoors.

Two other processes which produce a potentially valuable effluent are the manufacture of cheese and casein. Whey, the liquid remaining after the removal of casein and butter fat from milk, is produced in very large quantities and used to be regarded simply as effluent to be disposed of. Disposal, however, presented a problem because of the very high biological oxygen demand of whey. The high organic matter content of whey gives it a pollution potential about 100 times that of domestic sewage. While whey can be used to irrigate pastures, this is a wasteful procedure and is limited by the availability of land close to the factory.

Whey contains about 0·5–0·7% protein, 5% lactose and about 0·5–0·9% mineral salts. In 1970–71 about 1600 million litres of whey were produced in Australia representing about 90 000 tonnes of dried solids containing about 11 000 tonnes of protein and 68 000 tonnes of lactose, together with vitamins and minerals. Use of whey as a source of food stuff has been limited because of the unbalanced composition of the dried solid. Some years ago the Dairy Research Laboratory of the DIVISION OF FOOD RESEARCH began to look into the problems of whey-utilization and to investigate the use of membrane processes such as ultra filtration for separating the various components of whey. Early work on ultra filtration led to problems associated with blockage of the membranes, but fundamental studies on the whey protein enabled this difficulty to be overcome. Pilot plant studies showed that a practical objective might be the production of a concentrate containing 25–30% protein. Feeding trials on calves proved successful and indicated that the concentrate could be used in a 50:50 mix with skim milk. Later developments have concentrated on the separation of whey solids by means of membranes of different fineness. This has given whey processing a new flexibility and opened the way to the manufacture of products with a range of compositions adapted to large potential markets both at home and abroad. Work is now being undertaken on product development and at this stage there appear to be good prospects of using protein concentrates in calf feeds, infant foods, baked goods, special dietary foods, yoghurt, confectionery and soft drinks. Processes for converting the remaining lactose and mineral salts into useful products are also being investigated.

Often the most satisfactory way of dealing with an effluent problem is to study the nature of the process itself and to try to devise a new process which does not produce effluent. One approach is the total utilization of the raw material so that everything is used profitably. This has led to the development by the DIVISION OF CHEMICAL TECHNOLOGY of the concept of an integrated photosynthetic product industry (IPPI) which involves the fractionation and total utilization of plant raw material except for that portion which must be returned to the soil to maintain fertility. A suitable crop could, for example, be separated into fibre for paper production and composite materials for building and packaging; protein for food; and cellulose, starch and sugar for animal feed or for conversion to chemicals such as ethanol. The ethanol could be used as a motor fuel or converted to ethylene, the basic raw material of the petrochemical industry.

As part of the IPPI project the DIVISION OF TROPICAL AGRONOMY and the AGRO-INDUSTRIAL RESEARCH UNIT are

working on the cultivation of plants which can be harvested continuously throughout the year to avoid down time on expensive capital equipment. Studies have been concentrated on kenaf (*Hibiscus cannabinus*) and other tropical plants because the faster growth rate of these plants allows continuous cropping to begin within a few months of planting. Paper of a satisfactory quality can be made from the stems and bark of kenaf, but other possible crops are elephant grass and lucerne. The DIVISION OF CHEMICAL TECHNOLOGY is investigating the utilization of the materials from these plants for the manufacture of paper and other useful products. Novel methods of pulping, which produce much less effluent, are also being investigated by the Division, while the DIVISION OF ANIMAL PHYSIOLOGY is testing the non-paper-making parts of the various plants as animal feedstock material. The DIVISION OF PROTEIN CHEMISTRY is assessing the protein quality of the leaf proteins of various plants.

While the technological aspects of this concept are being developed rapidly, its ultimate success will depend on economic factors, especially if the establishment of an IPPI complex is to take place in a remote area in the north of Australia.

Keeping mining safe

Without reducing standards of safety, modern geomechanical techniques are allowing higher recovery of ore from mines than was previously possible.

Underground mining inevitably leads to at least one thing: less rock and more space. And as ore is extracted and space created, the strength and stability of the mine are greatly affected, whether or not the cavity is filled with waste rock or left open. In general, the older and bigger the mine, the larger the problem becomes. In January 1975 the DIVISION OF APPLIED GEOMECHANICS commenced a four-year research program costing over $3 million to investigate the stability of the rock surrounding underground openings. Twelve mining companies,* all of which are members of the Australian Mineral Industries Research Association Ltd (AMIRA), are helping with the program by granting over $500 000 and making a number of mine sites and facilities available to the Division.

The aim of the program is to increase the efficiency of underground metal mining in Australia by enabling ore which is too difficult or expensive to mine at present to be recovered safely. This will be done by investigating improved design procedures for supporting and stabilizing the ever larger and more intricate openings associated with modern mining techniques.

One of the major techniques to be studied is 'cut-and-fill', in which upward excavation of ore from lower reaches of an ore body is followed by the building up from waste material of a working platform upon which heavy rubber-tyred mining equipment can operate. In this way, the cavity (or stope) proceeds upwards.

Removal of ore redistributes the high and often variable rock stresses that occur at depths ranging to 500 m or more. For reasons of safety, therefore,

* Australian Selection (Proprietary) Limited;
Australian Mining and Smelting Limited;
BH South Limited;
The Broken Hill Proprietary Company Limited;
Cobar Mines Pty Limited;
Electrolytic Zinc Company of Australasia Limited;
ICI Australia Limited;
Mount Isa Mines Limited;
North Broken Hill Limited;
Peko-Wallsend Limited;
Poseidon Limited; and
Western Mining Corporation Limited.

the resulting deformations and permissible working tolerances associated with the surrounding rock need to be known so that the maximum height of a stope can be calculated. The stability of the fill material is also very important, since it not only provides a working floor but also assists in resisting deformations of the stope walls.

The Division has already partially solved a number of problems in this area as a result of a similar but smaller scale research program at a copper mine operated by Cobar Mines Pty Ltd at Cobar, N.S.W. This program commenced in 1969 and was sponsored through AMIRA by eight mining companies† who made nearly $400 000 available in direct contributions. Additional technical support was provided by Cobar Mines Pty Ltd. One of the cavities or stopes in the mine at Cobar has already reached a height of more than 150 m. The Division showed that there was no reason why the stopes at Cobar should not ultimately rise to around 200 m, as planned. The Division also demonstrated that under current mining practice the present uncemented (hydraulic) fill is intrinsically stable, showing no tendency to liquefaction and presenting an adequate bearing surface for heavy mining vehicles.

The scope of the new research program will allow additional problems to be tackled and will permit the expertise gained at the Cobar mine to be enhanced and extended to mines at Broken Hill, Mount Isa and King Island, where techniques involved in the mining of copper, zinc, silver, lead and tungsten ore bodies can be studied.

† Broken Hill South Limited;
Cobar Mines Proprietary Limited;
Conzinc Riotinto of Australia Limited;
Mount Isa Mines Limited;
New Broken Hill Consolidated Limited;
North Broken Hill Limited;
Peko-Wallsend Limited; and
Renison Limited.

At Cobar, further work needs to be done to determine the desirable thickness of crown pillars (the rock between the top of one stope and the base of the one above it). The use of steel cables, a technique new to Australian mines, to provide mechanical support for rock above a stope, is also being studied at Cobar.

The older and deeper mines worked by Australian Mining and Smelting Limited at Broken Hill are very rich, and it is therefore worth the difficulty of recovering the crown pillars after the intervening working levels have been worked out. Again, the Division will investigate the possible use of cable bolts to provide support so that these pillars can be narrowed.

The potential problems at Peko-Wallsend's King Island mine are significantly different. King Island is a tungsten ore mine that was originally open cut but went underground after the surface ore ran out. The mine is now operating beneath the sea bed, so it is essential that mining operations do not cause any surface subsidence.

A new mining technique known as 'post pillar' mining is being used, where narrow 'posts' of rock, rather than conventional thick pillars, are left to support the roof. For stability, cavities are filled with sandy waste material as mining progresses. In this way, up to 87% of the ore can be recovered in a single 'one-pass' operation. This compares with the established method in which 30–50% is recovered in the first pass and the cavities are filled with a cemented fill. The remaining ore is then recovered in subsequent passes. The detailed behaviour of the post pillar method is beyond the range of present mining experience and so a theoretical and actual study of the King Island mine will give valuable information on the general stability of this underground mining technique.

At Mount Isa, a method has been devised which allows almost total extraction of the ore. It involves drilling the orebody, then detonating explosives in the holes so that large vertical slabs are removed in turn. As each slab is removed the resulting stope is filled with cement-bound waste to support the ground during the excavation of the next stope in the sequence. The Division is investigating the stabilities of the stopes and the properties of the materials used so that the behaviour of the cemented fill can be predicted.

At the Warrego Mine, near Tennant Creek in the Northern Territory, Peko Mines N.L. is mining a copper–bismuth orebody by means of open stoping techniques. Since 1972, with financial and technical support from the company, the Division has been engaged in a 3-year investigation to increase the efficiency of ore extraction. Primary stopes up to 150 m high are back-filled with a cement-stabilized mine-fill strong enough to allow the pillars of ore between each stope to be recovered.

The mechanical properties of low moisture mine-fill consisting of local surface gravels strengthened with small amounts of Portland cement have been tested in the laboratory. Tests have also been carried out at the mine to determine rock properties so that the stability of the stope could be predicted. In addition, instruments have been installed to monitor rock behaviour for safety purposes and to enable comparisons to be made with theoretical predictions.

Controlled drawdown of the ore from secondary stopes is being investigated and the next objective is to assess the possibility of increasing the width of the primary stopes from 20 m to 30 m and of reducing the amount of cement fill.

The Division is not only concerned with metalliferous mines, however. In July 1974 it began a collaborative study with the Utah Development Co. Ltd at its open pit coal mines in the Bowen Basin area of Queensland, 200 km south-west of Mackay. The coal seam in this region is about 7 m thick and is currently mined from 30–50 m below the surface. The coal is exposed by removing the overlying material which is then dumped in a spoil pile in the strip that was occupied by coal in the previous mining cycle. Consequently the pit, which often extends for several kilometres, is bounded by a high, almost vertical, wall of rock on one side and spoil dumps on the other.

Slope failures in the spoil pile and the high walls of some of the pits, which in some cases resulted in complete loss of coal in the area of failure, led the company to seek the help of the Division. The Division's investigations into the cause of failures so that remedial or preventive action can be taken is expected to take four years. The Company has provided substantial financial and technical support for the project.

Movement monitoring equipment has been installed to measure the detailed behaviour of a slippage right from the very beginning. The material in which the slip surface develops will be studied and its mineralogical and mechanical properties investigated in the laboratory. This information in conjunction with knowledge of the geology, structure, stratigraphy and hydrology of the mine locality, will, it is hoped, allow a mathematical model to be constructed which will assist in defining both the conditions that lead to failure and the failure mechanisms themselves.

Preliminary results indicate that the instability of the high wall and spoil pile may be caused by high water pressures in weak rocks close to the coal seam. Stability might therefore be greatly improved if water in the material close

to the pit could be removed.

The results of the multi-disciplinary investigations outlined above are being made available throughout the Australian mining industry. They will enable mining operations to be undertaken more confidently and will allow higher recovery of ore while maintaining existing high standards of safety. Advances in knowledge and expertise arising from the projects will also be of great value in research on problems encountered in the civil, coastal and offshore engineering industries. Moreover, many of the scientists and engineers engaged in the above work are also involved in other Divisional research programs concerned with foundations for engineering structures, earth and rockfill dams, road pavements and embankments, underground tunnels and power stations, stability of natural slopes, and geomechanical problems arising from engineering construction.

Expanding research on energy

CSIRO has expanded its research into the more effective utilization of Australia's energy resources.

In 1973, CSIRO's MINERALS RESEARCH LABORATORIES, which comprise the Divisions of CHEMICAL ENGINEERING, MINERAL CHEMISTRY, MINERAL PHYSICS, and MINERALOGY, undertook, for its own purposes, a survey of world energy resources and research to identify areas of research where CSIRO could usefully participate while making best use of its considerable background of experience and expertise.

Attention was drawn to the need for a continuing assessment of all energy resources as a prerequisite to monitoring technical changes in the utilization of these resources for energy production. The environmental impact of new energy technologies and studies by social scientists of such matters as consumer demand for energy and the effect of pricing policies on energy demand and use were identified as important features in future CSIRO research programs.

In the light of this survey, attention is being focused on the utilization of coal, assessment of coal and oil resources, development of methods of reducing energy demands in mineral processing, energy storage, and the utilization of solar energy. The research is centred in the MINERALS RESEARCH LABORATORIES, the DIVISION OF MECHANICAL ENGINEERING and the SOLAR ENERGY STUDIES UNIT, with other Divisions making valuable contributions as well.

The work on coal utilization follows up earlier work undertaken in the 1950s and 1960s and is aimed at improving and developing processes for converting Australian coals into gaseous, liquid and solid fuels. A new project, which was given high priority in the energy survey, is the conversion of coal to heavy furnace oil by flash pyrolysis. The DIVISION OF APPLIED ORGANIC CHEMISTRY is collaborating on the project with the MINERALS RESEARCH LABORATORIES. A testing rig was commissioned in April 1975 and a second improved and more advanced unit is expected to be operational in 1976.

For many years CSIRO has been assessing Australia's coal reserves. The work on characterizing many of the major coals was completed some years ago, and the DIVISION OF MINERALOGY is now concerned with improving the methods used for characterization and applying them to more recently discovered deposits of coal and oil. The properties of coals are also important in determining their use, and the Division is examining the suitability of various coals for making coke, generating

power, and for conversion to liquid and gaseous fuels.

The research program on low energy metallurgy is aimed at reducing the energy needed to extract metals from ores. Flash smelting of ores uses less energy than conventional smelting and is already being used by some Australian mining companies to extract copper and nickel. The DIVISION OF MINERAL CHEMISTRY is studying the mechanism of this process so that it can be applied to the extraction of other metals and also to ensure the more effective utilization of energy.

Recently the DIVISION OF CHEMICAL ENGINEERING developed a new process, known as reflux crystallization, for refining metals. A pilot plant has been constructed which is producing 1 tonne of lead a day from a feed containing lead and silver. Results so far indicate that the process will probably use 70–80% less energy than conventional methods. The Division plans to apply the technique to other metals.

Some years ago the DIVISION OF MINERAL CHEMISTRY, in conjunction with Conzinc Riotinto of Australia Limited, investigated a method of producing aluminium from the electrolysis of aluminium chloride rather than aluminium oxide. This work is now being reappraised as a result of recent developments overseas. The new process uses less electricity than the conventional method and has the added advantage of not producing red mud as a by-product.

In the field of energy storage, the DIVISION OF MINERAL CHEMISTRY is trying to improve the storage capacity of the batteries used in an electric car designed at Flinders University, South Australia.

CSIRO Divisions engaged in solar energy research include the Divisions of MECHANICAL ENGINEERING, CHEMICAL ENGINEERING, MINERAL CHEMISTRY and ATMOSPHERIC PHYSICS. In addition, a SOLAR ENERGY STUDIES UNIT was formed in 1973 to advise the Executive on matters relating to planning and policy for solar energy research in CSIRO. Until recently, much of the research in CSIRO on the utilization of solar energy has concerned the development of domestic water heating systems. However, increasing attention is now being given to solar energy as a source of heat for industrial purposes.

The DIVISION OF MECHANICAL ENGINEERING is continuing work on the development of a kiln for drying timber by means of solar energy. The possibility of using the kiln for drying other products such as foodstuffs is being examined. The Division has also assisted the SOLAR ENERGY STUDIES UNIT to assess the opportunities for using solar energy in the food-processing industry.

Solar energy is trapped by plants during photosynthesis. Cellulose, one of the end products of this process, can be converted into ethanol which, in turn, can be converted into various fuels. The DIVISION OF CHEMICAL ENGINEERING has now completed a study on the feasibility of producing ethanol from plant sources.

Australia, through CSIRO, has recently become a party to an international cooperative study aimed at encouraging the effective utilization of solar energy for heating and cooling in residential, commercial, industrial, agricultural and public buildings. This project involves exchanging information related to research programs and experiments, and the development of an agreed format for reporting the performance characteristics of solar heating and cooling systems.

The need to reach international agreement on standards of performance for solar energy systems has led to collaboration between Australian and American workers in measuring the thermal characteristics of solar

collectors. Now that the solar energy industry in Australia is expanding, and Australian-designed collectors are being manufactured under licence overseas, such international agreements on standards have become very necessary.

Coordinating polymer research

The properties of natural and synthetic polymers are being investigated and exploited for a wide range of practical applications.

Many of the technological advances made in the last 50 years have stemmed from the chemist's ability to make polymers—that enormous variety of materials which range from common plastics to highly specialized substances performing specific functions such as resins for softening water. Important advances have also resulted from increased understanding of the physical and chemical properties of naturally occurring polymers such as cellulose, starch and proteins.

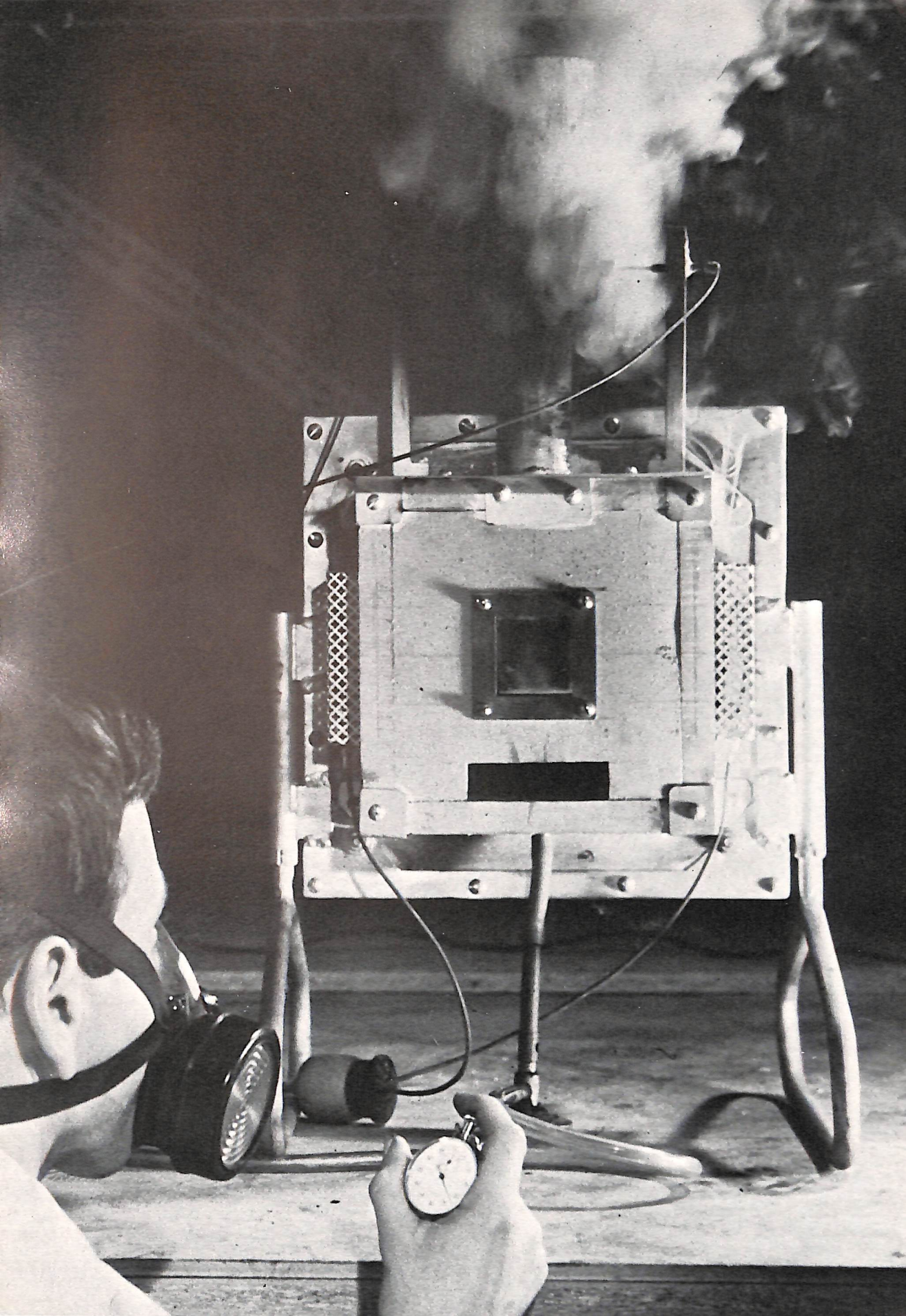
Many of the projects worked on by CSIRO scientists over the years have inevitably concerned polymers, but there was little apparent need to identify these enquiries as 'polymer research'. More recently, however, it has become evident that a substantial number of people in CSIRO working with polymers would benefit from closer contact with those of their colleagues who were working on polymers as their major interest. Following a conference of CSIRO scientists whose work was related in some way to polymer research, several small committees were established in specific areas of interest to foster contact among scientists in different Divisions who were working on polymer-related problems which would not otherwise be obviously connected.

Recent symposia for CSIRO scientists organized by these committees included one concerned with the elasticity, viscosity and plasticity of polymers. It brought together scientists whose research interests were as far apart as the extrusion of dough for bread, the mechanical properties of a single fibre of wool in bending and twisting, the penetration of one layer of soil into another, and the flow of wood fibres in pulp and paper making. Another symposium was concerned with the hazards associated with the behaviour of polymers under the influence of heat and fire. And a third symposium dealt with the degradation of polymers through such agents as sunlight, moisture, mechanical wear and microorganisms.

In those Divisions with a major interest in polymer science and technology, research is concentrated on important national problems where various materials with specified properties are required, and naturally occurring or synthetic polymers or composites of both are tailored to meet the need. Other Divisions are engaged in polymer research because of their interest in naturally occurring polymers such as the proteins of wool, meat, or leather. The following examples illustrate the variety of polymer research in CSIRO.

A scientist from the DIVISION OF BUILDING RESEARCH studying the characteristics of smoke produced by various plastic building components during combustion.

Photograph: Peter Lee



The paint and surface coating industry in Australia is a major one. Synthetic polymers such as paints tend to be expensive, and there is an obvious advantage in adding cheaper mineral fillers to them to increase their bulk. Studies by the DIVISION OF APPLIED ORGANIC CHEMISTRY aimed at modifying both the pigments and the fillers to enable them to mix together have led to significant improvements in properties such as weathering, and have had useful application in solid plastics where toughness and other properties have been enhanced.

Plastics are being used increasingly as building materials and both the advantages and disadvantages of their use are under investigation by the DIVISION OF BUILDING RESEARCH. For instance PVC (polyvinyl chloride), which is used so widely to cover walls and floors, has the disadvantage of swelling and softening in damp conditions. The effect is well known in vinyl floor tiles. The commonly held belief that such swelling is caused by the action of water on minor additives in the tile has been disproved by showing that it occurs in pure PVC resins.

Plastics used on the exterior of buildings in the form of rigid PVC sheets, flexible sheets for weather-proofing, stormwater pipes, downpipes and paints are subjected to a variety of weather conditions from strong sunlight and heat to damp and cold. Information is being gathered on the weathering of all these externally used plastics through a program of outdoor trials and field inspections in order to define the critical changes that occur in the properties of these materials and the way in which plastic structures fail. Exposure to xenon arcs under controlled conditions and laboratory tests have been used to predict the relative performance of different products in particular applications. The Division has shown that the degradation of PVC by light is independent of moisture and air temperature, but it is directly dependent upon the intensity of radiation and is most sensitive to the wavelength region between 315 and 385 nm.

The Division has helped draw up specifications for PVC stormwater pipes and downpipes and also a code of practice on outdoor weathering of plastics for commercial products.

Comparatively little is known about the behaviour of plastics in fire—a cause for concern since they are combustible and are used so extensively in buildings, not only as wall and floor coverings, but for fitments and furnishing fabrics. Initial tests on a series of rigid plastic foams have shown that some retract from the fire front while others form a char. Recently, the DIVISIONS OF BUILDING RESEARCH, MINERAL CHEMISTRY, PROTEIN CHEMISTRY and TEXTILE PHYSICS collaborated in assessing the hazards that could be caused by the emission of toxic gases from furnishings should a fire break out in the cabin of a commercial aircraft. A good deal more information is needed, particularly about what happens in real fire situations, before laboratory assessment of plastic and textile products can be accomplished.

Motivated by the world-wide increase in demand for fibre, the DIVISION OF CHEMICAL TECHNOLOGY and the DIVISION OF APPLIED ORGANIC CHEMISTRY are collaborating in an intensive program in which the sources of the natural polymers cellulose, starch, protein, lignin and tannin are being studied. Efforts are also being made in this same program to improve the technology for separating the fibrous and nutrient components of plants. With the appropriate technology,

suitable crop plants could be made to yield fibres for paper production, composite materials for building and packaging, protein for food, and cellulose, starch and sugar for use as animal feed or for conversion to chemicals such as ethanol.

Although not a new area, there is considerable scope for using expertise in polymer science and pulp and paper technology to produce better and cheaper building and packaging materials and thereby increase the efficiency of these industries. The combination of polymers with cellulose fibres, readily obtained from trees, woody shrubs and other plants, can yield many types of material. For example, structural materials such as 'reconstituted wood' can be made from sawdust. The composites differ from normal reinforced plastics as the fibre is the major component. Materials with mechanical properties approaching those of glass-reinforced plastics have been produced, but at present these do not withstand wet conditions. The Division is seeking ways of overcoming this difficulty.

Polymer science has found applications in biology and medicine. For example, the DIVISION OF APPLIED ORGANIC CHEMISTRY has developed special polymer coatings to protect veterinary drugs and nutrients from chemical attack in the rumen of sheep and cattle, and a study of polymer properties under physiological conditions has provided a basis for preparing new long-lasting substitutes for soft body tissues.

Textiles, whether natural like wool and cotton, or synthetic like nylon, are made of polymer fibres. Consequently, many of the research programs in the field of textiles are polymer-oriented. The DIVISION OF TEXTILE INDUSTRY has investigated the use of synthetic polymers in wool textile finishing for a variety of purposes including shrinkproofing, permanent pressing, control of wrinkling, pigment dyeing and mothproofing. To gain an understanding of all these processes, the DIVISION OF TEXTILE PHYSICS is studying the mechanical and surface properties and other physical characteristics of the fibres.

Re-use of water will become more urgent in the next two decades, at least in agriculture and industry. Effluent from sewage treatment provides a large potential source of water if satisfactory purification technology can be developed, and desalination will be needed on a large scale in the 1980s for municipal supplies in areas such as Perth, the Eyre Peninsula and south-west Victoria. New technology must be developed quickly if it is to be available in time to overcome the foreseen shortages of clean water. The DIVISION OF CHEMICAL TECHNOLOGY has mounted a vigorous program, based on its polymer research, which is aimed principally at the areas of desalination, improved sewage treatments, water softening and clarification, and methods for removing harmful chemicals, microorganisms and other biological matter.

The most advanced of the processes being developed is the Sirotherm method of desalinating brackish water. CSIRO has granted ICI Australia Ltd permission to sub-licence the process to overseas manufacturers. Commercial plants are expected to be established in the United States, Japan and the Common Market Countries. In Australia a full-scale unit will be operating shortly at ICI's plant at Osborne, S.A. The process was achieved only through the development of highly efficient desalting resins. Continuing work is leading to better resins for use in a variety of other water

treatments such as flocculation, softening, filtration and the removal of heavy metals.

Understanding the atmosphere

Knowledge of the atmosphere is helping both in the solution and assessment of many environmental problems and in increasing our understanding of weather and climate.

About one-third of the short-wave radiation that reaches the earth's atmosphere from the sun is reflected back into space. The remaining two-thirds that reach the earth interact with the atmosphere and clouds, the land, sea, snow and ice, and eventually return to space in a modified form as terrestrial radiation with a longer wavelength. The forces set up by these complex interactions generate considerable motions in the atmosphere and oceans—these are our winds and ocean currents. They, in turn, play an important role in modifying radiation and flow of energy. The net result of this turmoil of activity is our weather, and when considered over a longer time-interval, our climate. Therefore to understand weather and climate adequately it is necessary to study phenomena ranging in scale from millimetres to the entire globe, and in duration from seconds to millenia.

In its research program the DIVISION OF ATMOSPHERIC PHYSICS aims to gain a better understanding of the atmosphere, and of the oceans as they affect the atmosphere. Its research ranges from fundamental studies to the finding of practical solutions to environmental problems, and includes field studies, laboratory experiments, observational and theoretical analyses, and the use of numerical models.

The Division has close contacts with the other members of CSIRO's ENVIRONMENTAL PHYSICS RESEARCH LABORATORIES—the DIVISION OF CLOUD PHYSICS, the DIVISION OF ENVIRONMENTAL MECHANICS, and the AUSTRALIAN NUMERICAL METEOROLOGY RESEARCH CENTRE. Collaborative ventures with the DIVISION OF CLOUD PHYSICS include the use of aircraft and balloons as observing platforms and research into convection and aspects of atmospheric chemistry. Common interests with the DIVISION OF ENVIRONMENTAL MECHANICS include studies of atmospheric turbulence, carbon dioxide, and hydrology. Particularly close links exist with the AUSTRALIAN NUMERICAL METEOROLOGY RESEARCH CENTRE which is operated jointly by CSIRO and the Department of Science. While the Division probes the physical systems in the atmosphere, the Centre conducts experiments on a computer with numerical models of broad-scale weather patterns and global wind systems. As the Division's knowledge of the physics of these processes improves, so does its ability to lay down specifications for the Centre's models. The models are used as test beds for numerical experiments in meteorology.

Because solar radiation and its passage through the atmosphere are the primary cause of weather, they are the starting point for the Division's research program. This has developed along three lines: the interaction of clouds and radiation, the use of radiation to monitor certain environmental standards, and the maintenance of the national calibration and standards laboratory for radiation instrumentation.

A related line of research concerns atmospheric chemistry, since the conversion of radiation into heat depends on the chemical composition of the atmosphere. The Division is studying the distribution and movement of

certain critical chemical components, some of which occur naturally, while others occur as pollutants. The aim is to determine the nature and magnitude of the sources and sinks of these chemical components, to assess their regional and global significance, and to monitor short- and long-term trends in their distribution. Established programs on ozone, carbon dioxide, and oxides of nitrogen are being supplemented by other chemical studies.

The Division's ozone monitoring network is the most extensive in the southern hemisphere and one of the most important in the world. Together with similar networks in the northern hemisphere, it has detected changes in the amount and distribution of ozone in the atmosphere. Ozone measurements have provided information on the movement of air in the stratosphere and a reasonably detailed picture of the circulation of the southern hemisphere stratosphere has emerged. The Division has also studied the seasonal variations of ozone concentration, and the effect that solar activity such as sun spots and geomagnetic storms has on ozone levels.

The carbon dioxide content of the atmosphere is increasing and there are strong grounds for associating this with future variations in climate. The Division is undertaking a large-scale monitoring program involving air samples collected by balloon and aeroplane at altitudes varying from ground level to 5 km. The carbon dioxide content is then measured at the Division's Melbourne laboratories. The southern hemisphere data collected by the Division together with data from groups in Antarctica and the northern hemisphere are providing details of the movements and concentrations of carbon dioxide on a world scale. In due course this program should lead to an understanding of the causes and effects of the increase in carbon dioxide.

Gases, dust particles and water vapour are constantly being exchanged between the atmosphere and the earth's surface. So also are heat and momentum—both vital factors in the physics of atmospheric motion on all scales. Scientists of the DIVISION OF ATMOSPHERIC PHYSICS have co-operated actively with Japanese scientists in measuring fluxes of water vapour, momentum and heat in the Japanese western Pacific area as part of the international Global Atmospheric Research Program.

The most obvious areas for applying the research results of the DIVISION OF ATMOSPHERIC PHYSICS are in weather forecasting and in solving local environmental problems. The Division is concerned therefore with studying various meteorological phenomena both on a local and a broad regional scale. There is a particular need to study the way in which regional geographic features modify the broad-scale weather patterns. For example, in Victoria, the Latrobe Valley is being used as a field site for such a study. The topographical features of the site and its nearness to the coast will enable the modulating effect that these have on weather patterns to be studied. The information so obtained will be invaluable in future years in assessing the likely impact on the environment of any new power stations.

Investigations into the physical basis of climate and climatic change aimed at developing means of forecasting major climatic changes in the future are also topical. The climate is monitored by assembling the detailed observations made at the meteorological stations operated by the Australian Bureau of Meteorology and from the information gathered by satellites and other such observation platforms. An attempt is being made to use the data to

construct a theory of climate that will take adequate account of the complex feedback and adjustment processes involved in the interaction between land, sea and atmosphere.

Associated with the above research is an important program combining theoretical and experimental studies on basic fluid mechanics. Laboratory studies of wave movements in large water tanks are involved. The work provides part of the mathematical and physical background needed to understand and quantify motion in the atmosphere and oceans. This knowledge has already proved useful in solving many of the environmental problems tackled by the Division.

Solids and surfaces

The performance of many materials can be improved when more is learnt about the way in which performance is related to the surface properties of the material.

The performance of many materials used in everyday life and in industry is controlled by their behaviour at the surface. For example, wear, which costs Australian industry hundreds of millions of dollars a year, is a phenomenon that is confined to the surface or near surface of materials. Again, a number of important chemical transformations in industry depend on reactions which occur at the surface of added catalysts. Many other examples could be quoted.

The DIVISION OF TRIBOPHYSICS has a particular interest in surface science—that branch of science which deals with the problem of understanding and controlling the surface properties of materials. One difficulty facing workers in this field is that more often than not, surface chemistry is literally dictated by the single layer of atoms at the very surface itself, and these are relatively few in number. For instance, only one in every 3 million atoms in a one cent piece lies on the surface of the coin. Such small quantities of matter are difficult to study, but in recent years surface science has been revolutionized by the development of new and extremely sensitive analytical techniques.

Special electron diffraction techniques are being used by the DIVISION OF TRIBOPHYSICS to gain information about the geometric arrangement of atoms at a metal surface and to study the changes that occur when the surface starts to corrode. When a metal is corroded by oxygen, metal oxide crystals are deposited on the surface. The manner in which the crystals are initially deposited is important because it often determines the course of further chemical reaction.

Recently the Division has used a combination of various techniques based on electron diffraction and electron microscopy to study the reaction at high temperatures between tungsten metal and oxygen. The Division found that the product of the reaction—tungsten oxide—does not grow as a uniform layer on the surface of the metal, but as an array of separate crystals which have a characteristic relationship with the metal beneath. Since oxygen can penetrate fairly easily between the oxide crystals, this type of oxide layer offers little protection to the underlying metal and further reactions can occur.

On the other hand, in cases where an oxide film covers the metal completely and adheres to it, the metal is protected, to some extent at least, from further oxidation. The protective film can be ruptured, however, by stresses caused by changes in crystal structure or molecular volume. Stress can also arise when a noble metal is used to overlay a corrodible metal, and the Division has been studying metal overlayers with a view to

overcoming this problem. The Division has found that when the overlayer is very thin (less than 100 Å) the stress may be accommodated by elastic strain in either the overlayer, or the metal beneath, or it may be eliminated by heavy faulting on certain crystallographic planes of the overlayer. If the overlayer is thicker, the stress is not absorbed in this way, but by plastic deformation at the interface.

The Division is currently developing certain aspects of electron spectroscopy in order to measure the surface composition of solids since this has an important bearing on behaviour. For example, most solid materials of practical importance are composed of masses of crystals, and the adhesion between adjacent crystals depends on the chemical composition of their interface. The strength of this adhesion in turn influences the strength of the material. Surface composition also affects the efficiency of catalysts and electrodes.

Most high performance cutting tools are made from a tungsten carbide/cobalt composite, and their ability to withstand wear determines the length of their useful life. The Division is using electron microscopy to examine the surface structure of these composites in order to learn more about the complex surface processes involved in their wear. It has found that carbide can be removed from the composite either by cracking across or between granules, depending on the conditions under which the tool is operated. To some extent the relative propensity for wear by these two mechanisms can be adjusted according to requirements by altering the composition and grain size distribution of the composite.

Probing the solid state

Basic research into the solid state can lead to useful and often unexpected developments.

The properties of solids and their surfaces are fundamental to many industries ranging from mining and metallurgy to electronics and computing. One CSIRO Division with a particular interest in the solid state is the DIVISION OF CHEMICAL PHYSICS, which uses the theoretical and experimental methods of modern physics to gain a better understanding of the basic physical and chemical processes that occur in solids.

The information sought in studies of the solid state is essentially of two kinds—structural and energetic. Investigations of structure are based on the phenomena of X-ray diffraction and electron scattering, while studies of energetics rely on magnetic resonance and luminescence. Correlation of information on structure with that on energy can lead to considerable advances in understanding the solid state.

X-ray diffraction, the most widely used technique for determining the arrangement of atoms within crystalline solids, is being employed by the Division to determine the structure of many plant and animal constituents of pharmacological or biochemical interest. The Division has also reexamined the basis of X-ray analysis of crystal structures. This has led to an important new formulation for X-ray analysis which has had a number of successful applications and which is expected to yield much additional information on chemical bonding in solids and on the reactions between atoms and molecules in general.

Electron scattering is being used to obtain information on crystal structure complementary to that obtained from X-ray scattering. Beams of electrons scattered by an object can be studied

directly as in electron diffraction, or after they have been suitably recombined to form an electron image of the object, as in an electron microscope.

In the area of fast electrons (above 50 keV) the principal technique used in the Division is convergent-beam electron diffraction. This technique was developed in the early 1960s in collaboration with the Fritz-Haber-Institut in Berlin, to test a general theory of fast electron diffraction proposed earlier by two members of the Division. The Division's work in this area has resulted in a number of important applications. These include the structure analysis of multiphase systems and intercalates; the determination of the symmetries in certain minerals and clays (in collaboration with the DIVISION OF SOILS); the study of crystals with dipole fields; and the elucidation of the general pattern of charge density along a fibrous protein (in collaboration with the DIVISION OF PROTEIN CHEMISTRY).

In conjunction with the DIVISION OF TRIBOPHYSICS, the DIVISION OF CHEMICAL PHYSICS has developed a quantitative explanation of how contrast arises in electron micrographs. This theory has been applied to the interpretation of high-resolution electron micrographs which show the detail within crystal lattices. Theoretical and computational techniques have been developed to calculate 'theoretical' electron microscope images, and a novel technique for visually displaying these theoretical images in the form of half-tone pictures has been evolved. The advantages of this new technique of lattice imaging are that crystal defects, which influence many important properties of solids, and multiphase structures can now be studied directly with an electron microscope.

The Division's work on electron microscope contrast has also led to the Division designing and constructing a novel type of high-precision electron microscope specimen holder with cooling and heating facilities. Specimen stages of this type are now made under licence to CSIRO and are used in commercial electron microscopes and diffraction cameras.

The Division has contributed to the development of two additional electron scattering techniques used in solid state studies: electron interferometry, where two new types of interferometer have been devised; and low-energy electron diffraction (LEED), for which a theory has been developed and a LEED camera built.

In the early morning a team fills a plastic balloon with helium at the Department of Science's balloon launching station at Mildura, Victoria. The balloon will be released shortly after dawn and will begin a 28 000 metre ascent into the stratosphere. Instruments attached to the balloon will capture microscopic particles in the upper atmosphere for analysis by the DIVISION OF CLOUD PHYSICS. This is part of a program begun in 1967 by the Division to obtain reference information that will enable any future changes in the stratosphere to be monitored. The balloon also carries an instrument from the DIVISION OF ATMOSPHERIC PHYSICS which will measure the water content of the stratosphere.

Photograph: David Whillas

The Division's work on the energetics of solids is based on magnetic resonance and luminescence. Significant advances have been made in the techniques of nuclear magnetic resonance, electron spin resonance, and nuclear quadropole resonance (NQR), which have enabled these techniques to be applied to the solution of a number of problems of scientific and industrial importance. Currently a pulsed NQR spectrometer is being commissioned to extend studies of order–disorder phase transitions in crystalline materials to completely disordered or amorphous materials. These materials are finding increasing applications in fields such as optics and electronics. The sensitivity of an NQR spectrometer developed in the Division has been demonstrated within the past year by the first direct measurement of NQR spectra from metallic arsenic and bismuth.

Luminescence—the absorption and re-emission of light by a solid—yields much useful information on the solid state. Studies of the mechanisms involved in this phenomenon in both crystalline and amorphous solids have required the development of refined optical measurement techniques involving complete control of the experimental rig by mini-computers.

Among the current development programs that have arisen from the Division's solid state research is one concerned with developing the new technique of reaction bonding to a stage where it can be used industrially. This technique, which enables metals to be bonded to ceramics, was first suggested by an unexpected reaction between an oxide and a metal observed at high temperatures during fundamental electron microscopic research. In collaboration with Flinders University, the same type of reaction was later attempted with bulk materials outside the high vacuum of the electron microscope. It was found that the reaction could be used to form a strong bond between ceramics and metals and that such a bond could withstand temperatures almost as high as the melting point of the metal.

The process was patented and development work started. Areas of possible application include materials technology, where it could be used in the manufacture of fibre-reinforced materials; microcircuitry, for bonding conductors to ceramic substrates; solid state batteries, for joining electrodes to solid state electrolytes; and in the manufacture of furnace elements. Reaction bonding has recently been used by the Division in the manufacture of two types of oxygen probe for monitoring oxygen concentrations in high-temperature environments.

Finance and Buildings

General

The table below summarizes the sources of CSIRO funds for 1974/75 and the categories of expenditure. Some 83% of CSIRO's income for the year was provided directly by the Australian Government. Of the remaining 17%, more than three-quarters was contributed from trust funds concerned with various primary industries. Most of these funds are derived from a statutory levy on produce with a supporting contribution from the Australian Government.

During 1974/75 CSIRO spent $84·4 million of Treasury funds on salaries and general running expenses, an increase of $17·1 million over the previous year's expenditure.

About $13 million, or three-quarters of the increase, was absorbed by salary

Source of funds	Salaries and general running expenses ($)	Grants for studentships and grants to outside bodies ($)	Capital works and services and major items of equipment ($)	Total ($)
Treasury appropriation, including revenue	84,455,133	2,928,083	2,332,411	89,715,627
Wool Research Trust Fund	10,543,731	—	438,997	10,982,728
Meat Research Trust Account	2,237,462	—	13,376	2,250,838
Tobacco Industry Trust Account	292,619	—	—	292,619
Dairy Produce Research Trust Account	287,440	—	—	287,440
Wheat Research Trust Account	221,319	—	13,162	234,481
Fishing Industry Research Trust Account	215,008	—	10,740	225,748
Dried Fruits Research Trust Account	45,511	—	19,083	64,594
Chicken Meat Research Trust Account	7,413	—	—	7,413
Pig Industry Research Trust Account	5,468	—	1,784	7,252
Poultry Research Trust Account	—	—	3,680	3,680
Other contributors	3,379,321	—	1,172,354	4,551,675
Total	101,690,425	2,928,083	4,005,587	108,624,095

adjustments arising from arbitration determinations and by increments, reclassifications and other inescapable commitments in the nature of salaries. A further $2·9 million was allocated towards offsetting increased costs of goods and services resulting from price rises and the occupation of new accommodation.

The remainder of the increase, $1·2 million, was available to the Executive to expand existing research programs and initiate new research activities in certain selected areas. The Executive was able to increase this amount by a further $1 million by redeploying the Organization's existing resources. This was over and above the usual redeployment which takes place on a continuing basis within Divisions. In this way the Executive was able to allocate a total of $2·2 million to support and expand research in the following areas: population genetics of beef cattle, infertility of sheep in Western Australia, biological control of dung and weeds, storage of grain, marsupial physiology, tropical grain crops, evaluation of vertebrate fish resources, characteristics of the marine coastal environment, forest land use and resources, plant proteins, the built environment, and utilization of solar energy.

In addition to the money that CSIRO received from the Government and from industry and other contributors, some $13·1 million was spent by the Department of Housing and Construction and the Department of Services and Property on buildings and other works for CSIRO and on the acquisition of land.

Buildings

CSIRO's building program continued to be affected during the year by rising building costs which were reflected in higher tender prices received for projects during 1973/74. Accordingly an additional $1·4 million had to be found to let the necessary contracts.

The largest single construction project undertaken by CSIRO to date is the National Measurement Laboratory at Bradfield Park, Sydney. This project, which commenced in 1972/73, is now well advanced and should be completed by 1977.

Below This Wine Grape Quality Laboratory at the research station of the DIVISION OF HORTICULTURAL RESEARCH at Merbein, Victoria, was opened by the Minister for Science, Mr W. L. Morrison on 30 May 1975.

Photograph: Ted Lawton

During the year the Parliamentary Standing Committee on Public Works considered the submission for the proposed Australian National Animal Health Laboratory at Geelong, Victoria, and recommended to Parliament that the project should proceed to construction as early as possible. Site preparation is scheduled to commence during the 1975/76 financial year.

Contracts were let for the following major building works during 1973/74:
ANIMAL HEALTH—Specific Pathogen-free Poultry Unit at Maribyrnong, Melbourne —$684,000. Insect-proof, large-animal accommodation and gas-fired incinerator at Long Pocket Laboratories, Indooroopilly, Brisbane—$819,000. Animal room prototype for the Australian National Animal Health Laboratory at Maribyrnong, Melbourne—$375,000.
COMPUTING RESEARCH—Alterations and extensions to Black Mountain laboratory, Canberra—$2,326,000.
FOOD RESEARCH—Chiller refrigeration, Food Research Laboratory, North Ryde, Sydney—$248,000.
MECHANICAL ENGINEERING—New laboratory, Highett, Melbourne—$242,000.
FISHERIES AND OCEANOGRAPHY—Fish biology laboratory at Cronulla, Sydney—$280,000. Fisheries laboratory at Cleveland, Brisbane—$1,770,000.

Major projects completed during the year include:
ANIMAL GENETICS—New laboratory at North Ryde, Sydney—$509,000.
ATMOSPHERIC PHYSICS—Extension to the machine shop and laboratory at Aspendale, Melbourne—$283,000.
BUILDING RESEARCH—Urban studies building at Highett, Melbourne—$217,000. Environment laboratory at Highett, Melbourne—$690,000.
MINERAL CHEMISTRY—Library and services block at Port Melbourne—$255,000.
RADIOPHYSICS—Laboratory workshop and offices at the Australian National Radio Astronomy Observatory at Parkes, N.S.W.—$210,000.

In addition to the above some $150,000 worth of site engineering work was carried out at Black Mountain, Canberra. This site is occupied by a number of CSIRO Divisions.

Below The new Environment Laboratory for the DIVISION OF BUILDING RESEARCH at Highett, Melbourne.

Photograph: Peter Lee

Annual Expenditure

The following summary gives details of expenditure by CSIRO Divisions and other Units on other than capital items from 1 July 1974 to 30 June 1975.

DIVISION OR UNIT	Treasury funds ($)	Contributory funds ($)	Total ($)
Head Office			
The main items of expenditure under this heading are salaries and travelling expenses of the administrative staff at Head Office and the Regional Administrative Offices, salaries and expenses of officers at the Liaison Offices in London, Washington and Tokyo, and general office expenditure.	7,023,097	16,554	7,039,651
Research Programs			
Animal Health and Reproduction			
Animal Genetics	2,061,900	805,362	2,867,262
Animal Health	3,351,698	918,269	4,269,967
Animal Physiology	1,238,359	2,515,831	3,754,190
Human Nutrition	854,594	199,689	1,054,283
Animal Research Institute—Indonesia	—	414,447	414,447
Plant Industry	5,209,799	608,465	5,818,264
Entomology and Wildlife			
Entomology	3,871,295	1,044,312	4,915,607
Wildlife Research	1,617,394	511,106	2,128,500
Horticulture and Irrigation			
Horticultural Research	1,104,649	51,472	1,156,121
Irrigation Research	910,047	61,352	971,399
Tropical Agronomy	3,350,600	1,084,491	4,435,091
Land Resources			
Soils	3,015,396	51,821	3,067,217
Land Use Research	1,965,098	281,854	2,246,952
Agro-Industrial Research Unit	110,418	—	110,418
Land Resources Management	2,238,395	619,960	2,858,355
Processing of Agricultural Products			
Food Research	3,963,557	959,654	4,923,211
Wheat Research	99,507	112,215	211,722
Textile Industry	176,993	2,452,829	2,629,822
Textile Physics	86,099	1,589,049	1,675,148
Protein Chemistry	445,793	1,409,924	1,855,717
Fisheries and Oceanography			
Fisheries and Oceanography	3,581,399	212,282	3,793,681
Marine Biochemistry Unit	89,799	—	89,799
Chemical Research of Industrial Interest			
Applied Organic Chemistry (including Microanalytical Laboratory)	1,831,989	168,228	2,000,217
Chemical Physics	1,806,896	3,096	1,809,992
Chemical Technology	1,654,521	140,416	1,794,937
Processing and Use of Mineral Products			
Mineral Research Laboratory, Clayton	1,389,793	14,372	1,404,165
Mineral Research Laboratory, Port Melbourne	2,028,499	100,858	2,129,357
Mineral Research Laboratory, Floreat Park	801,280	10,465	811,745
Mineral Research Laboratory, North Ryde	3,170,699	87,368	3,258,067
Baas Becking Geobiological Group	13,400	90,978	104,378
Physical Research of Industrial Interest			
National Measurement Laboratory	5,168,500	—	5,168,500

DIVISION OR UNIT	Treasury funds ($)	Contributory funds ($)	Total ($)
General Physical Research			
Radiophysics	2,915,999	128,108	3,044,107
Atmospheric Physics	1,471,505	—	1,471,505
Cloud Physics	807,699	10,553	818,252
Environmental Mechanics	458,499	1,658	460,157
Australian Numerical Meteorological Research Centre	191,084	—	191,084
General Industrial Research			
Building Research	3,963,892	103,033	4,066,925
Tribophysics	1,696,999	12,322	1,709,321
Applied Geomechanics	1,214,487	137,234	1,351,721
Mechanical Engineering	1,259,785	123,934	1,383,719
Solar Energy Studies Unit	73,981	—	73,981
Research Services			
Computing Research	591,796	—	591,796
Mathematics and Statistics	1,524,782	89	1,524,871
Western Australian Administrative Group	294,993	—	294,993
Extra-mural grants	109,296	—	109,296
Australian Mineral Development Laboratories	60,000	—	60,000
Developmental projects	339,765	—	339,765
Radio Research Board	50,000	—	50,000
Information and Publications			
Central Library	922,396	—	922,396
Editorial and Publications	1,311,306	—	1,311,306
Film and Video Centre	153,994	1,934	155,928
Miscellaneous	811,411	179,710	991,121
Grants			
Research Associations	676,085	—	676,085
Research Studentships	362,599	—	362,599
Other grants and contributions	1,889,400	—	1,889,400
Total expenditure	**87,383,216**	**17,235,294**	**104,618,510**

General Revenue

During 1974/5, general revenue amounting to $672,665 was received by the Organization. Details of receipts are as follows:

	($)
Sale of publications	94,289
Receipts in respect of expenditure of former years	193,004
Sale of produce, including livestock	120,091
Royalties from patents	140,360*
Testing fees	55,613
Miscellaneous receipts	69,308
Total	672,665

With the approval of the Minister for Science and Consumer Affairs and the Treasurer the above amount was expended as part of the general estimates.

* A further $332,106 was received as royalties on CSIRO patents and was paid to the Department of Agriculture for credit to the Wool Research Trust Fund. The patent royalties included $289,176 for the self-twist spinning machine.

Capital Expenditure under CSIRO Control

The table which follows shows capital expenditure from funds made available directly to CSIRO. It includes expenditure on capital and developmental works and on items of equipment costing more than $10,000 each.

DIVISION OR UNIT	Treasury funds ($)	Contributory funds ($)	Total ($)
Head Office	14,540	—	14,540
Animal Health and Reproduction			
Animal Genetics	79,394	92,534	171,928
Animal Health	97,045	10,743	107,788
Animal Physiology	9,524	180,804	190,328
Human Nutrition	24,087	—	24,087
Animal Research Institute—Indonesia	—	811,000	811,000
Plant Industry	65,496	26,356	91,852
Entomology and Wildlife			
Entomology	74,545	13,376	87,921
Wildlife Research	45,374	—	45,374
Horticulture and Irrigation			
Horticultural Research	6,324	62,634	68,958
Irrigation Research	20,265	—	20,265
Tropical Agronomy	121,508	250,480	371,988
Land Resources			
Soils	48,444	—	48,444
Land Use Research	31,920	—	31,920
Land Resources Management	47,012	26,008	73,020
Processing of Agricultural Products			
Food Research	72,999	3,797	76,796
Textile Industry	21,621	71,826	93,447
Textile Physics	32,791	69,063	101,854
Protein Chemistry	26,033	4,384	30,417
Fisheries and Oceanography	101,630	10,740	112,370
Chemical Research of Industrial Interest			
Applied Organic Chemistry	66,659	—	66,659
Chemical Physics	11,170	—	11,170
Chemical Technology	69,862	—	69,862
Processing and Use of Mineral Products			
Mineral Research Laboratory, Clayton	16,122	—	16,122
Mineral Research Laboratory, Port Melbourne	11,217	—	11,217
Mineral Research Laboratory, Floreat Park	20,070	—	20,070
Mineral Research Laboratory, North Ryde	71,929	—	71,929
Physical Research of Industrial Interest			
National Measurement Laboratory	75,692	—	75,692
General Physical Research			
Radiophysics	125,502	—	125,502
Atmospheric Physics	91,373	—	91,373
Cloud Physics	1,824	—	1,824
Environmental Mechanics	44,041	—	44,041
General Industrial Research			
Building Research	87,856	—	87,856
Tribophysics	23,213	—	23,213
Applied Geomechanics	49,336	—	49,336
Mechanical Engineering	43,179	35,823	79,002
Research Services			
Computing Research	543,008	—	543,008
Western Australian Administrative Group	3,807	—	3,807
Information and Publications			
Editorial and Publications	17,045	—	17,045
Miscellaneous	18,953	3,609	22,562
Total capital expenditure	**2,332,410**	**1,673,177**	**4,005,587**

AUDITOR-GENERAL'S OFFICE
Prudential Building, University Avenue,
Canberra City, A.C.T. 2601
18 September 1975

The Honourable the Minister for
Science and Consumer Affairs,
Parliament House,
CANBERRA, A.C.T.

Dear Sir,

Commonwealth Scientific and Industrial Research Organization

In compliance with Section 30(2.) of the Science and Industry Research Act 1949–1973, financial statements of the Commonwealth Scientific and Industrial Research Organization for the year ended 30 June 1975 have been submitted for my report. These comprise—

Summary of Receipts and Payments
Consolidated Statement of Payments
Statement of Payments—Special Account
Statement of Payments—Specific Research Account

One set of the statements, which are in the form approved by the Treasurer, is attached.

I now report, in terms of Section 30(2.) of the Act that, in my opinion—

(a) the accompanying statements are based on accounts and financial records kept in accordance with the Act;
(b) the statements are in agreement with the accounts and financial records and show fairly the financial operations of the Organization; and
(c) the receipt, expenditure and investment of moneys, and the acquisition and disposal of other property, by the Organization during the year have been in accordance with the Act.

Yours faithfully,

(Sgd.) D. R. STEELE CRAIK

(D. R. STEELE CRAIK)
AUDITOR-GENERAL

Summary of Receipts and Payments

	Funds held 1 July 1974 ($)	Receipts ($)	Total funds available ($)	Payments ($)	Funds held 30 June 1975 ($)
Special Account					
Parliamentary Appropriation: Operational	—	86,622,000.00	86,622,000.00	86,622,000.00	—
	(—)*	(68,908,000.00)	(68,908,000.00)	(68,908,000.00)	(—)
Parliamentary Appropriation: Capital	116,457.81	2,480,000.00	2,596,457.81	2,332,410.64	264,047.17
	(44,238.00)	(5,550,000.00)	(5,594,238.00)	(5,477,780.19)	(116,457.81)
Revenue and Other Receipts	217,999.79	672,665.77	890,665.56	761,216.27	129,449.29
	(98,659.11)	(714,017.86)	(812,676.97)	(594,677.18)	(217,999.79)
Total: Special Account	334,457.60	89,774,665.77	90,109,123.37	89,715,626.91	393,496.46
	(142,897.11)	(75,172,017.86)	(75,314,914.97)	(74,980,457.37)	(334,457.60)
Specific Research Account	1,830,292.46	19,137,255.18	20,967,547.64	18,908,469.69	2,059,077.95†
	(2,576,520.59)	(14,068,426.14)	(16,644,946.73)	(14,814,654.27)	(1,830,292.46)
Other Trust Moneys‡	195,410.22	1,504,180.01	1,699,590.23	1,548,133.92	151,456.31
	(126,243.80)	(1,356,442.85)	(1,482,686.65)	(1,287,276.43)	(195,410.22)
Cafeteria Account§	6,569.11	52,149.76	58,718.87	56,752.97	1,965.90
	(7,612.60)	(63,095.77)	(70,708.37)	(64,139.26)	(6,569.11)
Total	**2,366,729.39**	**110,468,250.72**	**112,834,980.11**	**110,228,983.49**	**2,605,996.62**
	(2,853,274.10)	**(90,659,982.62)**	**(93,513,256.72)**	**(91,146,527.33)**	**(2,366,729.39)**

* Figures in brackets refer to 1973/74 financial year.
† Includes investments totalling $176,550.00.
‡ Moneys held temporarily on behalf of other organizations and individuals.
§ Operating receipts and expenses of CSIRO cafeterias at Melbourne.

J. R. Price (*Chairman*)

R. C. McVilly (*Acting Senior Assistant Secretary, Finance and Properties*)

Consolidated Statement of Payments

1973/74 ($)		1974/75 ($)
	Head Office (including Regional Administrative Offices)	
3,956,374	Salaries and allowances	5,177,081
279,840	Travelling and subsistence	342,777
327,418	Postage, telegrams and telephone	428,430
919,546	Incidental and other expenditure	1,091,363
5,483,178		7,039,651
	Research Programs	
	Agricultural research	
9,892,229	Animal health and reproduction	12,360,149
4,784,945	Plant industry	5,818,264
5,638,911	Entomology and wildlife	7,044,106
1,752,980	Horticulture and irrigation	2,127,521
3,257,938	Tropical agronomy	4,435,091
6,680,658	Land resources	8,282,943
9,183,513	Processing of agricultural products	11,295,621
2,664,518	Fisheries and oceanography	3,883,480
4,628,509	Chemical research of industrial interest	5,605,148
6,392,422	Processing and use of mineral products	7,707,711
4,357,365	Physical research of industrial interest	5,168,499
5,027,439	General physical research	5,985,105
7,001,430	General industrial research	8,585,666
2,235,639	Research services	2,970,721
1,727,657	Information and publications	2,389,630
789,491	Miscellaneous	991,120
76,015,644		94,650,775
	Grants	
531,905	Research associations	676,085
322,654	Research studentships	362,599
1,320,781	Other grants and contributions	1,889,400
2,175,340		2,928,084
	Capital Works and Services	
989,621	Buildings, works, plant and developmental expenditure	1,876,600
1,178,309	Major items of laboratory equipment	1,595,979
19,263	Development of new area for Ginninderra field station	—
3,933,756	Expansion of CSIRO computer network	453,007
—	Construction of research vessel	80,000
6,120,949		4,005,586
	Other Trust Moneys	
	Remittance of revenue from investigations financed from Industry	
589,029	Trust Accounts	554,637
698,248	Other miscellaneous remittances	993,497
1,287,277		1,548,134

1973/74 ($)		1974/75 ($)
	Cafeteria Account	
64,139	Operating expenses of CSIRO cafeterias at Melbourne	56,753
64,139		56,753
91,146,527	**Total Expenditure**	**110,228,983**

J. R. Price (*Chairman*)

R. C. McVilly (*Acting Senior Assistant Secretary, Finance and Properties*)

Statement of Payments—Special Account*

1973/74 ($)		1974/75 ($)
	Head Office (including Regional Administrative Offices)	
3,946,913	Salaries and allowances	5,172,882
279,671	Travelling and subsistence	342,663
327,418	Postage, telegrams and telephone	428,430
919,296	Incidental and other expenditure	1,079,122
5,473,298		7,023,097
	Research Programs	
	Agricultural research	
6,187,028	Animal health and reproduction	7,506,551
4,214,750	Plant industry	5,209,799
4,283,783	Entomology and wildlife	5,488,689
1,676,282	Horticulture and irrigation	2,014,697
2,534,299	Tropical agronomy	3,350,600
5,701,373	Land resources	7,329,307
3,758,650	Processing of agricultural products	4,771,949
2,465,224	Fisheries and oceanography	3,671,198
4,465,728	Chemical research of industrial interest	5,293,407
6,201,945	Processing and use of mineral products	7,403,670
4,348,670	Physical research of industrial interest	5,168,499
4,749,918	General physical research	5,844,786
6,620,686	General industrial research	8,209,144
2,235,639	Research services	2,970,632
1,726,551	Information and publications	2,387,696
683,513	Miscellaneous	811,411
61,854,039		77,432,035
	Grants	
531,905	Research associations	676,085
322,654	Research studentships	362,599
1,320,781	Other grants and contributions	1,889,400
2,175,340		2,928,084
	Capital Works and Services	
519,480	Buildings, works, plant and developmental expenditure	529,997
1,020,004	Major items of laboratory equipment	1,269,797
19,263	Development of new area for Ginninderra field station	—
3,919,033	Expansion of CSIRO computer network	452,616
—	Construction of research vessel	80,000
5,477,780		2,332,410
74,980,457	**Total Expenditure**	**89,715,626**

* Special Account refers to moneys paid to CSIRO out of the Consolidated Revenue Fund of the Commonwealth and other related moneys specifically covered by Section 26C of the Science and Industry Research Act 1949–1973.

J. R. Price (*Chairman*)

R. C. McVilly (*Acting Senior Assistant Secretary, Finance and Properties*)

Statement of Payments—Specific Research Account

1973/74 ($)		1974/75 ($)
	Head Office (including Regional Administrative Offices)	
9,461	Salaries and allowances	4,199
169	Travelling and subsistence	114
—	Postage, telegrams and telephone	—
250	Incidental and other expenditure	12,241
9,880		16,554
	Research Programs	
	Agricultural research	
3,705,201	Animal health and reproduction	4,853,598
570,195	Plant industry	608,465
1,355,128	Entomology and wildlife	1,555,417
76,698	Horticulture and irrigation	112,824
723,639	Tropical agronomy	1,084,491
979,285	Land resources	953,636
5,424,863	Processing of agricultural products	6,523,672
199,294	Fisheries and oceanography	212,282
162,781	Chemical research of industrial interest	311,741
190,477	Processing and use of mineral products	304,041
8,695	Physical research of industrial interest	—
277,521	General physical research	140,319
380,744	General industrial research	376,522
—	Research services	89
1,106	Information and publications	1,934
105,978	Miscellaneous	179,709
14,161,605		17,218,740
	Capital Works and Services	
470,141	Buildings, works, plant and developmental expenditure	1,346,603
158,305	Major items of laboratory equipment	326,182
14,723	Expansion of CSIRO computer network	391
643,169		1,673,176
14,814,654	**Total Expenditure**	**18,908,470**

J. R. Price (*Chairman*)

R. C. McVilly (*Acting Senior Assistant Secretary, Finance and Properties*)

Research Activities

The various CSIRO Divisions, their fields of research, and the location of their laboratories and field stations are as follows:

ANIMAL GENETICS
Genetics and its application to the improvement of beef cattle, dairy cattle, sheep and poultry through breeding and selection.
Sydney, with a laboratory and field station at Rockhampton, Qld., field stations at Armidale and Badgery's Creek, N.S.W., and a field investigation unit at Wollongbar, N.S.W.

ANIMAL HEALTH
Diseases of livestock and poultry caused by bacteria, viruses, mycoplasmas, protozoa and plant poisons; external parasites—cattle tick, lice and biting insects—as potential transmitters of disease; worm parasites of sheep and cattle; immunology.
Melbourne, with laboratories in Sydney, Brisbane, Perth and Townsville, Qld., and field stations at Maribyrnong, Sungarrin, Werribee and Tooradin, Vic., Badgery's Creek, N.S.W., and Jimboomba and Magnetic Island, Qld.

ANIMAL PHYSIOLOGY
Physiology, endocrinology, nutrition and ecology of sheep and cattle in relation to reproductive performance and the production of wool and meat; control of metabolic disorders in grazing ruminants; use of chemical methods for defleecing sheep.
Sydney, with the Pastoral Research Laboratory at Armidale, N.S.W., the Beef Cattle Research Unit at Townsville, Qld., and the Bloat Research Unit at Melbourne.

APPLIED GEOMECHANICS
Properties and behaviour of soils and rocks in relation to the design of civil and mining engineering structures such as building foundations, earthen embankments, road pavements, surface excavations and underground openings.
Melbourne, with a laboratory in Adelaide and a field station at Cobar, N.S.W.

APPLIED ORGANIC CHEMISTRY
Application of chemistry to problems of national and industrial importance. Investigations concerned with synthesis of potentially useful new chemicals; natural and synthetic biologically active compounds; organometallic compounds; catalysis; polymer chemistry; mechanisms of chemical reactions at normal and high pressures; nucleation and growth of crystals; surface chemistry; physical chemistry; atmospheric chemistry.
Melbourne.

ATMOSPHERIC PHYSICS
Physical and chemical atmospheric processes that underlie and control the weather and are responsible for the distribution of airborne material including gases; the physical basis of climate and variations in climate.
Melbourne.

BUILDING RESEARCH
Development of the built environment, community planning and urban design; systems research; physical performance of buildings in relation to the well-being of occupants; building operations and economics; structural design and engineering; conversion of forest products for the production of wood-based

building elements; design and improvement of building components and systems; development, processing and properties of building materials.
Melbourne.

CHEMICAL ENGINEERING
Mechanisms of selected unit operations related to the minerals and other process industries, process simulation, design, evaluation, improvement, optimization and control, including pollution control.
Melbourne.

CHEMICAL PHYSICS
Development and application of chemical–physical techniques and instruments in the fields of spectroscopy, mass spectroscopy, electron diffraction, electron microscopy, X-ray diffraction, theoretical chemistry and solid-state chemistry.
Melbourne.

CHEMICAL TECHNOLOGY
Application of chemical technology and particularly polymer technology to developing ways whereby Australia's renewable and recyclable resources can be more effectively utilized and protected. Investigations include fractionation of plants to produce fibre, protein and other marketable products; studies of pulp and paper and the use of cellulose materials in packaging, writing, printing and building products; technology of purifying and recycling water; energy collection, transmission and conservation; biodegradable packaging materials; fire research for the protection of forests.
Melbourne.

CLOUD PHYSICS
Natural mechanisms of cloud and rain formation; artificial induction of rainfall by techniques such as cloud-seeding; studies of atmospheric particles.
Sydney.

COMPUTING RESEARCH
Computer science and the application of computers to research and development projects. The Division also provides a computer service to other Divisions, certain Australian Government Departments and some universities.
The Division operates a computer network which has its centre in Canberra and is linked by Australian Telecommunications Commission lines to subsidiary installations in Adelaide, Brisbane, Melbourne (various locations), Perth, Sydney (various locations), Armidale and Griffith, N.S.W., and Rockhampton and Townsville, Qld.

ENTOMOLOGY
Taxonomy, ecology, population dynamics, genetics, behaviour, physiology and biochemistry of insects, mites and ticks, particularly in relation to the development of methods of control that reduce or eliminate the disadvantages commonly associated with the use of pesticides.
Canberra, with laboratories in Brisbane, Perth and Sydney, and field stations at Armidale, Trangie and Wilton, N.S.W., Rockhampton, Qld., Hobart, and Port Moresby, Papua New Guinea. The Division also has biological control units at Curitiba, Brazil; Montpellier, France; and Pretoria, South Africa.

ENVIRONMENTAL MECHANICS
Transfer processes in the natural environment (physical interactions between soils, plants and the lowest layers of the atmosphere involving the exchange of energy, water and carbon dioxide) and their effect on plant growth; mathematical and physical aspects of ecology.
Canberra.

FISHERIES AND OCEANOGRAPHY
Survey and appraisal of certain marine fishery resources including rock lobsters, prawns and pelagic fisheries of the

south-eastern area of Australia; biology of the western rock lobster and prawn species of commercial importance; biological, chemical and physical oceanography of south-east Indian Ocean and south-west Pacific Ocean; studies on the dynamics of Australian estuarine ecosystems.
Sydney, with laboratories in Brisbane and Perth, and field stations at Darwin and Groote Eylandt, N.T., Karumba and Weipa, Qld., and Sams Creek, W.A.

FOOD RESEARCH
Properties, preservation, processing, packaging, storage and transport of foods; quality at the consumer level; properties of bacterial spores; membrane structure and biochemistry; identification and evaluation of flavours; plant physiology; polyunsaturated meat and dairy products; new protein and dairy foods; treatment and utilization of processing wastes.
Headquarters and Food Research Laboratory, Sydney; Meat Research Laboratory, Brisbane; Dairy Research Laboratory, Melbourne; Tasmanian Food Research Unit, Hobart.

FOREST RESEARCH
Long-term studies in resource assessment and production, tree genetics, pests and diseases of trees, physiology, forest ecology, harvesting and taxonomy.
Canberra, with regional stations at Atherton, Qld., Darwin, Kelmscott, W.A., Traralgon, Vic., Hobart, and Mount Gambier, S.A.

HORTICULTURAL RESEARCH
Development of varieties of fruit trees and grape vines better suited to Australian conditions; physiology and biochemistry of horticultural plants; orchard ecology; production of grape crops; plant parasitic nematodes.
Adelaide, with a laboratory and field station at Merbein, Vic., and a laboratory at Hobart.

HUMAN NUTRITION
The study of human nutritional processes including biochemical aspects of nutrition in relation to growth and development.
Adelaide.

IRRIGATION RESEARCH
Water management and engineering in irrigation; soil–plant–atmosphere interactions; crop growth, management and quality of irrigated crops, especially oil-seed crops and vegetables; environmental plant physiology and biochemistry; data collecting and processing systems.
Griffith, N.S.W.

LAND RESOURCES MANAGEMENT
Principles for management of Australia's land resources for efficient productivity consistent with conservation of those resources; environmental implications of land use in pastoral, agricultural, forested and near-urban areas.
Perth, with laboratories at Deniliquin, N.S.W., Alice Springs, N.T., and Canberra, and field stations at Baker's Hill, W.A., and Deniliquin, N.S.W.

LAND USE RESEARCH
Inventory of land and water resources and assessment of their current and potential uses; development of methods for relating natural and socio-economic resources in balanced land-use planning techniques.
Canberra, with a laboratory at Lawes, Qld.

MATHEMATICS AND STATISTICS
Mathematical modelling and statistical analysis with agricultural, biological, environmental, physical and industrial applications. The Division provides advisory and consultative services to other Divisions on their mathematical and statistical problems, and carries out theoretical research in selected areas of applied mathematics and statistics.

Canberra, with officers stationed at Adelaide, Brisbane, Hobart, Melbourne, Perth and Sydney, and at Townsville, Qld.

MECHANICAL ENGINEERING
Controlled-environment engineering; utilization of solar energy in low-temperature applications; industrial fluid dynamics; physical methods of preservation of grain; agricultural mechanization.
Melbourne.

MINERAL CHEMISTRY
Application of chemistry and metallurgy to mineral beneficiation and utilization and to improving the efficiency of existing mineral treatment processes; development of new mineral processing techniques.
Melbourne, with a laboratory in Sydney.

MINERAL PHYSICS
Application of physical techniques to mineral exploration; exploitation of physical properties of minerals in processing and extraction.
Sydney, with a laboratory in Melbourne.

MINERALOGY
Role of physical and chemical factors in the origin of mineral deposits and the effect of these factors on the relationships between mineral deposits and the surrounding rocks; application of this knowledge to mineral exploration and to the characterization of known ore bodies.
Perth, with laboratories in Canberra and Sydney.

NATIONAL MEASUREMENT LABORATORY
Establishment and maintenance of the national legal standards for the measurement of physical quantities; problems associated with precise measurements; magnetic and dielectric properties of materials; solid-state physics; physics of fluids; optics; solar physics; molecular collisions; air glow.
Sydney, with an optical observatory at the CSIRO Solar Observatory, Culgoora, N.S.W.

PLANT INDUSTRY
Research in the plant sciences as a basis for the development and utilization of crops and pastures better adapted to Australian conditions; ecology and conservation of plant communities.
Canberra, with a cotton research unit at Narrabri, N.S.W., ecology units at Brisbane, Waste Point and Broken Hill, N.S.W., and an experiment farm at Canberra.

PROTEIN CHEMISTRY
Structure and chemistry of wool fibres as a basis for developing new and improved wool manufacturing processes; tanning and leather manufacture; meat proteins; plant proteins; biologically active proteins.
Melbourne.

RADIOPHYSICS
Cosmic and solar radio astronomy; development of microwave instrument landing systems for aircraft.
Sydney, with the Australian National Radio Astronomy Observatory at Parkes, N.S.W., and a radio observatory at the CSIRO Solar Observatory, Culgoora, N.S.W.

SOILS
Physics, chemistry, mineralogy and biology of soils in relation to the growth and health of plants, animals and man. Soils in relation to forestry, water supplies and land use problems in urban and rural areas.
Adelaide, with laboratories in Brisbane, Canberra, Townsville, Qld., and Hobart.

TEXTILE INDUSTRY
Development of new and improved methods and machinery for processing wool; development of new and improved textile products from wool; relationships between fleece properties and processing;

new uses for wool; cotton processing.
Geelong, Vic.

TEXTILE PHYSICS
Development of methods for testing wool as an aid to marketing and manufacturing; physical properties and behaviour of wool and wool products; processing studies; surface properties of polymers.
Sydney.

TRIBOPHYSICS
Properties, behaviour and utilization of industrially important metals, alloys, ceramics and refractories; structure of these materials in relation to bulk properties such as strength and plasticity and surface reactions such as catalysis, adsorption and oxidation.
Melbourne.

TROPICAL AGRONOMY
Development of efficient systems for beef production in northern Australia (excluding arid zones); research on some tropical crops; agronomic research integrated with work on introduction, selection and breeding of new pasture and crop varieties; studies on pasture and crop nutrition, genetics, physiology and biochemistry, and on legume nodulation and animal nutrition.
Brisbane, with laboratories at Townsville and Lawes, Qld., and field stations at Beerwah, Mundubbera, Samford and Townsville, Qld., Katherine, N.T., and Kununurra, W.A.

WILDLIFE RESEARCH
Biology of birds and mammals, both native and introduced, in relation to pest control and conservation. Species investigated include those which are clearly pests, such as the rabbit and wild pig, those which are exploited, such as water-fowl and quail, and those which need to be conserved.
Canberra, with laboratories at Perth and Darwin, and staff located at Alice Springs, N.T., and Prospect, N.S.W.

In addition to the above Divisions, CSIRO has five smaller research units. They are:

AGRO–INDUSTRIAL RESEARCH UNIT
Potential innovations in agricultural technology, in particular the year-round harvesting of tropical crops, the industrial processing of crop products and the feeding of animals on crop and industrial by-products.
Canberra, with staff located at South Johnstone, Qld.

AUSTRALIAN NUMERICAL METEOROLOGY RESEARCH CENTRE
Development of numerical and laboratory models that simulate atmospheric behaviour and application of these models to improving the accuracy and time scale of weather predictions.
Melbourne. The Centre is jointly operated by CSIRO and the Department of Science.

MARINE BIOCHEMISTRY UNIT
Distribution, structure and biochemistry of unicellular marine algae, particularly in relation to the effects of environmental variations.
Sydney.

SOLAR ENERGY STUDIES UNIT
Development of policy and planning of research within CSIRO on the use of solar energy and advising the Executive on allocation of resources; feasibility studies; analysis and provision of data.
Melbourne.

WHEAT RESEARCH UNIT
Structure and biochemistry of the wheat grain and relationship to flour quality; rapid methods for grain protein determination and wheat variety identification.
Sydney.

Organization

CSIRO has a total staff of some 7100 people located in more than 100 laboratories and field stations throughout Australia. About one-third of the staff are scientists.

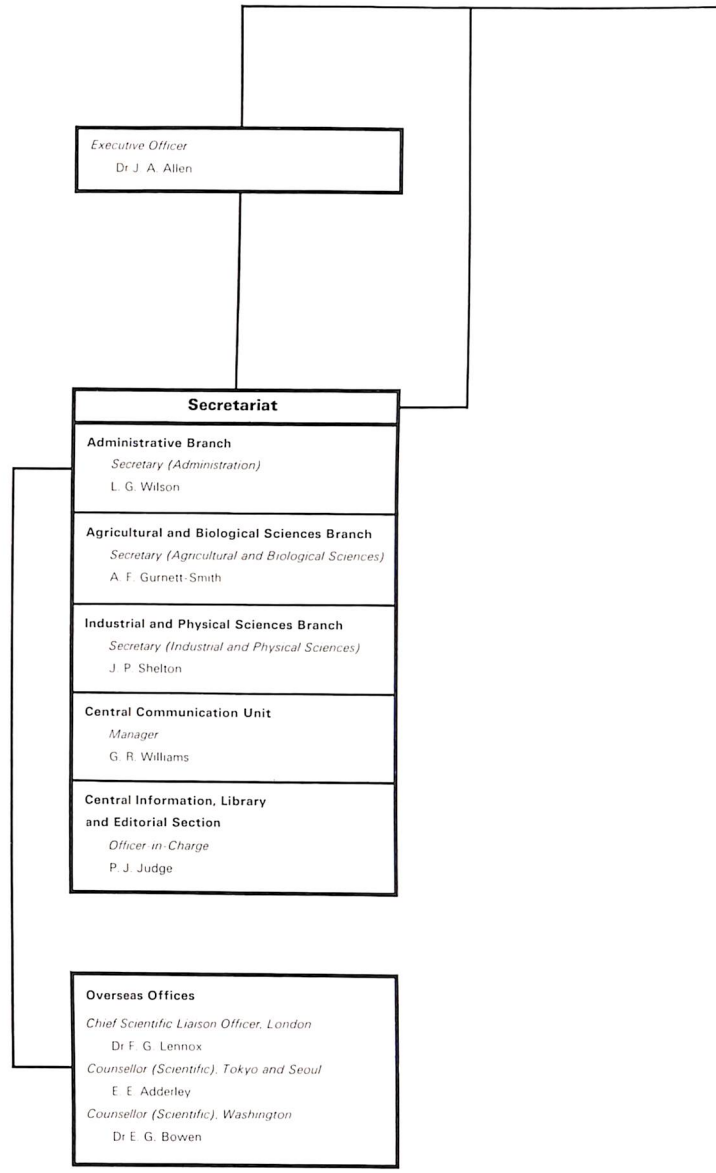
Previous Annual Reports contained a list of professional and senior staff of CSIRO. These lists will now be published separately.

CSIRO is governed by an Executive comprising a full-time Chairman, four other full-time members, and four part-time members. Most of the members of the Executive are scientists.

CSIRO has 37 research Divisions, each led by a Chief who is responsible to the Executive for the work of that Division. There are also five smaller research Units. The staff of a Division consists of research scientists, experimental officers, other professional staff engaged on a variety of service functions, and supporting technical, administrative, and trades staff. A number of Divisions have been linked together in what are known as group laboratories.

The Executive is assisted in the development, administration, and implementation of its policies by a Secretariat comprising an Administrative Branch, an Agricultural and Biological Sciences Branch, an Industrial and Physical Sciences Branch, a Central Communication Unit, and a Central Library, Information and Editorial Section. The Executive and Secretariat are located at the Organization's Head Office in Canberra. Some of the administrative functions of the Administrative Branch relating to financial and personnel matters have been decentralized by the creation of Regional Administrative Offices in Brisbane, Canberra, Melbourne and Sydney.

The chart opposite shows the organizational structure of CSIRO as at 1 July 1975.



Executive

Chairman
Dr J. R. Price

Members
V. D. Burgmann
Dr M. F. C. Day
L. Lewis
Dr A. E. Pierce

Part-time members
V. E. Jennings
Professor E. J. Underwood
W. J. Vines
F. M. Wiltshire

Divisions and Chiefs

Animal Research Laboratories
Animal Genetics Dr J. M. Rendel
Animal Health Dr A. K. Lascelles
Animal Physiology Dr T. W. Scott

Applied Chemistry Laboratories
Applied Organic Chemistry Dr D. H. Solomon
Chemical Technology Dr D. E. Weiss

Environmental Physics Research Laboratories
Atmospheric Physics Dr G. B. Tucker
Cloud Physics J. Warner
Environmental Mechanics Dr J. R. Philip

Land Resources Laboratories
Land Resources Management R. A. Perry
Land Use Research Dr R. J. Millington
Soils Dr A. E. Martin

Minerals Research Laboratories
Chemical Engineering Dr D. F. Kelsall
Mineral Chemistry Dr D. F. A. Koch
Mineral Physics Dr K. G. McCracken
Mineralogy A. J. Gaskin

Wool Research Laboratories
Protein Chemistry Dr W. G. Crewther
Textile Industry Dr M. Lipson
Textile Physics J. G. Downes

Applied Geomechanics Dr G. D. Aitchison
Building Research Dr R. W. R. Muncey
Chemical Physics Dr A. L. G. Rees
Computing Research Dr G. N. Lance
Entomology Dr D. F. Waterhouse
Fisheries and Oceanography Dr K. Radway Allen
Food Research M. V. Tracey
Forest Research Dr M. F. C. Day, *Acting Chief*
Horticultural Research Dr J. V. Possingham
Human Nutrition Dr A. T. Dick, *interim chief*
Irrigation Research E. R. Hoare
Mathematics and Statistics Dr J. M. Gani
Mechanical Engineering Dr B. Rawlings
Plant Industry Dr L. T. Evans
Radiophysics Dr J. P. Wild
Tribophysics Dr J. R. Anderson
Tropical Agronomy Dr E. M. Hutton
Wildlife Research Dr H. J. Frith

National Measurement Laboratory
F. J. Lehany, *Director*

Units and Officers-in-Charge

Agro-industrial Research G. A. Stewart
Marine Biochemistry Dr G. F. Humphrey
Solar Energy Studies R. N. Morse, *Director*
Wheat Research E. E. Bond

Australian Numerical Meteorology Research Centre
R. H. Clarke, *Officer-in-Charge*

Animal Research Laboratories Committee
Chairman
Dr K. A. Ferguson

Applied Chemistry Laboratories Committee
Chairman
Dr S. D. Hamann

Environmental Physics Research Laboratories
Chairman
Dr C. H. B. Priestley

Land Resources Laboratories Committee
Chairman
Dr E. G. Hallsworth

Minerals Research Laboratories
Director
I. E. Newnham

Wool Research Laboratories Committee
Chairman
Dr M. Lipson

Advisory Council

Executive

J. R. Price, D.Phil., D.Sc., F.A.A. (*Chairman*)
V. D. Burgmann, B.Sc., B.E.
M. F. C. Day, B.Sc., Ph.D., F.A.A.
V. E. Jennings, B.E.(Civil), M.I.E.(Aust.) (part-time)
L. Lewis, B.Met.E.
A. E. Pierce, M.Sc., Ph.D., D.Sc., F.R.C.V.S., D.V.S.M., F.A.C.V.Sc.
Professor E. J. Underwood, C.B.E., Ph.D., Hon. D.Rur.Sc., Hon. D.Sc.(Agric.), F.R.S., F.A.A. (part-time)
W. J. Vines, C.M.G., F.A.S.A., A.C.I.S., L.C.A. (part-time)
F. M. Wiltshire, C.B.E., B.A., F.A.I.M. (part-time)

Chairmen of State Committees

QUEENSLAND—Professor F. N. Lahey, D.Sc.
SOUTH AUSTRALIA—A. M. Simpson, C.M.G., B.Sc.
TASMANIA—V. G. Burley, C.B.E., B.E.
VICTORIA—Professor J. M. Swan, Ph.D., D.Sc., F.A.A.
WESTERN AUSTRALIA—L. C. Brodie-Hall, A.W.A.S.M.

Co-opted Members

A. P. Beatty
C. K. Coogan, M.Sc., Ph.D.
Professor R. W. Cumming, A.M., M.E.
J. Darling
Professor L. W. Davies, B.Sc., D.Phil.
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