Commonwealth Scientific and Industrial Research Organization, Australia

CSIRO Twenty-first Annual Report 1968/69

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This Report of the work of the Commonwealth Scientific and Industrial Research Organization for the year ending June 30, 1969, has been prepared as required by Section 30 of the Science and Industry Research Act 1949–1968.

The Executive gratefully acknowledges the valuable help that CSIRO has received from Commonwealth and State government departments and instrumentalities, the Australian universities, 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.

F. W. G. White (*Chairman*)
C. S. Christian
M. F. C. Day
L. Lewis
J. R. Price
E. P. S. Roberts
H. B. Somerset
K. L. Sutherland
E. J. Underwood

CSIRO, the Commonwealth Scientific and Industrial Research Organization, 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 for the promotion of primary and secondary industries in the Commonwealth and its Territories;

- the training of scientific research workers and the awarding of studentships;

- the making of grants in aid of scientific research;

- the recognition and support of research associations;

- the maintenance of the Commonwealth standards of measurement;

- the dissemination of scientific and technical information;

- the publication of scientific and technical reports.

CSIRO is governed by an Executive of five full-time members and four part-time members. The Executive is responsible to the Minister for Education and Science for the policy and work of the Organization.

For carrying out research, CSIRO is divided into a number of Divisions and Sections. Each Division is under the control of a Chief (in the case of a Section, an Officer-in-Charge), who is responsible to the Executive. Each Chief is responsible for the activities of his Division, within the limits of the funds allocated and the general policy decisions made by the Executive.

The Executive is assisted in the development, administration, and implementation of its policies by a Secretariat comprising an Administration Branch, an Agricultural and Biological Sciences Branch, and an Industrial and Physical Sciences Branch. Each Branch is under the control of a Secretary.

Contents

Cover
Townsville lucerne (*Stylosanthes humilis*) has come to symbolize pasture improvement in Australia's tropics and subtropics.

A native of central and South America, Townsville lucerne is a free-seeding annual legume which can provide high-protein year-round feed on poor soils in those parts of northern Australia which have a rainfall of 25 inches or more a year (see story on page 28).

On the basis of the results of research by CSIRO, the Queensland Department of Primary Industries, and the Northern Territory Administration, it has been estimated that the use of Townsville lucerne on some 60 million acres of northern Australia would enable the area to carry some 12 million cattle as compared with about $2\frac{1}{2}$ million at present.

The painting on the cover is by Melbourne artist Robert Ingpen who also designed this Report.

Meteor trails

The photograph opposite was taken at 7.46 a.m. on November 11, 1968, at a height of about 100,000 feet near Longreach, Queensland.
The camera was mounted on a Hibal balloon operated by the Department of Supply for a study by the Division of Radiophysics of dust in the stratosphere.
Apparently, a large cometary meteor had a grazing collision with the Earth, shedding most of its mass in the high atmosphere and leaving four solid pieces which left luminous trails as they passed through the atmosphere at a height of about 60 miles. In this picture the meteor entered the upper atmosphere near the horizon and the four remaining fragments emerged near the left top. The meteor travelled towards, but over the top of, the camera.
The scientific importance of the photograph lies in the 'red cloud' which suggests that much of the meteor's mass was shed at a very great height in the form of tiny particles. These particles would escape detection in night-time sightings and radar observations of meteors.
Obtaining the photograph was an extraordinary coincidence which is unlikely to recur.

Introduction

The Science and Industry Research Act places on the Executive the responsibility for planning the present and future programmes of CSIRO. During the past year, the Executive has given particular thought to the directions in which it would like to see the programme of CSIRO develop, having regard to the very considerable changes that are occurring in the Australian economy.

Exploitation of the massive mineral deposits discovered in this country over the past 15 years is providing an important share of our export income. By 1975 the value of exports of minerals is expected to exceed the value of exports of wool. However, growth in the export of raw ores, which are then processed in other countries, will, it is hoped, be accompanied by growth of the industries processing these ores in Australia. To obtain the maximum benefit from its natural resources Australia must take every opportunity to increase the proportion of primary products, especially minerals, that are processed before export. Research on new techniques for processing our ores could lead to new technology that would tip the balance in favour of a rapid expansion of the Australian mineral processing industry.

For many years, one of the objectives of the CSIRO research programme has been to assist in the growth of manufacturing industry. With the much greater emphasis today on this sector of industry, greater research efforts are required. Much of the development that has taken place in manufacturing industry over the past 20 or 30 years has been based on the introduction into this country of technology that has been developed overseas. However, the stage has now been reached when imported technology should be supplemented by new technologies having their origins in further Australian research.

The growth of manufacturing industry depends to a large degree on the initiative taken by industry in carrying out its own research and there is a good deal of evidence to show that the amount of this research is increasing. A recent review reveals that private firms are now spending some $35 million a year on research. In addition, there is the assistance being given by the Government through the Australian Industrial Research and Development Grants Board to stimulate this type of activity. It is to be expected that these developments will lead to an extension of the existing arrangements between CSIRO and Australian manufacturing firms for collaborative research.

Since its inception, CSIRO has paid particular attention to the many and varied problems of agricultural development in the southern half of Australia. While this activity must continue, there is ample evidence today of the need for greater attention to the agricultural and pastoral development of the northern areas of the continent, and to the more arid parts of Australia. A move in this direction was made some years ago with the expansion of CSIRO's research activities in Queensland. This has shown the way towards progress in the higher-rainfall areas of the north. There is now an increasing rate of public and private investment in the northern part of the continent, in the pastoral industry, and in crop production under either natural rainfall or irrigation. Without the backing of a substantial research effort these enterprises could suffer from a lack of the knowledge that is so essential for their successful development.

Australians are now beginning to appreciate that notwithstanding the rapid growth of industry and agriculture, there is still an opportunity to conserve much of the natural beauty of this continent, and the unusual plants and animals that are part of our heritage. Conservation has a wide variety of implications, but there is no doubt that the scientific study of our indigenous and unique plants and animals is basic to all plans for their preservation.

General review

Finance

In 1968/69 CSIRO spent \$46·6 million, an increase of \$4·1 million over the previous year's expenditure. This amount included grants totalling \$1·35 million which were made for studentships and to outside bodies such as the Commonwealth Agricultural Bureaux and the Standards Association of Australia. It also included \$2·45 million which CSIRO spent on capital works and services under its control and on items of research equipment costing more than \$10,000 each. In addition, the Department of Works and the Department of the Interior spent \$2·9 million on buildings and other works for CSIRO and on the acquisition of land.

About three-quarters of CSIRO's income for 1968/69 was provided directly by the Commonwealth Government. The remainder was contributed by primary industry, individual companies, Australian and overseas government instrumentalities, and private foundations. About four-fifths of these contributory funds came from five Trust Funds set up by primary producer groups representing the wool, meat, wheat, dairying, and tobacco industries. These funds are derived from a levy on produce matched by a Government contribution.

Details of where CSIRO's funds came from and how they were spent during 1968/69 are given in Chapter 4 of this Report.

New research programmes

Much of the money provided by the Government and by industry committees for expenditure on research during 1968/69 was committed to existing research programmes and to inescapable increases such as higher salaries and running costs, and new equipment and facilities. This left the Executive with \$409,000 to start new research projects and to expand some projects started in the previous year. The most important of these projects were:

ANIMAL GENETICS
Expansion of basic studies of inheritance in simple forms of life with particular reference to the genetics of strains of myxoma virus which vary greatly in their ability to kill rabbits.

ANIMAL HEALTH
Establishment of a microbiology unit at Long Pocket Laboratories, Brisbane, to investigate infectious diseases of livestock in northern Australia.

APPLIED CHEMISTRY
Development of new insecticides of low mammalian toxicity (see page 60).

BUILDING RESEARCH
Application of systems research to the planning of buildings.

HORTICULTURAL RESEARCH
Mechanical harvesting of grapes for dried fruit and wine.

RANGELANDS PROGRAMME
Expansion of research into problems confronting graziers in arid and semi-arid regions of Australia.

WILDLIFE RESEARCH
Expansion of research on ecology of birds in Western Australia, including wedge-tailed eagle, emu, and black cockatoo.

Changing research programmes

CSIRO's research programme is kept constantly under review and its direction and emphasis are adjusted periodically to meet changes in the scientific and economic prospects of the various investigations concerned.

As a result of terminating the following projects during 1968/69, CSIRO has been able to redeploy 35 members of staff and some $385,000 among new or expanded investigations of other problems.

Atlas of Australian Soils
This has been a major project by the DIVISION OF SOILS. It has extended over ten years and has involved the preparation of a key to the major soils of Australia and a considerable amount of field work. The work has now been completed and the maps published. Transfer of staff and finance has made possible some expansion in studies on the factors involved in soil fertility and a hydrological study of saline soils in Western Australia.

Transport of meat and fruit
The Physics Section of the DIVISION OF FOOD PRESERVATION has been engaged in work on problems associated with changes in methods of exporting meat and fruit to overseas markets. The work has reached a stage when recommendations have been made and minor modifications can be left to commercial organizations. The Section has now been able to divert its attention to other physical problems associated with cold storage.

Irrigation research
A project at the DIVISION OF IRRIGATION RESEARCH on the influence of transpiration of water from plants on the timing of irrigation has been terminated and staff have been transferred to plant physiological and other studies.

Keeping quality of butterfat
An investigation into this problem by the DIVISION OF DAIRY RESEARCH came to a successful end when the relationship between the copper content, pH, and keeping quality of butterfat during butter manufacture was determined. This finding is being widely applied in the industry and the research team is concentrating on the centralized production of deep-frozen cheese starter concentrates to supply the cheese industry.

Genetics and breeding of soybeans
This breeding programme came to an end when the officer concerned left the DIVISION OF TROPICAL PASTURES to join the staff of the University of Queensland. The plant material that he was using has been made available to him so that he can continue his work at the University. His successor is studying the genetics and breeding of the tropical legume *Glycine javanica.*

Concrete
Studies by the DIVISION OF BUILDING RESEARCH on the steam curing of concrete and the curing conditions required to maximize the strength of light-weight concrete have been successfully concluded. Similarly, work directed towards producing a design of either reinforced or prestressed concrete housing structure strong enough to withstand stresses due to movements of foundations has been satisfactorily completed. Staff and finance have been transferred to work on the use of computers for structural design.

Fuel cells
The completion by the DIVISION OF MINERAL CHEMISTRY of work designed to provide an understanding of the chemical processes occurring within fuel cells has enabled the staff to join a team studying the genesis of ore bodies. While some research on fuel cells will continue, the funds allocated to this project have been reduced.

Inorganic combustion products
The DIVISION OF MINERAL CHEMISTRY is studying inorganic combustion products to overcome problems of atmospheric pollution and fouling deposits on the heat transfer surfaces of boilers. The work related to fouling deposits has been satisfactorily concluded and staff and finance have been reallocated to the team studying ore genesis.

Electrode processes
The commercial production of metals such as aluminium and copper generally involves an electrolytic process. A programme in the DIVISION OF MINERAL CHEMISTRY has been concerned with the properties of electrode surfaces and the mechanisms of electrode reactions. Although the more practical aspects of electrode research are still being pursued, the fundamental studies have ceased. As a result, some staff and finance have been transferred to work on other projects, principally the chemistry of molten salts.

Fluidization
As an important part of a research programme in the DIVISION OF MINERAL CHEMISTRY concerned with the combustion of pulverized coal, an investigation was made of the behaviour of coal when burned in a fluidized bed. Successful completion of this part of the programme has enabled staff and finance to be reallocated to work on the flotation of sulphide ores containing carbonaceous materials and on other projects.

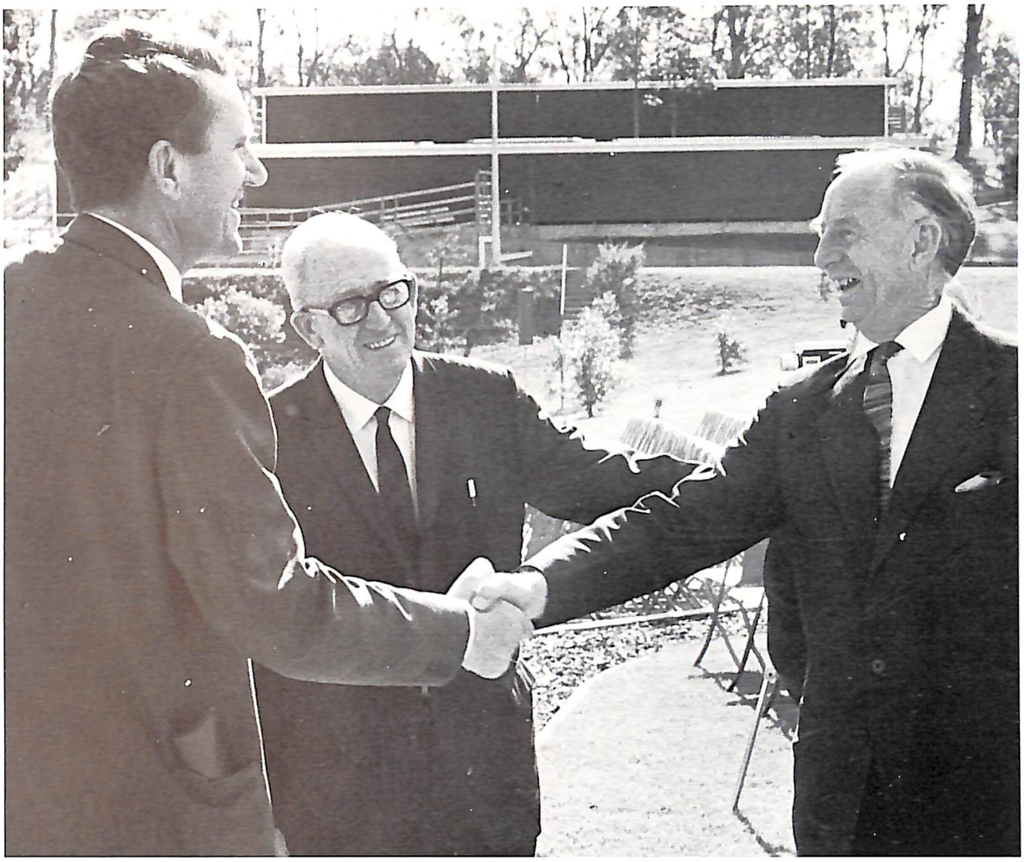
Rock drilling
Two years ago a programme was established in the DIVISION OF APPLIED MINERALOGY in Western Australia to test whether ultra-high-pressure hydraulic drilling of rocks was practical. Although the work was partially successful, unexpected problems were encountered which indicated that the technique could not be easily applied in the field. The programme has now been terminated and the research scientist concerned has returned to the DIVISION OF CHEMICAL PHYSICS to lead work on instrument engineering.

Buildings

Among the most important building projects commenced during the year were a $340,000 extension to the Cunningham Laboratory of the DIVISION OF TROPICAL PASTURES at St. Lucia, Brisbane, a $130,000 small-animal house for the DIVISION OF ANIMAL HEALTH at the new Long Pocket Laboratories at Indooroopilly, Brisbane, and an $828,000 agronomy laboratory and administrative building for the DIVISION OF PLANT INDUSTRY at Black Mountain, Canberra. The Australian Wool Board has contributed $500,000 to the cost of the agronomy laboratory.

A contract was let by the National Capital Development Commission for the Organization's HEAD OFFICE in Canberra. The building will cost some $1,450,000 and should be ready for occupation by the end of 1970. In addition, a contract was let by the Department of Works for a laboratory at North Ryde, Sydney, for the DIVISION OF MINERAL CHEMISTRY. The laboratory will cost in the order of $2,169,000 and will replace the present unsatisfactory accommodation for the Division at the North Ryde site. The laboratory is

Above right The Minister for Education and Science, Mr. Malcolm Fraser (left), is greeted on arrival at the Long Pocket Laboratories by the Chief of the Division of Entomology, Dr. D. F. Waterhouse (right), and the Chairman, Sir Frederick White.
Below right The Long Pocket Laboratories at Indooroopilly, Brisbane.



expected to be complete by mid 1971.

'Narayen Research Station', which the DIVISION OF TROPICAL PASTURES is establishing at Mundubbera, Queensland, has been further developed and $60,000 was spent during the year on accommodation for staff and on a field laboratory.

The biggest project completed during the year was the $1·27 million Long Pocket Laboratories which occupy a 17-acre site at Indooroopilly, Brisbane. The laboratories house research teams from the DIVISIONS OF ANIMAL HEALTH and ENTOMOLOGY which were previously located at the Veterinary Parasitology Laboratory in the neighbouring suburb of Yeerongpilly. They also house smaller groups from the DIVISIONS OF APPLIED CHEMISTRY, MATHEMATICAL STATISTICS, and PLANT INDUSTRY. The laboratories were opened by the Minister for Education and Science, Mr. Malcolm Fraser, on June 2, 1969.

At Cannon Hill, Brisbane, a $628,000 extension to the Meat Research Laboratories of the DIVISION OF FOOD PRESERVATION has enabled the Division to extend its research to lamb and mutton. Some $403,000 was contributed towards the cost of the extension by the Australian Meat Research Committee and $112,000 by the Australian Meat Board.

A $200,000 structure testing laboratory built at Highett, Melbourne, will be used by the DIVISION OF BUILDING RESEARCH to test building structures and components under loads of several hundred tons.

Two wool research laboratories were built during the year with money provided by the Australian Wool Board. They are a $132,000 extension to the wet process bay for the DIVISION OF TEXTILE INDUSTRY at Geelong, Victoria, and a $140,000 wool testing laboratory for the DIVISION OF TEXTILE PHYSICS at North Ryde, Sydney.

Other major projects completed during the year include:

NUTRITIONAL BIOCHEMISTRY—Refurbishing of laboratory, Adelaide. $130,000

TEXTILE INDUSTRY—Process development laboratory, Geelong, Vic. $120,000

MECHANICAL ENGINEERING—Fluid dynamics laboratory, Highett, Melbourne. $81,340

MINERAL CHEMISTRY—Development laboratory, Garden City, Port Melbourne. $61,300

ENTOMOLOGY—Workshop and services buildings, Black Mountain, Canberra. $58,000

Site services for Divisions located at Black Mountain, Canberra—site development, glasshouses, mechanical services. $56,000

MECHANICAL ENGINEERING—Extension to fluid dynamics building, stage 2. $55,000

RADIOPHYSICS—Display area for tourists at Australian National Radio Astronomy Observatory, Parkes, New South Wales. $50,000

Economic benefits of atomic absorption spectroscopy

Previous Annual Reports have described atomic absorption spectroscopy, a novel method of chemical analysis developed by the DIVISION OF CHEMICAL PHYSICS.

In 1968 the INDUSTRIAL AND PHYSICAL SCIENCES BRANCH at Head Office undertook a cost-benefit analysis of atomic absorption spectroscopy to assess its economic value to Australia. The assessment was made conservatively and a number of substantial indirect benefits that could not readily be given a value in economic terms were excluded. Even so, the measured benefits obtained up to June 1968 were estimated to have a net present value of $22 million when discounted at 10%.

Moreover, it was expected that by 1978 this figure would reach at least $120 million. The amount spent by CSIRO on research on atomic absorption up to June 1968 was $1·3 million.

The above estimates are based on improved productivity in laboratories using atomic absorption spectroscopy and on licence fees and income from sale of instruments. Productivity gains were assessed by calculating the cost of making particular analytical determinations by the most appropriate alternative method. This gave an average productivity gain per instrument of about $9000 a year for applications other than geochemical assaying. Due largely to the differences in instrument work loads, the average productivity gain per instrument in geochemical assaying was $169,000 a year.

Benefits not accounted for in the calculations are important even though they cannot be quantified. The ability to determine calcium and magnesium accurately in low concentrations is helping improve our knowledge of the role these elements play in human and plant metabolism. Atomic absorption spectroscopy has increased the chance of making important mineral discoveries as it offers an extremely rapid and cheap method of performing geochemical assays. In a number of ways atomic absorption spectroscopy has contributed to an improvement in industrial efficiency. For example, it has helped one company to increase its efficiency in extracting alumina from bauxite. In these cases the use of atomic absorption spectroscopy was only one of the contributing factors, so that an estimate of its value was impracticable.

Substantial benefits resulted from the early application of atomic absorption spectroscopy in Australian industry. If the research had been done overseas it would have been another two years at least before benefits began to flow to Australia from the invention. The loss to the economy caused by this delay would have exceeded $10 million.

Experience gained from the study suggests that the technique of cost-benefit analysis is likely to be of little value in assisting the decision-maker interested in the allocation of resources to original and fundamental research because of the unpredictability of the scientific results.

The technique of cost-benefit analysis could, however, be of use in helping the decision-maker who is concerned with allocating resources to applied research or who is reviewing a fundamental research programme that has advanced to the stage of yielding knowledge with an obvious application. For example, during 1969 the Executive considered a proposal from the DIVISION OF MINERAL CHEMISTRY to conduct research aimed at improving recoveries and grades of base metal concentrates. A cost-benefit analysis of the potential value of this research to the Australian mining industry was undertaken and the information was used by the Executive to assist in deciding how much of the Organization's resources should be devoted to the project.

Commonwealth Meteorology Research Centre

In April 1969, Cabinet approved the establishment of the Commonwealth Meteorology Research Centre under the joint agency of the Commonwealth Bureau of Meteorology and the DIVISION OF METEOROLOGICAL PHYSICS. The Centre, which is located in Melbourne, will study the behaviour of the atmosphere, with emphasis on its general circulation, in order to obtain a better understanding of the distribution and variations in climate on the Earth, and to improve the accuracy and time-scale of weather forecasting.

Funds for the operation of the Centre are provided jointly by the Bureau and CSIRO. Research and administrative staff are being appointed by CSIRO, and other professional, technical, and ancillary staff by the Bureau. Dr. G. B. Tucker, formerly Assistant Director (Research and Development) of the Bureau, has been appointed Officer-in-Charge. A Committee of Management, comprising the Chief of the DIVISION OF METEOROLOGICAL PHYSICS, the Director of Meteorology, and the Officer-in-Charge of the Centre, is responsible for the formulation and review of the Centre's research programme.

Research on prawns

The Minister for Education and Science, Mr. Malcolm Fraser, announced in June 1969 that the Government would provide finance to enable the DIVISION OF FISHERIES AND OCEANOGRAPHY to undertake a programme of research on prawns in northern Australian waters. The work will cover an area ranging from eastern Queensland to Exmouth Gulf in Western Australia and will be aimed at obtaining a thorough knowledge of the biology and ecology of the various prawn species in these waters and the factors controlling their distribution and number. This information is essential for the development of sound management practices that will enable the resource to be utilized fully without detriment to breeding stocks. The programme will involve a capital expenditure of about $600,000 over three years and when in full operation a recurrent expenditure in the order of $330,000 a year.

Post-graduate studentships

Each year CSIRO awards a number of studentships to graduates of Australian universities as part of its policy of providing opportunities for research training. Most of the local studentships and all of the overseas studentships are awarded to persons wishing to work in certain nominated fields of specific interest to CSIRO.

There is no obligation on studentship holders to seek employment in CSIRO, but the Organization does encourage them to develop close contacts with appropriate CSIRO laboratories. Holders of overseas studentships must give an undertaking to return and work in Australia for at least three years upon completion of their course.

Pre-doctoral studentships

These are awarded to persons who have completed at least one year of full-time post-graduate study. The tenure is two years with provision for extensions of up to two years in certain cases. In exceptional circumstances pre-doctoral students can study overseas in areas of specific interest to CSIRO. The successful candidates are listed below together with their fields of research and the institutions at which they will study.

Abbott, I. J.	Monash University	Animal ecology
Appels, R.	University of Adelaide	Biochemistry
Barber, M. N.	Cornell University	Physics of liquid state
Baverstock, P. R.	University of Western Australia	Animal ecology

Blake, J. R.	University of Cambridge	Fluid dynamics
Bradbury, R. H.	University of Queensland	Animal ecology
Burgess, A. W.	University of Melbourne	Wool science
Burton, P. G.	Monash University	Chemistry
Butler, A. J.	University of Adelaide	Animal ecology
Cake, M. H.	University of Western Australia	Biochemistry
Cannon, R. M.	University of Melbourne	Mathematical statistics
Connell, H. J.	University of Queensland	Fluid dynamics
Couch, G. H.	University of New South Wales	Electrical engineering
Davies, H. I.	University of North Carolina	Mathematical statistics
Denny, M. J. S.	University of New South Wales	Ruminant physiology
Fandry, C. B.	Monash University	Fluid dynamics
Frederiksen, J. S.	Australian National University	Physics
Goddard, I. V.	Monash University	Mathematics
Havas, G.	University of Sydney	Computing science
Hendrickson, A. R.	University of Melbourne	Chemistry
Holt, J. N.	University of Queensland	Physics
Hulbert, A. J.	University of New South Wales	Ruminant physiology
Jarrett, R. G.	Imperial College, London	Mathematical statistics
Marks, R. E.	Massachusetts Institute of Technology	Engineering systems analysis
Morjanoff, M. P.	Monash University	Engineering systems analysis
Noble, K. J.	University of Adelaide	Operations research
Parkinson, E. W.	University of New South Wales	Chemistry
Scollay, R. G.	Australian National University	Parasitology and immunology
Sears, M.	Flinders University	Mathematics
Soh, W. K.	University of New South Wales	Fluid dynamics
Thomas, I. L.	RAAF Academy, Melbourne	Physics and dynamics of stratosphere
Wilksch, P. A.	University of Adelaide	Physics and dynamics of stratosphere
Wilson, D. J.	University of Adelaide	Operations research
Woods, W. H.	University of Adelaide	Biochemistry
Wray, S. D.	Flinders University	Mathematics

Overseas post-doctoral studentships

These are awarded to post-doctoral scientists to enable them to proceed overseas for one year to work with leaders of research in their special field of interest. Awards were made to the following:

Andrews, P. R.	Institute of Physico-Chemical Biology, Paris	Biochemical pharmacology
Antonia, R. A.	Imperial College, London	Atmospheric circulations
Black, J. L.	National Institute for Research in Dairying, Reading	Ruminant physiology
Hynes, M. J.	University of Edinburgh	Biochemical pharmacology
MacBean, I. T.	University of Liverpool	Plant ecology
Patrick, J. W.	University College of Wales	Developmental plant physiology
Ralston, G. B.	Carlsberg Laboratory, Denmark	Physical chemistry of proteins
Rose, R. J.	Carleton University, Canada	Developmental plant physiology

Research

In a report of this size it is not possible to give a full account of all of CSIRO's current research. This chapter includes only one or two items of interest from each Division. Anyone wanting more comprehensive information on the work of the Organization should consult the separate annual reports of the individual Divisions and Sections and the annual lists of 'Papers, Books, and Patents by Members of the Staff of CSIRO' and 'Serial Publications, Monographs, and Pamphlets issued by CSIRO'.

In selecting the items for this chapter, an attempt has been made to select those which are of general interest and which lend themselves to description in terms that can be understood by the lay reader. This condition inevitably introduces a bias as a good deal of fundamental work in the basic sciences is excluded by it. Often the scientific significance of such research can be appreciated only by specialists in the same field.

Taken together, the items in this chapter show something of the tremendous range of the Organization's activities and the relevance of CSIRO's research to Australia's primary and secondary industries. Individually, however, each item describes only a few aspects of the work of a particular Division, so that the reader may be left with an incomplete view of what that Division does. To help overcome this and to keep the items in perspective, a series of tables has been included in the chapter. The purpose of these tables is to show for each Division and Section the location of its laboratories and field stations; its size in terms of staff and finance; the sources of its finance; the composition of its staff in terms of research scientists, other professional staff, and supporting staff; and the main fields of research in which it is engaged. It is hoped that in this way the reader will be able to see each item within the broader context of CSIRO's overall research programme.

The agricultural environment

Division of Soils

Location: Glen Osmond, Adelaide, with laboratories in Brisbane, Canberra, Hobart, Perth, and in Townsville, Qld.
Finance: $1,524,461 (Treasury $1,396,626, contributory $127,835)
Staff: Research scientists 66, other professional staff 26, supporting staff 94

Fields of research:
Soil fertility—physical, chemical, and biological properties of soils in relation to plant growth
Soil water—landscape hydrology, water resources, salinity, water use by plants ●
Soil mineralogy and geochemistry—mineral forms of nutrient elements, changes in weathering, clay minerals
Surface chemistry—studies of nutrient and toxic elements, factors affecting availability, design of fertilizers ●
Clay soils—nature of water movement in clays, electrolyte and cation effects, structure and physical stability
Organic matter—chemical nature; formation and decomposition and effect on this of soil microorganisms, ants, and termites; toxic factors in soil
Tillage—effects of cultivation on physical properties of soil, on water loss, and on plant growth
Formation, distribution, and classification of soils—micromorphology, landscape relationships, transport of sediment

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Division of Meteorological Physics

Location: Aspendale, Melbourne
Finance: Treasury $561,028
Staff: Research scientists 19, other professional staff 13, supporting staff 44

Fields of research:
Weather—its development and movement
Global circulation patterns in the upper atmosphere and their relationship with weather systems
Exchange of heat, water vapour, and momentum between the atmosphere and the Earth's surface ●
Solar, atmospheric, and terrestrial radiation
Maintenance of radiation standards, calibration of anemometers and radiation instruments

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● A black dot against a research programme indicates that one of the items which follow deals with that area of research.

Division of Land Research

Location: Canberra, with laboratories and field stations at Alice Springs, Katherine, and Coastal Plains, N.T., and at Kununurra, W.A.
Finance: $1,462,519 (Treasury $1,202,391, contributory $260,128)
Staff: Research scientists 37, other professional staff 26, supporting staff 114

Fields of research:
Land resources surveys in Australia and Papua–New Guinea
Principles and methodology of land classification
Dynamics of landscape
Hydrology in relation to catchment characteristics
Regional crop and pasture investigations at Kimberley Research Station, Coastal Plains Research Station, and Katherine Research Station
Crop–environment and root nutrient relations ●
Biological systems analysis
Plant taxonomy
Structure and function of the climate/land/plant/animal ecosystem in arid Australia

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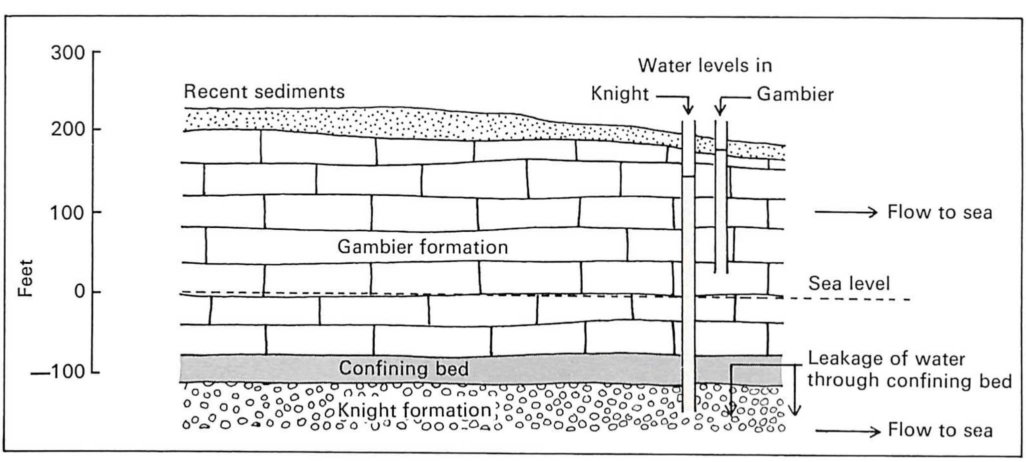
More water for South Australia

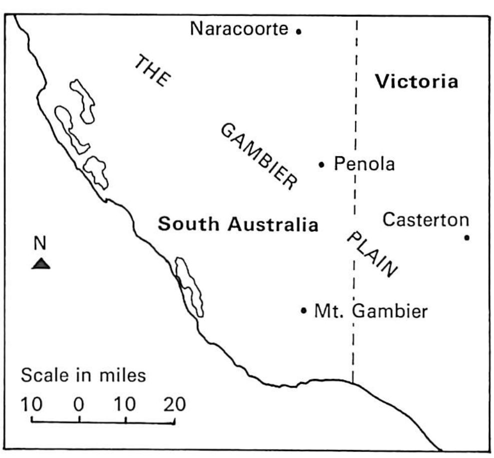
While the water flowing in rivers and streams can be charted and its volume measured with weirs and locks without too much difficulty, it is not so easy to estimate the direction of flow and the volume of underground water. Over the last 10 years the DIVISION OF SOILS has been attempting to measure the recharge of ground water beneath the Gambier Plain of south-eastern South Australia and south-western Victoria. Recharge of this underground water occurs during winter and spring by direct infiltration of soil water into an aquifer (a layer of porous, water-conducting rock) beneath the Gambier Plain. The aquifer is a bed of Gambier limestone and in many places is more than 300 feet thick. Water is redistributed by flow through the porous limestone to zones of leakage and from there into a second underlying aquifer of sand and gravel. Both aquifers



conduct the water to the sea where some of it reappears as springs along the coastline. The Division's research lends no support to the long-held theory that the underground water has its origin in the Grampians and western Victoria. It appears to be local water, and the intake diminishes towards the north-east of the Gambier Plain.

The Division has estimated that the annual recharge is about half a million acre-feet, making this body of underground water by far the largest single resource of good-quality water in South Australia apart from the River Murray. On the basis of experiments on water use by irrigated pastures, the Division has estimated that there is enough water beneath the Gambier Plain to irrigate up to 350,000 acres of pasture a year without exceeding the annual recharge. An even greater area of land could be irrigated if the discharge of water into the sea from artificial drains was prevented and the water used to recharge the aquifers.

Land use can have an important effect on recharge. The Division found that the evaporation from pine forests in south-eastern South Australia during winter and spring equalled the rainfall so that there was no recharge of the underground water beneath the forests. It



also found that the evaporation from the forests was about twice that from neighbouring grassland. This result probably applies to most catchments other than high mountain catchments. It seems likely, therefore, that stream flow from forested catchments is less than from catchments in grassland or crop land.

Supplying trace elements to plants

The commonest way of overcoming a trace element deficiency in a soil is to add the element as a water-soluble salt mixed with a fertilizer such as superphosphate. However, many soluble salts are easily leached from the soil. Some salts also have a tendency to absorb water from the air and this creates difficulties during handling and spreading. Another problem, particularly in the use of manganese, is that in some soils at least the element can become chemically bound to other soil components and so rendered unavailable to plants growing in the soil. These disadvantages can often be overcome by adding the element as a chelate compound, a type of organic compound of low solubility, but chelates are generally expensive.

A class of compounds which could provide a reliable and comparatively cheap source of trace elements for plants is now being investigated by the DIVISION OF SOILS. The Division found that it could produce crystalline complexes between trace elements and glycerol which were insoluble in water but were broken down by strong oxidative and reductive reactions. Preliminary experiments have shown that when cultivated into the soil or sprayed on the leaves, these complexes can supply trace elements to plants as readily as other common and sometimes more costly methods. The complexes, which have been named Sirochels, also appear to have some promise as additives to medicine and stockfoods. They are the subject of an Australian patent application.

Do reeds waste water?

In the Murrumbidgee Irrigation Area, much of the excess irrigation water drains into what has now become a large but shallow reservoir known as Barrenbox swamp. Some of the water in the swamp is used again for irrigation. During 1968 the DIVISION OF METEOROLOGICAL PHYSICS was asked to determine whether the presence of tall reeds growing in the swamp led to increased loss of water through evaporation. This request was prompted by a suggestion that removing the reeds might be an economic way of conserving more water.

In collaboration with the Water Conservation and Irrigation Commission of New South Wales and the DIVISION OF IRRIGATION RESEARCH, the DIVISION OF METEOROLOGICAL PHYSICS determined evaporation rates over the reed-covered swamp and over a reed-free lake nearby using a modified version of the Fluxatron. This instrument, developed by the Division, measures evaporation directly by correlating water vapour fluctuations in the atmosphere with the vertical movements of air.

The Division found that the evaporation rates over both swamp and lake were similar after heavy rainfall, but that in the generally prevailing dry conditions of the area the presence of reeds actually inhibited evaporation. The most likely explanation for this is that the reeds shield the surface of the water from the radiation of the Sun and shelter it from the drying effect of winds.

Measuring carbon dioxide in the crop

In sunlight, green plants make their tissues out of water and minerals from the soil and carbon dioxide from the air. Agronomists and plant physiologists are interested in the individual contribution which each of these components makes to plant growth and crop yields. But while it is comparatively simple to measure the uptake of water and minerals by a crop and the amount of sunshine at different levels in the crop, it is not so easy to determine the exchange of carbon dioxide between the crop and its environment. It is not enough simply to measure the carbon dioxide concentration of the air at some particular point, the scientist wants to measure carbon dioxide concentrations at several levels both within and above the crop simultaneously and with an accuracy of one part per million or better. This cannot be done with existing equipment.

The DIVISION OF LAND RESEARCH has developed an instrument that accurately measures carbon dioxide concentrations in air by passing the air over deionized water in an absorption tube and measuring the electrical conductivity of the water which is then recycled through a column of deionizing resin. The instrument is well suited to continuous multi-channel operation for studying carbon dioxide profiles in the field, and it is also well suited to growth studies of single plants or leaves in the laboratory. It is much simpler in design and operation than existing equipment, and readings are independent of changes in the concentration of water vapour in the air. Although designed primarily for measuring carbon dioxide concentration in air, the instrument can be used to determine concentrations of other soluble gases such as sulphur dioxide and ammonia.

Crops and pastures

Division of Plant Industry

Location: Canberra, with laboratories in Brisbane, Deniliquin, N.S.W., Hobart, and Perth, and field stations and experimental farms at Canberra, Deniliquin, N.S.W., Baker's Hill, Kelmscott, and Pinjar, W.A., and the Tobacco Research Institute at Mareeba, Qld.
Finance: $3,773,368 (Treasury $2,530,761, contributory $1,242,607)
Staff: Research scientists 117, other professional staff 68, supporting staff 320

Fields of research:
Pasture improvement and utilization—plant introduction, breeding, selection, establishment, evaluation, and management in grazing and ley systems ●
Nutrition of plants—nutritional requirements, soil fertility, fertilizers, physiology of nutrient uptake, nitrogen fixation
Plant–environment interactions—ecology and management of native vegetation; weed control; biophysics—interactions with physical environment, particularly energy and water
Biochemical and physiological processes in plants ●
Plant diseases—host–pathogen interactions
Tobacco agronomy and breeding
Plant taxonomy

Division of Horticultural Research

Location: Glen Osmond, Adelaide, with a branch laboratory and field station at Merbein, Vic.
Finance: $466,797 (Treasury $438,594, contributory $28,203)
Staff: Research scientists 17, other professional staff 3, supporting staff 44

Fields of research:
Grape vines
- Genetic improvement—plant introduction, hybridization, clonal selection
- Virus diseases—assessment of importance, control
- Crop management and production—control of fruit set, forecasting yields, mechanical harvesting, drying, and processing ●
- Physiology and biochemistry of vines and grapes

Fruit trees
- Physiology—photosynthesis and translocation, growth, salt toxicity
- Genetic improvement by introduction of new varieties
- Orchard ecology—spacing and shape of trees, light penetration

Parasitic nematodes (eel-worms)
- Physiology—locomotion, infection, reproduction
- Host–parasite–environment interactions
- Relationships between nematodes and viruses in plants
- Methods of control

Division of Irrigation Research

Location: Griffith, N.S.W.
Finance: $457,034 (Treasury $436,605, contributory $20,429)
Staff: Research scientists 13, other professional staff 7, supporting staff 51

Fields of research:
Water utilization by irrigated plants: soil–plant–water–atmosphere interactions
Agronomy of irrigated crops—citrus, cotton, rice ●
Plant physiology
Climatology, hydrology of irrigated basins

Division of Tropical Pastures

Location: St. Lucia, Brisbane, with laboratories at Townsville and Lawes, Qld., and field stations at Mundubbera, Samford, and Townsville, Qld.
Finance: $1,489,443 (Treasury $1,202,219, contributory $287,224)
Staff: Research scientists 40, other professional staff 16, supporting staff 156

Fields of research:
Development of better pastures for tropical and subtropical eastern Australia
- Provision of new pasture species through plant introduction and breeding ●
- Pasture agronomy—selection of legumes and grasses, pasture establishment, management, utilization, and productivity ●
- Pasture ecology and physiology
- Nutrition and biochemistry of pasture plants—soil fertility, fertilizers, legume bacteriology
- Animal nutrition and pasture evaluation
- Ecology and control of re-growth of woody species
- Numerical taxonomy

More grains in the crop

At flowering an ear of wheat consists of a series of spikelets. Each spikelet contains several small flowers or florets, some of which later develop grains. The DIVISION OF PLANT INDUSTRY is trying to discover what determines the number of grains in a spikelet and the number of spikelets in an ear. If the Division can find this out, it may then be able to increase wheat yields by increasing the number of grains per ear.

Ear development in twelve varieties of wheat was studied at Canberra in the Division's phytotron—a laboratory in which plants can be grown under a wide range of closely controlled environmental conditions. The rate of spikelet production, the final number of spikelets, and the time taken from sowing to ear emergence were affected in all varieties by length of day and in some varieties by exposing the seeds to low temperatures (vernalization).

With the variety Triple Dirk, for example, the number of spikelets per ear could be varied from 17 to 25 by subjecting plants to different numbers of long days (16 hours) after first subjecting them to a period of short days (8 hours). In Late Mexico 120, cold treatment of the seed for 12 weeks caused earlier earing and reduced the number of spikelets per ear from 34 to 15. The other varieties that responded to vernalization were affected in much the same way.

The effect of the long-day treatment and vernalization was to shorten the developmental stages between sowing and flower initiation and between flower initiation and ear emergence. Since the spikelets were usually laid down at a rate of about three a day, the shortening of the second stage resulted in fewer spikelets per ear. The Division is trying to determine the factors involved in laying down the final spikelet.

The Division also found that while more spikelets meant more grains, some varieties produced fewer grains per spikelet than others. A study of Triple Dirk, for example, showed that the fourth floret, which was normally sterile, could be filled if other florets in the spikelet were prevented from developing. If the reasons for the fourth floret remaining empty were known, it might be possible to remedy the condition and so increase yields.

One possible explanation for the failure of some florets to fill is that florets compete with each other for carbohydrate produced in the ear and other parts of the plant by photosynthesis. A study of the movement of carbohydrate in the plant during grain filling has therefore been started.

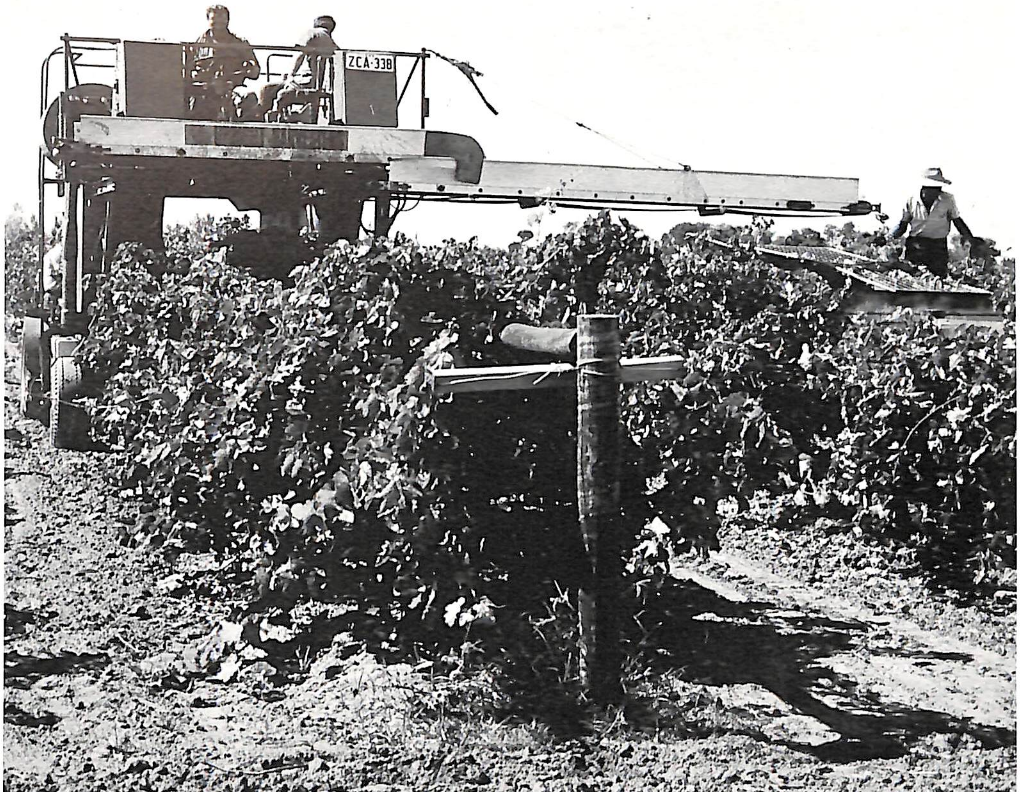
Pastures from the air

There are extensive areas of non-arable land in southern Australia which receive enough rain to support improved pastures. Although aerial sowing of pastures has been tried in these areas, it has not been widely adopted because of the failure of many temperate grasses and legumes to establish well after surface sowing.

Conditions for establishment are much more critical for a seed lying on top of the ground than for a seed buried in a well-prepared seed-bed. The DIVISION OF PLANT INDUSTRY, in conjunction with the New South Wales Department of Agriculture, has therefore been studying germination and early seedling development in a range of commercial pasture species to determine the factors affecting establishment after surface sowing. Among other things, the results of this work should help the Division's plant breeders define the criteria for new varieties of pasture plants specifically adapted to the conditions of aerial sowing.

The stage at which a seed becomes moist enough to germinate is controlled by the ability of the seed to balance its water uptake against loss of water caused by evaporation from the seed coat. By coating seeds with an absorbent material such as bentonite or lime combined with an adhesive, the Division has been able to increase the rate of moisture uptake and so promote earlier germination.

Once a seed has germinated, the roots must enter the soil and make contact with a more permanent supply of moisture below the surface. Experiments by the Division have shown that preventing the upward movement of seed during germination increases the number of roots entering the soil and greatly improves establishment. This



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suggests that under field conditions, vegetation or irregularities in the soil surface may have a similar restraining effect on seeds during their establishment.

Reduction of competition from other plants is essential during establishment. On non-arable sites this can be achieved by grazing, burning, or spraying with herbicides before sowing. The Division has found, however, that protection of the seedling during the early stages of development is also important and that the highest level of establishment is obtained on ungrazed standing cover that has been treated with herbicide. Heavy grazing before sowing was found to be detrimental, because although it reduces competition it also removes the plant cover that offers protection to the newly established seedlings.

Warm soils grow more oranges

Since 1947 the DIVISION OF IRRIGATION RESEARCH has been conducting a long-term experiment at Griffith to investigate the effects of different cultural treatments and different levels of nitrogen fertilizer on the growth, yield, and fruit composition of Late Valencia and Washington Navel orange trees. To date, the best soil management practice has been to maintain a bare uncultivated soil surface kept free of weeds by chemical sprays. Adequately fertilized trees receiving this treatment have produced higher yields of better-quality fruit than trees receiving permanent sod or winter cover crop treatments. Initially kerosene was used to control weed growth but this caused poor water penetration and necessitated spray irrigation and the construction of levee banks to prevent run-off. However, new herbicides that do not affect penetration are now being used on both spray and furrow irrigation systems.

Using bare surface culture and applications of only 400 lb of ammonium sulphate or calcium ammonium nitrate and 400 lb of superphosphate per acre, together with 4 ft of water (about one-third of this is received as natural rainfall), the Division has obtained average annual yields of 20 tons of oranges an acre. These yields, which are several times the local average, show that under good management orange trees can be very efficient food producers, comparable with other crops such as rice, sugar-cane, and potatoes.

Some of the benefits of bare surface culture are thought to be due to higher root temperatures, particularly in spring. Work at Griffith in 1932 showed that during the period October to March soil temperatures at a depth of 6 in. were on average about 5·5 degF warmer in non-cultivated bare surface soils than in cultivated soils. In a series of recent glasshouse studies using orange cuttings propagated and grown in sand, raising root temperatures from 66°F to 77°F more than doubled root growth and increased stem and leaf growth by more than 50%. Fruit growth was increased by about 30% and the quality and palatability of the fruit were improved. Although increasing root temperatures in the field by 11 degF is not feasible, conversion of soil cultural treatments in the orchard from cultivated to uncultivated bare surface systems could increase temperatures by 3·5 to 5·5 degF and so cause substantial increases in the growth of trees and the yield of fruit.

Above. Studying the effect of root temperature on the growth and yield of orange trees.

Below. One of two grape harvesting machines on loan to the Division of Horticultural Research for investigations into the mechanical harvesting of grapes for dried fruit and for wine.

Less grit in the grapes

Although dried vine fruits are washed during processing in packing sheds, it is not always possible to remove the last traces of soil that collect on the fruit during picking and drying. If too much soil remains, the fruit tastes gritty.

The recent development by the DIVISION OF HORTICULTURAL RESEARCH of a simple and inexpensive grit-measuring device known as the SIRO Gritometer has provided the dried fruit industry with a valuable tool in its campaign to improve fruit quality. The Gritometer is designed to measure only soil particles over 0·05 mm in diameter, because finer particles are easily removed from fruit by washing and because tasting tests conducted by the Division have shown that these finer particles do not contribute greatly to the gritty taste. Conventional methods for measuring grit are slower and give an estimate for total soil particles rather than for the fraction responsible for grittiness.

Gritometers were used successfully on a trial basis in a number of packing houses in 1968. In 1969 they were used in all packing houses and growers were advised of the grit content of the fruit they delivered.

Legume with potential

Leucaena leucocephala, a leguminous tree native to Central America, has considerable potential as a protein-rich forage for cattle in the wetter areas of Australia's tropics. At Samford, near Brisbane, yields of up to 1·4 tons of protein to the acre have been recorded by the DIVISION OF TROPICAL PASTURES. However, there have been reservations about its practical use in Australia because it contains mimosine, a compound which can cause loss of hair in mammals and which has been suspected of having an adverse effect on reproduction in sheep and cattle.

Some years ago the DIVISIONS OF TROPICAL PASTURES and ANIMAL PHYSIOLOGY showed that sheep fed a sole diet of *Leucaena* shed their fleece, but that sheep which were introduced to *Leucaena* gradually were able to break down mimosine in the rumen. The two Divisions have now completed a series of experiments with dairy cattle which show that feeding *Leucaena* as a sole diet has no harmful effects on the reproductive performance of cattle.

Feeding *Leucaena* for periods of up to 14 months had no effect on oestrus, conception, or the gestation period of heifers or lactating cows, or on subsequent milk production. Although calves had somewhat lower birthweights and enlarged thyroid glands, subsequent growth and development were normal. These experiments would have accentuated any possible harmful effects of *Leucaena* because under practical conditions the legume would form only part of the diet of breeding stock. These results should remove any doubts about using *Leucaena* as a feed for breeding and fattening cattle. A long-term programme to breed superior types of *Leucaena* as cattle feed is progressing well and a grazing experiment at Rodd's Bay has demonstrated the value of *Leucaena* as a feed in spring, when pastures cannot supply cattle with sufficient protein and energy and when other tropical legumes are dormant.

Pastures for the dry tropics

The country west of the Dividing Range in tropical Queensland carries open eucalypt woodlands and tall grasses which are typical of much of northern Australia. Most of the annual rainfall of 25 inches occurs between December

Cattle relish *Leucaena leucocephala*, a plant with considerable potential as a protein-rich forage for cattle in the wetter areas of Australia's tropics.

and March. Pasture quality declines during the dry season, reaching critically low levels in the spring. Cattle properties in the area are large, but stocking rates on unimproved country are low—about one animal to 45 acres. Breeding cows usually bear a calf every second year and steers take about six years to fatten.

Research over the last four years by the DIVISION OF TROPICAL PASTURES has shown that much higher levels of production are possible. Clearing trees from the native pasture increases the amount of soil moisture sufficiently to double the production of grass and to allow the ready establishment of Townsville lucerne (*Stylosanthes humilis*). Pastures improved in this way have carried bullocks at one to six acres and fattened them to market weight at three years of age.

Among other plants being tested for use in northern pastures is a large legume collection, including many *Stylosanthes* species from South America and a number of types of *Urochloa mosambicensis* and allied grasses recently collected in Africa. These grasses can respond rapidly to light falls of rain and are better feed in the dry season than the widely used drought-resistant buffel grasses.

Livestock

Division of Animal Genetics

Location: North Ryde, Sydney, with a laboratory and field station at Rockhampton, Qld., and field stations at Armidale and Badgery's Creek, N.S.W.
Finance: $1,298,834 (Treasury $879,945, contributory $418,889)
Staff: Research scientists 32, other professional staff 28, supporting staff 121

Fields of research:
Basic studies—molecular biology and genetics, genetics and physiology of morphogenesis, statistics
Genetics in relation to breeding and selection of beef cattle, dairy cattle, sheep, and poultry
Myxomatosis—genetics of myxoma virus, genetics of rabbit resistance, transmission by rabbit fleas

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Division of Animal Physiology

Location: Prospect, N.S.W., with a laboratory and field station at Armidale, N.S.W., and the Beef Cattle Research Unit at Brisbane
Finance: $1,720,146 (Treasury $216,013, contributory $1,504,133)
Staff: Research scientists 48, other professional staff 41, supporting staff 180

Fields of research:
Physiological basis of productive functions in ruminants
- Reproduction—spermatogenesis, ovarian function, pregnancy, parturition, neonatal physiology
- Body growth—hormonal control, intermediary metabolism
- Wool growth—keratin synthesis, follicle development, crimp formation, hormonal control
- Differences in production between individuals

Animal production from temperate and tropical pastures
- Ecology of grazed ecosystems, soil–plant–animal interactions and nutrient cycles; intake and energy expenditure of grazing sheep, dietary selection; stocking rates, behaviour of grazing animals, forage conservation

Nutrition and animal production—sheep and cattle
- Nutrition in relation to body growth, wool growth, and reproduction; appetite and food intake; digestion and absorption; rumen microbiology; metabolism of carbohydrates, proteins, and lipids; feed requirements, efficiency of feed utilization, and nutritional value of feeds

Influence of environment on physiology of sheep and cattle
- Regional and seasonal effects on wool growth and reproduction; effect of heat on testicular function and foetal development; effects of cold on young and adult sheep; physiology of sheep in semi-arid environments

Metabolic disorders of ruminants
- Metabolic failure in stressed animals; digestive disorders; urinary calculi; pasture oestrogens

Division of Animal Health

Location: Parkville, Melbourne, with laboratories in Sydney, Brisbane, and Townsville, Qld., and field stations at Maribyrnong and Werribee, Vic., Badgery's Creek, N.S.W., and Jimboomba, Qld.
Finance: $1,709,757 (Treasury $1,289,396, contributory $420,361)
Staff: Research scientists 44, other professional staff 21, supporting staff 188

Fields of research:
Infectious diseases of livestock—contagious bovine pleuropneumonia, bovine tuberculosis, infertility of cattle and sheep, foot diseases of sheep and cattle, virus diseases
Cattle tick and tick fever
Worm parasites of sheep and cattle
Animal viruses—basic studies and transmission by insects
Immunology
Livestock diseases caused by plant poisons

Division of Nutritional Biochemistry

Location: Adelaide, with a field station at O'Halloran Hill, S.A.
Finance: $573,717 (Treasury $374,288, contributory $199,429)
Staff: Research scientists 18, other professional staff 12, supporting staff 64

Fields of research:
Digestion and fermentation in the rumen
Mineral nutrition of ruminants—role of major elements—calcium, magnesium, phosphorus, sodium, potassium; role of trace elements—copper, cobalt, molybdenum, selenium; tolerance and adaptation of sheep to saline waters
Tissue biochemistry—pathways in energy metabolism
Nutritional disorders—phalaris staggers, heliotrope poisoning
Organic chemistry—carbohydrates, plant alkaloids, chelating complexes in plants

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The Divisions of Animal Genetics, Animal Health, Animal Physiology, and Nutritional Biochemistry comprise the ANIMAL RESEARCH LABORATORIES.

Dairy cattle for the tropics

European breeds of dairy cattle do not perform well in the tropics and subtropics of northern Australia, where temperature and humidity are high and parasites such as ticks are prevalent. Zebu cattle, on the other hand, tolerate higher temperature and humidity, are more tick-resistant, and fare better on poor-quality dry feed, but they produce less milk than European breeds and cows tend to dry up as soon as their calves are removed from them.

In 1956 a breeding programme to combine the most desirable qualities of both European and Zebu breeds was started by the DIVISION OF ANIMAL GENETICS at its McMaster Field Station at Badgery's Creek, New South Wales. Jerseys were chosen for the programme because they have the best reputation among European breeds for hardiness in the tropics and because they are relatively small and economical animals under difficult conditions. The Zebu cattle used were pure-bred Sahiwals and Red Sindhis derived from a group of cattle given to Australia in 1952 by the Government of Pakistan.

The first crossbred generation was obtained by mating pure-bred Sindhi and Sahiwal bulls with grade Jersey cows. Bulls and cows of the first generation were then mated with each other to produce the second generation, and bulls and cows of the second generation were mated with each other to produce the third generation. In each generation of crossbreds all the females were milked for at least one lactation and all cross-bred heifers that failed to lactate normally were culled from the breeding programme. Males were selected for breeding on the production of their dams and female ancestors. As information on production accumulated, it became obvious that the Sahiwals performed better than the Sindhis and further selection was concentrated on the Sahiwal crosses.

The second stage of the breeding programme began in 1962 with the introduction of a progeny testing scheme based on a group of cooperating dairy herds in the Lismore district of New South Wales. The six most promising crossbred bulls from Badgery's Creek were mated with some 600 Jersey females. In due course, about 30 daughters of each sire were themselves mated and their milk production recorded. The bulls with the most productive daughters were then mated to the top 10% of females at Lismore, and with selected cows at Badgery's Creek to produce further sires for progeny testing.

Since matings of proven sires are producing some 40 young bulls a year of which only six can be progeny-tested, the Division is using the knowledge it has gained from its research on heat tolerance and tick resistance in cattle to

screen out the best available six. Each bull is first tested in a hot room at Badgery's Creek to determine its ability to regulate its body temperature and maintain its appetite under hot conditions. The most heat-tolerant bulls then undergo a further screening on the basis of tick resistance tests carried out at the Wollongbar Agricultural Research Station of the New South Wales Department of Agriculture at Lismore.

The Division's breeding programme, which is the only one in the world using heat tolerance and tick resistance tests as an aid in selection, is not aimed at producing an animal with specified levels of Zebu and Jersey blood; it is concerned only with trying to achieve the most desirable combination of genes from both breeds. Already at this stage the average milk yield and fat production of the crossbreds are at least equal to those of other local Jerseys, while the best of the crossbreds have outyielded the best of the Jerseys. In addition, heat tolerance and tick resistance have been greatly increased in the crossbreds and culling for failure to lactate is already down to 15%.

A group of Sahiwal cattle at Badgery's Creek, New South Wales.

Sheep that don't drink

When native pastures are replaced by improved pastures there may be less run-off of rainfall into the dams and surface tanks that supply stock with their drinking-water. At the same time stocking rates are increased, so that pasture improvement can lead to more stock but less drinking-water.

On the other hand, stock on lush improved pastures may be able to obtain enough water from the food they eat to lower their requirements for drinking-water. For example, a sheep grazing a pasture with a moisture content of 80% and eating the equivalent of 3 pounds of dry matter a day would obtain 1·2 gallons of water in its food.

At Armidale, where the normal growing period of improved pastures extends over a large part of the year, the DIVISION OF ANIMAL PHYSIOLOGY has been trying to determine whether drinking-water facilities need to be increased when pastures are improved. Dry Merino ewes kept in paddocks of improved pasture and provided with drinking-water were compared over a period of two years with similar sheep in similar paddocks without drinking-water. The first year was one of the driest on record and the sheep had to be given grain as a supplement for three months to keep them alive. The second year was more favourable and although pasture was still scarce for much of the time there were a few months when it was abundant. There was little difference in body weights or wool growth between those sheep that were given water and those that were not; if anything, the sheep that did not have access to water grew more wool.

The Division is now studying the water requirements of sheep in greater detail, using breeding ewes. As a result of this work the Division hopes to obtain answers to such questions as: How much of a sheep's requirement for drinking-water can be provided by the pasture without affecting the sheep's well-being or production? How much water does a sheep obtain from a pasture and how much from drinking under a particular set of circumstances? When drinking-water is restricted, does a sheep select moister material from the pasture, or does it become better able to conserve the water it obtains from its food?

Treated proteins for sheep

A few years ago the DIVISION OF ANIMAL PHYSIOLOGY showed that remarkable increases in wool growth could be obtained by putting protein directly into the fourth stomach (abomasum) of a sheep. As mentioned in the last two Annual Reports the Division has been investigating methods of reducing microbial breakdown of protein in the rumen so that more of the protein in the feed can reach the abomasum. The most promising method examined so far is treatment of feed with formaldehyde. This protects the protein in the feed against microbial attack without seriously affecting the digestion of fibre. The process is simple and cheap and, provided excessive treatment with formaldehyde is avoided, there is very little decrease in the digestibility of the treated protein. Sheep fed on maintenance rations containing protected proteins have grown almost as much wool as their genetic capacity will allow.

So far the process has been found to improve the utilization of a number of feedstuffs including cottonseed meal, peanut meal, linseed meal, soybean meal, wheat, lucerne, and berseem clover. The Division is now determining the most suitable degree of treatment for each of these supplements, the process specifications needed to ensure a good-quality meal suitable for formaldehyde treatment, and the most economical method for treating feed on a commercial scale.

The Division, in conjunction with the DIVISION OF APPLIED MINERALOGY, is also developing methods of protecting amino acids from breakdown in the rumen, so that small supplements of protected amino acids may be used to stimulate wool growth, either alone or with formaldehyde-treated protein.

Foot abscess in sheep

Most infectious diseases are caused by a single organism. However, there is a small group of bacterial infections, known as mixed infections, which are caused by a combination of different bacteria acting together. Typical mixed infections are gum infection in humans, foot-rot in sheep, and calf diphtheria. Recent work by the DIVISION OF ANIMAL HEALTH on another of these diseases, foot abscess in sheep, may throw new light on the development of mixed infections. It will also help the Division in its search for an effective vaccine against foot abscess.

Foot abscess is caused by two bacteria, *Fusiformis necrophorus* and *Corynebacterium pyogenes*. Neither organism can cause the disease on its own. The Division has found that *Fusiformis* needs a nutrient not found in the host tissues, but produces a substance that kills white blood cells. *Corynebacterium* on the other hand is susceptible to the action of white blood cells but produces the nutrient needed by *Fusiformis*.

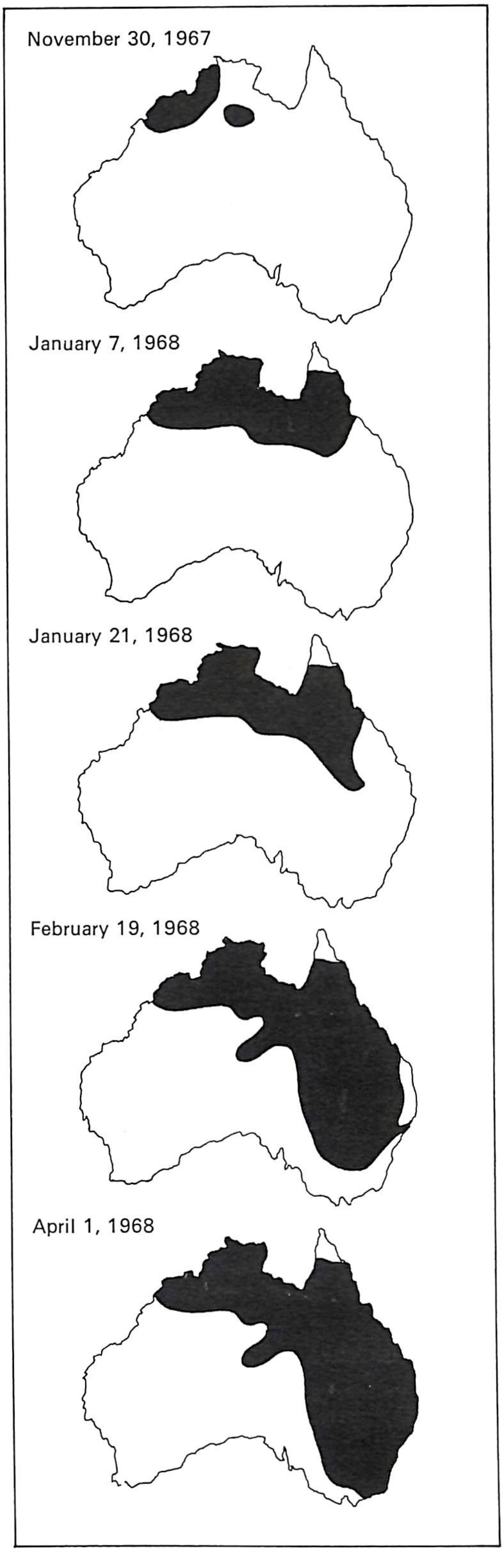
Tracking a wind-borne epidemic

Ephemeral, or three-day, fever is a virus disease of cattle and is thought to be spread by insects carried on wind currents. Its most serious effect is to cause a drop in production for one or two weeks in infected dairy cows. Since 1936, Australia has experienced three major epidemics of ephemeral fever. The largest of these began in the Northern Territory in September 1967 and in the following six months moved southward across the continent into Victoria.

Although ephemeral fever is of no great economic importance, there are other insect-transmitted virus diseases of livestock, such as blue tongue of sheep, that are extremely serious. Fortunately

Australia has remained free of blue tongue so far, but the DIVISION OF ANIMAL HEALTH has found that biting midges capable of transmitting the disease occur in many parts of Australia. These midges are small enough to be carried on light breezes and have even been trapped on aircraft flying at 13,000 feet. Because of this, studies of ephemeral fever epidemics and their rapid spread can provide valuable insight into the enormous problems of control and eradication that would result if a disease such as blue tongue gained access to Australian livestock. In collaboration with State veterinary services, private veterinarians, and the Queensland Institute of Medical Research, the DIVISION OF ANIMAL HEALTH made a close study of the 1967/68 ephemeral fever epidemic on a national basis.

The maps opposite show how the ephemeral fever epidemic spread. The first known outbreak occurred 27 miles south of Darwin in late September 1967. During October the disease spread into the Kimberley district of Western Australia. In November it was affecting cattle near Tennant Creek and by December it had spread into northern Queensland. The speed of the subsequent spread was spectacular. It reached Charleville by mid January, an area bounded by a line joining Mackay and Roma in Queensland and Bourke in New South Wales by the end of January, and the Murray River by mid February. By the end of February it had spread over northern Victoria. The southern half of New South Wales and Victoria were experiencing a drought at that time, but the spread was in no way impeded. In Victoria, the disease spread into Gippsland and there were suspected cases in western Victoria as far as the coast. The epidemic did not spread into southern South Australia. Wherever



there was a gap in the Great Dividing Range, the disease spread rapidly to the eastern coast. The final phase of the epidemic was the slow spread into the coastal dairying areas from Bundaberg in Queensland to Lismore in northern New South Wales.

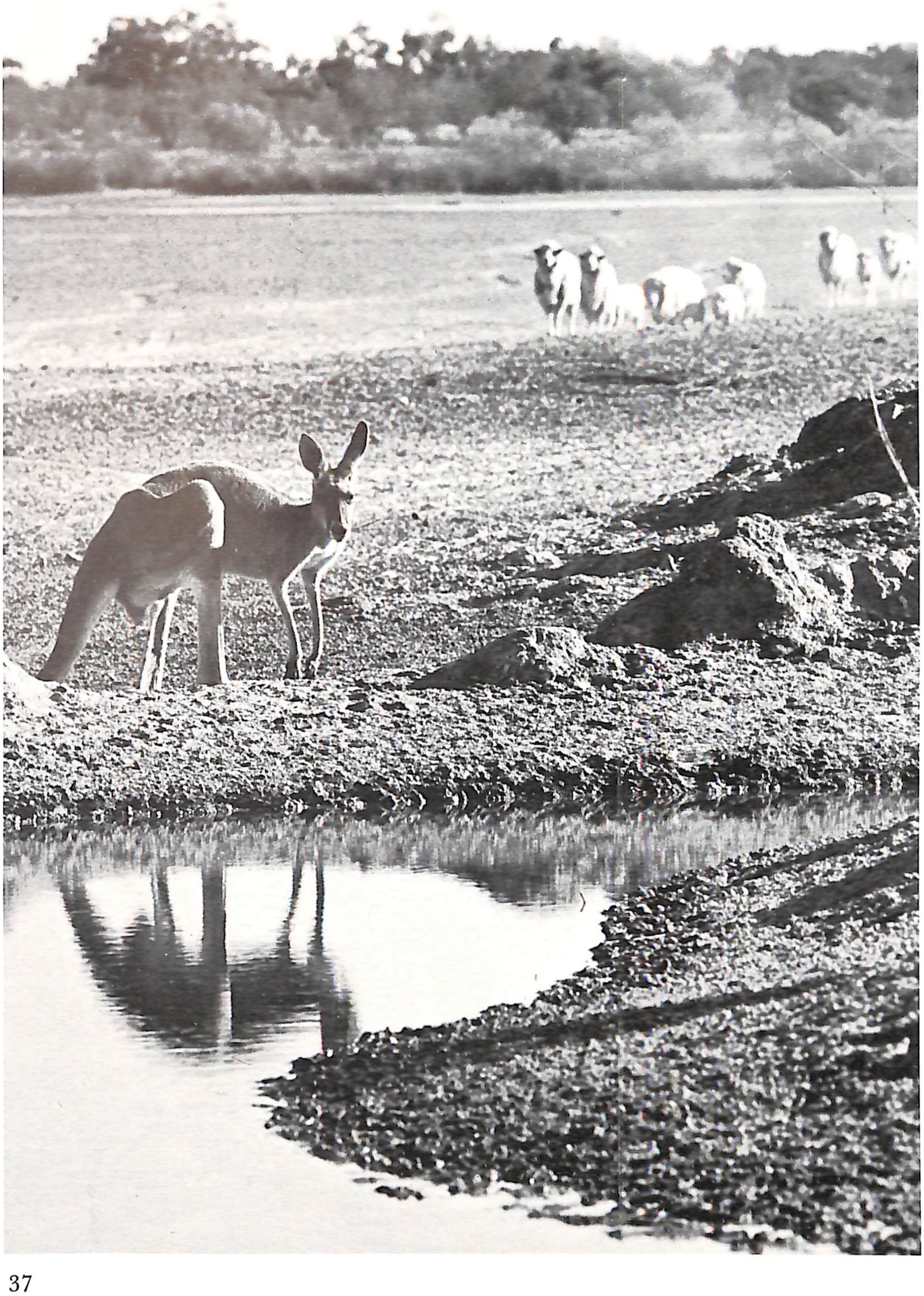
An analysis of the information obtained by the Division during its study revealed a strong correlation between the spread of the disease and surface wind-patterns. Recognition of this association while the epidemic was in progress enabled the Division to predict accurately the entry of the disease into Victoria and its subsequent spread. As a result of this experience, the Division hopes to be able to predict the pattern of spread of future ephemeral fever epidemics. The Division's findings lend strong support to the belief that the disease is transmitted by a wind-borne insect, such as a biting midge or sandfly, but so far the insect concerned has not been discovered.

Selenium and sheep fertility

Selenium is one of the trace elements needed by sheep in their diet. Lack of it causes white muscle disease in lambs and may cause infertility in ewes. Two or three years ago, the DIVISION OF NUTRITIONAL BIOCHEMISTRY noticed that in certain areas of South Australia where the level of selenium in pastures and sheep flocks was low, there was often an associated problem of infertility in breeding ewes, but only when the pastures contained subterranean clovers. Both red clover and subterranean clover are known to contain phyto-oestrogens. These are substances similar to female sex hormones; if eaten in sufficient quantity, they cause infertility in ewes.

The Division has been conducting trials to see if there is any relationship between infertility due to selenium deficiency and infertility due to oestrogenic pastures, and if so, whether the relationship is due to interaction of selenium and oestrogen in the plant or the animal or both. Results so far suggest that infertility in sheep grazing oestrogenic pastures can be greatly reduced if they are fed large doses of selenium a month before mating. This work is continuing. Meanwhile the Division is looking into the possibility of providing sheep with a regular supply of selenium by means of a heavy pellet containing selenium. When administered to sheep the pellet stays in the rumen where it dissolves slowly over a period of years, releasing a continuous dose of selenium. This technique was developed by the Division some years ago to prevent cobalt deficiency in sheep and cattle and has proved so successful that some millions of cobalt pellets are now made in Australia each year.

Kangaroos and sheep tend to eat different plants in different proportions. Because of this, direct competition between sheep and kangaroos for the same food is generally very much less than may at first appear, particularly when food is readily available. Research by the Division of Wildlife Research into the ecology of the red kangaroo has shown that it should be possible to develop methods of rangeland management that will allow sheep and kangaroos to live together in a dual grazing system.



Insects, fish, and wildlife

Division of Entomology

Location: Canberra, with laboratories in Brisbane, Perth, and Sydney, and field stations at Townsville, Qld., at Armidale, Trangie, and Wilton, N.S.W., and at Hobart, and biological control units at Ascot, England, and Montpellier, France
Finance: \$2,060,600 (Treasury \$1,600,048, contributory \$460,552)
Staff: Research scientists 59, other professional staff 27, supporting staff 148

Fields of research:
Genetics, physiology, biochemistry, and behaviour of insects as a basis for new methods of control—sterile male techniques, meiotic drive, lures
Ecology and control of insect pests—cattle tick, locusts and grasshoppers, pasture insects, forest insects, orchard insects, bush flies, sheep blowflies, insect pests of stored products
Insecticides—insect resistance, toxicology
Insect transmission of viruses
Biological control of insect pests and weeds ●●
Taxonomy and maintenance of National Insect Collection

Division of Wildlife Research

Location: Canberra, with a laboratory at Helena Valley, W.A., and staff located at the Arid Zone Research Institute, Alice Springs, N.T.
Finance: \$755,401 (Treasury \$504,976, contributory \$250,425)
Staff: Research scientists 16, other professional staff 13, supporting staff 73

Fields of research:
Biology of animals of economic importance—rabbits, kangaroos, dingoes, mice, ravens, black cockatoos, wedge-tailed eagles ●●
Biology and surveys of native fauna in relation to management and conservation
Bird banding and bird migration
Fundamental studies in population ecology, physiology, and animal behaviour

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Division of Fisheries and Oceanography

Location: Cronulla, Sydney, with laboratories in Brisbane and Perth
Finance: \$757,011 (Treasury \$727,737, contributory \$29,274)
Staff: Research scientists 21, other professional staff 20, supporting staff 69

Fields of research:
Biological and population studies of prawns, tuna, Western Australian crayfish, and Australian salmon; population studies of trawl fish ●
Primary productivity of marine environments
Structures and circulation of ocean waters ●
Distribution and abundance of zooplankton
Oceanography in relation to fisheries
Metabolism of single-celled algae
High-pressure studies of inorganic sea-water systems

Fighting the white wax scale

White wax scale, a serious pest of citrus, is found along the east coast of Australia, from Cairns in Queensland to the Victoria–New South Wales border. It is also found in isolated patches west of the Great Dividing Range in New South Wales and near Perth. A sugary secretion produced by the scales favours the growth of a black sooty mould on the fruit and leaves of citrus trees. This mould reduces the commercial value of the fruit and probably interferes with the health of the tree.

Attempts to control the scale in the 1930s by introducing parasites from East Africa were unsuccessful, but in 1965, following a reappraisal of the prospects for biological control, the DIVISION OF ENTOMOLOGY decided that a further attempt should be made. So far some 17 species of insects from South Africa have been considered as potential agents for biological control. Through the cooperation of the South African Department of Agricultural Technical Services several of these species have been imported under quarantine and two parasitic wasps have already been released near Sydney. Further importations are planned. One of the main difficulties so far has been the development of suitable techniques for mass-rearing parasites.

Finding enemies for skeleton-weed

Skeleton-weed, a deep-rooted perennial plant native to the Mediterranean region and central and southern Europe, has been present in Australia since 1914. Although it is an unimportant plant in its native environment, it is a major weed of wheat crops in south-eastern Australia. It reduces crop yields by competing with the wheat plants for water and nutrients, and its tough stems foul harvesting machinery. In recent years skeleton-weed has spread to Western Australia.

Skeleton-weed is attacked in its native habitat by a variety of insects and other organisms. If some of these could be introduced into Australia they might aid in the control of the weed, particularly in headlands and on roadsides where other measures are not appropriate. The DIVISION OF ENTOMOLOGY therefore established a research station at Montpellier in southern France in 1966 to look for natural enemies of skeleton-weed and to study its ecology. This work is being complemented by ecological studies conducted in Australia by the DIVISION OF PLANT INDUSTRY. To date the search for organisms attacking skeleton-weed has concentrated on a narrow strip of country running along the southern coastline of France and extending into north-eastern Spain. Because of its climate, this region should be the most likely place to find organisms adaptable to Australian conditions.

Three very promising enemies have been found so far—a fungus, a gall mite, and an aphid. Another aphid and a powdery mildew also appear promising. The fungus infects skeleton-weed seedlings in autumn and spring. When not fatal, the infection prevents or greatly reduces flowering. The gall mite attacks the flowering buds and the autumn seedlings, and the aphids attack seedlings and infest the tips of the growing flower shoots. Before any of these organisms can be allowed into Australia they must be carefully screened to make sure that they will not attack plants of economic importance. It is unlikely that these tests will be complete before the end of 1970, but present indications are that the organisms are all highly specific to skeleton-weed and should be safe to introduce.

On the track of the dingo

Early in 1966 the DIVISION OF WILDLIFE RESEARCH began a study of the ecology of the dingo. An area of nearly 10,000 square miles was chosen for the study in the Alice Springs district of central Australia because of its simple environment and the relative abundance of dingoes.

The first stage of the programme involved sampling the dingo population. After a few months experimenting with lures and placement of traps, and learning to read tracks, a two-man team from the Division developed considerable expertise at dogging, and by December 1968 they had trapped and shot some 550 dingoes. This has provided information on diet and breeding as well as on numbers, distribution, and population structure. Occasional domestic dogs roaming wild have been caught far out in the bush.

In the good seasons experienced so far, the dingo's diet has comprised rabbits, lizards, small mammals (mostly feral house-mice), and occasionally kangaroos and carrion. Only four calves are known to have been killed by dingoes; but none had been eaten. However, graziers expect that when drought comes again, killing of stock will increase.

Dingoes mate in late autumn to early winter, and whelp in late winter to early spring in caves, excavated rabbit warrens, and holes dug in places such as creek banks. Pups become independent in early summer and indications are that many of them die. Dingoes are unlike domestic dogs in that sexual maturity is not reached until their second year.

With the assistance of officers from the Northern Territory Administration, the Division has examined the effectiveness of aerial baiting. All permanent watering points on 18 properties covering 20,000 square miles of central Australia were surveyed before and after baiting. The method of assessment depended on the tested ability of survey teams to estimate accurately from tracks alone the number of dingoes that could be caught at a watering point. Results showed clearly that the baiting was not effective. Dingo numbers fell insignificantly on six properties, including two of the three unbaited properties used as controls, but rose on all others and almost trebled on the property with most dingoes.

Watch on the wedge-tail

Over the last few years the DIVISION OF WILDLIFE RESEARCH has been studying the wedge-tailed eagle to obtain a detailed understanding of its biology and to measure its importance as a predator on lambs.

A study conducted near Canberra and in north-western New South Wales of the eagle's food habits has shown that rabbits are its primary prey. Near Canberra the hare was the next most important species, followed by birds, sheep and lambs, small mammals, and lizards. In the arid interior, kangaroos and lizards were of considerable importance, taking the place of the hare. In both areas lamb remains constituted only about 7% of the eagle's diet. The Division is now trying to develop methods that will enable it to distinguish between the remains from healthy lambs, weak and dying lambs, and carrion.

A more intensive study has been in progress since 1967 in semi-arid areas typical of much of the pastoral zone in southern, western, and eastern Australia. Where rabbits were abundant, they formed by far the biggest part of the eagle's diet; where they were scarce, the diet was more varied and included a

Young wedge-tailed eagle in nest.
The picture shows the large number of rabbits brought to feed the young in a good season when rabbits were abundant and easily caught.

higher proportion of birds and reptiles.

Preliminary results show clearly that the impact of predation by nesting eagles on the pastoral industry is not significant, particularly when compared with the very heavy natural losses that occur among sheep. In the Canberra area for instance the density of nesting eagles was about one pair to 12 square miles. Sheep populations within the average nesting territory produced about 4000 lambs, out of which a pair of eagles could have taken at most two or three individuals.

It is not known at what age eagles start to breed, but there are indications that they may have quite a long period of immaturity. The plumage of three eagles taken as chicks from the nest was recorded at 6-monthly intervals. It darkened progressively, but even at 4 years had only just begun to attain the black adult coloration. At least some of the young move long distances after leaving the nest, and dispersals of 400 to 700 miles have been recorded within the first year. It is believed that pairs of adult eagles hold territories during the breeding season, and often throughout the year. Nevertheless flocks of five and more, sometimes many more, occur occasionally. These may consist of wandering immature birds or of birds driven from certain regions by drought or other hard conditions. The extent and nature of such movements may have some relationship to damage by eagles and the Division is investigating these questions further.

Clearing of forests and the introduction of exotic animals, particularly rabbits, appear to have provided the eagles with a better habitat than they had before European settlement, and have contributed to an increased density of the eagle population. Although more than 30,000 eagles are estimated to be killed by graziers each year, the present population appears high enough and productive enough to absorb this loss on a sustained yield basis and there is no immediate evidence to suggest that eagles are decreasing in Australia.

Southern bluefin tuna

The Australian tuna fishing industry is based on the southern bluefin tuna. This species occurs off the southern coasts of Africa, Australia, New Zealand, and South America. The only part of the southern oceans from which catches have not yet been recorded are the central south Pacific and the south-west Atlantic. Since 1962 the DIVISION OF FISHERIES AND OCEANOGRAPHY has caught, tagged, and released over 44,000 southern bluefin in Australian coastal waters to obtain information on the movement of the tuna population. The tagging programme has shown that tuna undertake long and rapid migrations, and that mixing takes place between tuna stocks from the Indian and Pacific Oceans. Tagged fish have been recaptured by Australian and Japanese fishermen east of New Zealand, south of Tasmania, and, in 1968, as far west in the Indian Ocean as 1000 miles south-east of the Cape of Good Hope. The mixing of stocks between the Indian and Pacific Oceans suggests that the southern bluefin caught off Australia might be part of a single stock ranging throughout the greater part of the southern oceans.

The East Australian Current

The East Australian Current is a major component of the oceanic circulation off the east coast of Australia. It is a south-flowing current and its strength is greatest about 20 miles from the coast at the edge of the continental shelf. South of Sydney it turns away from the coast and flows eastward across the Tasman Sea in a diffuse manner. Changes in the flow of the Current during the year bring about changes in the physical and chemical characteristics of the waters off the coast. These changes are of interest to scientists for a number of reasons. The DIVISION OF METEOROLOGICAL PHYSICS has found definite correlations between sea surface temperatures along the coast of New South Wales and rainfall on the mainland, but much more information on sea temperatures is needed before stronger and more definite relations can be established. Variations in the Current are also important for the tuna fishing industry. The southwards transport of warmer tropical waters by the East Australian Current during the summer months probably plays a significant role in creating conditions favourable to schooling behaviour in tuna off the south coast of New South Wales. Catchable schools of tuna have been found in this region only in waters with surface temperatures between 16 and 20°C. The temperature of the surface layers of water and the patterns of circulation of the Current affect the upwelling of nutrient-rich water from deeper layers and the subsequent abundance of zooplankton which is eaten by the fish on which the tuna feed.

The DIVISION OF FISHERIES AND OCEANOGRAPHY has been studying the Current to obtain a three-dimensional picture of it and to determine the volume of flow. Direct measurements of water movements at depths between 1300 and 3500 metres were made by tracking the movement of neutrally buoyant floats that had had their density adjusted to equal that of sea water at the desired depth. The main finding was a current flowing at a depth of 1300 metres in the same direction as the surface current, although its strength was about half a knot compared with about four knots at the surface. Previously it had been assumed that the flow at this depth was zero. At greater depths the currents were weaker still, about 0·1 knot, and did not seem to be connected with the surface current.

Textiles and leather

Division of Protein Chemistry

Location: Parkville, Melbourne
Finance: \$920,730 (Treasury \$48,089, contributory \$872,641)
Staff: Research scientists 41, other professional staff 35, supporting staff 54

Fields of research:
Composition and chemistry of wool proteins
Electron microscope and X-ray studies of fibre structure
Proteins from wool and the influence of breed and nutrition
Mechanism and improvement of wool setting
Whitening and prevention of yellowing ●
New dyes for wool
New uses for wool
Flammability of fabrics
Leather manufacture and hide proteins ●
Enzymes and muscle proteins

Division of Textile Industry

Location: Geelong, Vic.
Finance: \$1,173,008 (Treasury \$81,641, contributory \$1,091,367)
Staff: Research scientists 21, other professional staff 23, supporting staff 159

Fields of research:
Scouring and related processes
Spinning, other mechanical processes
Dyeing and whitening of wool
Shrinkproofing and other treatments ●
Setting and prevention of wrinkling
Fleece properties and processing performance of different types of wool
New uses for wool
Cotton processing

Division of Textile Physics

Location: Ryde, Sydney
Finance: Contributory \$837,818
Staff: Research scientists 20, other professional staff 23, supporting staff 89

Fields of research:
Wool testing methods and equipment ●
Implications of new wool testing methods for manufacturing
Properties of fabrics, felting, shrinkproofing, setting, wrinkling
Wool structure and physical properties
Wool pressing and sampling
Wool drying and dyeing

The Divisions of Protein Chemistry, Textile Industry, and Textile Physics comprise the WOOL RESEARCH LABORATORIES.

Whiter wool

Bleached wool is particularly suitable for white or pastel fabrics and so commands premium prices. The usual commercial method of bleaching wool is to treat it with hydrogen peroxide, but although this produces a desirable whiteness, peroxide-bleached wool is much more sensitive than untreated wool to subsequent yellowing by the action of sunlight, alkalis, or heat. In scouring mills one of the traditional methods used for upgrading slightly yellow wool is to spread the wool on the top floor of a building under a glass roof and turn it occasionally with a fork to expose fresh material to the light. The glass roof filters out the low-wavelength ultraviolet radiation which turns wool creamy yellow, but admits blue light which has a bleaching effect. The treatment usually takes one to two days.

Experiments conducted by the DIVISION OF PROTEIN CHEMISTRY a year or two ago showed that a similar bleaching effect could be achieved in one or two hours by exposing wet wool to filtered blue lights from banks of mercury vapour lamps, but the improvement in the value of the wool barely offset the cost of treatment.

However, following reports from overseas that certain reducing agents produce a bleaching effect, the Division found that treating wool with the reducing agent thioglycollic acid and exposing it to blue light resulted in much faster (5 to 10 minutes) and much better bleaching than if either the acid or the blue light were used alone. Thioglycollic acid and other reducing agents have the disadvantage of splitting disulphide bonds in the wool fibre and so decreasing fibre strength, but the Division found that this could be overcome quite easily by treating the bleached wool with a solution of zinc sulphate.

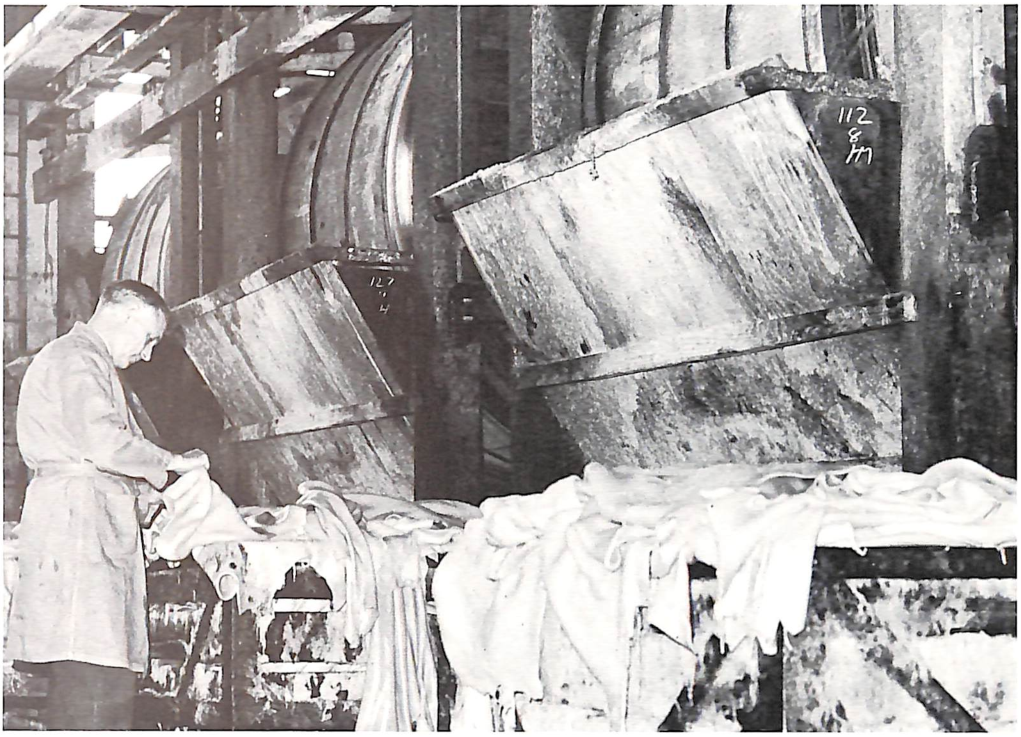
This process can be applied in the treatment of wool fabric, wool top, loose wool, and yarn or can be used on peroxide-bleached wools with advantage when very white wool is wanted. The peroxide gives an initial bleaching and the subsequent treatment whitens the wool still further and makes it much less susceptible to yellowing.

The new process is to some extent an alternative to the thiourea–formaldehyde anti-yellowing process described in last year's Annual Report and the Division is now examining the two processes to determine whether each has its own particular place in industry or whether one has some advantage over the other.

Recording temperatures in tanning drums

Tanning of hides to produce leather is usually carried out in rotating wooden drums like those opposite. One of the factors influencing the quality of the leather is the temperature at which tanning is carried out, but until recently little was known about the variations in temperature that occur inside the tanning drum during a run. Because of the movement of the drum and the eccentricity of the bearings, direct transmission of the temperature in the form of electrical signals via slip-rings is not practicable. The DIVISION OF PROTEIN CHEMISTRY has therefore designed an instrument which can be attached to the drum and which transmits information on the temperature by means of an audio-frequency electromagnetic signal to a pick-up coil mounted nearby on a stationary part of the machine. The signals can be taken by coaxial cable to a receiver and then to a chart recorder. Since the temperature fluctuates slightly each time the drum is opened, the chart provides a valuable record not

Tanning drums in a Melbourne tannery.



only of the temperature of each batch of hides during processing, but also of the times of adding water or chemicals to the drum. This information can be examined later in relation to the properties of each batch of finished leather.

Rotating wooden drums are also used in the dyeing of leather. Before dyeing, small-scale tests are conducted to determine what temperatures and what concentrations of dyes and other chemicals should be used in the drum to achieve the desired colour. In the past it has been difficult to reproduce this colour exactly when operating at full scale, partly because the rate of heat loss from the drum is different from that from the test equipment. With the new temperature-measuring device, the exact temperature conditions of the test dyeing can be maintained in the drum and the desired colour obtained.

Shrinkproofing of wool

In 1966 the DIVISION OF TEXTILE INDUSTRY announced the development of an improved method for shrinkproofing wool which involved applying a thin layer of resin to the surface of the wool fibres after treating them with a weak solution of chlorine. This process is now being applied industrially in Australia and New Zealand and is about to be taken up by a number of other countries.

During its research on the process the Division found that uniform application of the resin over the surface of the individual wool fibres was essential for good results. Too little resin resulted in inadequate shrinkproofing, while too much made the wool harsh to handle. A scanning electron microscope acquired by the Division in 1968 has greatly simplified the task of assessing the uniformity and extent of resin application (see pictures below). By varying processing conditions and examining the treated fibres with the scanning microscope, the Division has been able to determine the most suitable conditions for commercial processing.

Untreated fibre.

Treated fibre.

Measuring the fineness of wool

Interest in the wool industry in the measurement of fineness, or mean diameter of wool fibres, is growing rapidly. Makers of wool tops commonly sell their product on the basis of a specification that includes a value for fineness determined from the resistance offered to the flow of air by a given weight of wool when used as a plug in an air stream.

Past attempts to apply this air flow method to samples of greasy wool have not given particularly accurate results because the fibres in such samples are not aligned and carry a considerable amount of foreign matter. However, the DIVISION OF TEXTILE PHYSICS has now devised an improved method of washing and blending cored samples of greasy wool in a newly developed automatic sample washer and has shown that the fineness of these samples can be determined by the air flow method with substantially the same accuracy as for wool tops.

Although the air flow instrument is quick and reliable, it does not give an absolute measurement of fineness. If the results obtained with one instrument are to be compared with those from another, or if measurements on top and greasy wool are to be related meaningfully to each other, the instruments must be calibrated by reference to samples of wool of known fibre diameter. The fineness of these samples is usually determined by direct measurement of fibre diameter under the microscope, but the procedure involved is lengthy and tedious and is prone to operator error. Because of this the microscope method lacks the repeatability of the air flow method. The extension of the latter method to greasy wool has further accentuated this limitation.

A new procedure, known as the snippet gravimetric method, has now been developed by the Division. The new method involves measuring the length of fibres in a weighed sample under the microscope and using this information together with the known density of wool to calculate mean fibre diameter. Although no quicker than the conventional microscope method, it is far more accurate and gives much more consistent results.

Food processing

Division of Food Preservation

Location: North Ryde, Sydney, with the Meat Research Laboratory at Cannon Hill, Brisbane, and a laboratory at Gosford, N.S.W.
Finance: $1,596,506 (Treasury $1,293,367, contributory $303,139)
Staff: Research scientists 57, other professional staff 51, supporting staff 129

Fields of research:
Nature and control of changes in foodstuffs caused by time, temperature, and microorganisms
- Heat and mass transfer in fruit and meat storage and transport ●
- Chemistry of food constituents including flavours
- Physiology and ecology of food spoilage microorganisms ●
- Physiology and biochemistry of fruits, meats, and eggs
- Processing of foods by canning, freezing, and drying

Division of Dairy Research

Location: Highett, Melbourne
Finance: $502,486 (Treasury $330,422, contributory $172,064)
Staff: Research scientists 12, other professional staff 10, supporting staff 49

Fields of research:
Cheese—mechanization of cheddar manufacture, cheese starters, enzymology of cheese ripening
Casein and other milk proteins—fundamental chemistry, commercial manufacture ●
Flavour chemistry
Drying of dairy products, recombined products
New foods ●
Oxidative deterioration of butter-fat in stored dairy products

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Wheat Research Unit

Location: North Ryde, Sydney
Finance: $68,541 (Treasury $22,328, contributory $46,213)
Staff: Research scientists 4, other professional staff 4, supporting staff 3

Fields of research:
Biochemical aspects of wheat and flour quality
Biochemistry of wheat proteins, wheat carbohydrates, and wheat lipids
Morphology of the wheat kernel

Avoiding meat contamination

The best-known and most dangerous member of the *Salmonella* group of bacteria is *Salmonella typhi* which causes typhoid fever. However, there are also some 1300 other types of salmonella which live in the intestine of man and animals and which can cause food poisoning in man. While a wide variety of foods may contain salmonellae, the foods most often infected are meat, milk, and eggs.

Many countries are becoming increasingly concerned about food poisoning outbreaks caused by salmonellae. The United States, for example, has made considerable efforts to identify and control food and other materials contaminated with salmonellae and has laid down stringent standards of hygiene for beef imported from Australia and elsewhere.

Meat presents a special problem because all meat-producing animals can harbour salmonellae in their intestines. As part of a programme to determine sources of meat contamination, the Meat Research Laboratory of the DIVISION OF FOOD PRESERVATION has been examining the incidence of salmonella in the intestines of sheep and cattle at slaughter. This work showed that salmonellae can occur in the rumen of apparently healthy animals. It also showed that the frequency and degree of infection of the rumen and lower gut were quite variable and were related to food intake over the preceding few days. When a well-fed animal was given large numbers of salmonellae in its food, the organisms quickly disappeared from the rumen and faeces. But when small numbers of salmonellae were given to an animal that had been starved or fed only intermittently, extensive growth of the organism occurred in the rumen and large numbers were excreted in the faeces. Animals that were slaughtered within two days of leaving the farm were seldom infected, but animals that were held for longer periods and fed only occasionally before slaughter were often infected and had an abundance of salmonellae in their intestinal tracts.

Places such as rail trucks, sale yards, and abattoir holding pens represent a ready source of infection to livestock passing through them. They also cause extensive contamination of the animals' hides and fleeces. Because of the high incidence of salmonellae in animals at slaughter, correct pre-slaughter treatment of the animals and good abattoir hygiene are essential to prevent contamination of the meat.

Transporting beef in containers

In April 1969, Australia began shipping frozen boneless beef overseas in insulated containers. By April 1970 it is expected that some 45,000 tons of beef will have been shipped in this way. Each container has an overall size of 20 ft by 8 ft by 8 ft and can hold 16 tons of beef. At the meatworks the beef is packed into the containers in 60-lb cartons at temperatures well below freezing point and it is then transported by road or rail to the nearest container terminal. Both at the terminal and during the sea voyage, the containers are connected to a supply of refrigerated air to keep the beef at the right temperature. The containers can also be connected to a supply of cold air during the trip from the meatworks to the wharves by means of clip-on refrigeration units. Each of these units costs up to $3500 and weighs $1\frac{1}{2}$ tons.

In 1967 a group of shipping companies asked the DIVISION OF FOOD PRESERVATION to find out whether clip-on units would be needed for all containers during inland transport. Several unrefrigerated

In this picture volatile flavour compounds are being isolated from frozen peas. The isolation and analysis of the volatile compounds that give different foods their flavour are an important part of the research programmes of the Divisions of Dairy Research and Food Preservation. Since many of these compounds occur in minute quantities, extremely refined techniques are needed for their study.

trial runs by rail and road were made from the Queensland border area to Sydney and computer programs were set up to calculate heat flows into unrefrigerated containers. The computed temperature changes at different points inside the container matched the experimental ones closely and enabled the Division to develop methods for predicting temperature rises under a wide variety of outside conditions. The results, which were expressed as a table giving allowable transport times without refrigeration for a range of loading temperatures and outside air temperatures, showed that clip-on refrigeration units were needed only on rare occasions, mainly on long journeys in mid summer. A similar table is now being produced for lamb, which is less dense and has a lower thermal conductivity than beef.

Biscuits for the undernourished

In conjunction with the Arnott-Brockhoff-Guest Co., the DIVISION OF DAIRY RESEARCH has developed an attractive and nutritious milk biscuit containing all the essential ingredients of milk except lactose. The lactose is replaced with wheat flour and cane sugar to avoid undue browning, or even blackening, of the biscuit during baking and to make the biscuit suitable for people who, for various reasons such as malnutrition, do not digest lactose well. The biscuits are a versatile food—they can be softened with water to serve as a food for weanlings or eaten dry as a snack for children or adults. Such a product represents a useful means of supplementing the diet of any section of a community with deficiencies of minerals or vitamins. The biscuits keep well and under tropical conditions last at least six months with adequate packaging. Since refrigeration or elaborate sanitary precautions are unnecessary at any stage of handling, the biscuits are easy to store, transport, and distribute. Biscuits are a widely used food form and appear to be generally acceptable in all communities where nutrition is poor.

The milk biscuit is a prototype for high-protein biscuits made with protein from any new or established source. In some countries animal proteins or synthetic amino acids could be used as minor constituents to upgrade lower-quality plant proteins which might be available locally at moderate prices. Different cereals could be used to replace part of the wheat flour when such products were readily available locally.

Several countries, including India and the Territory of Papua and New Guinea, have become interested in the biscuit. In Zambia, arrangements are being made to establish a manufacturing plant capable of producing one ton of biscuits a day. Eventually the Zambian authorities hope to feed 700,000 school children with the equivalent of one-third of a pint of milk a day—in biscuit form. Australian butteroil and coprecipitate (a milk protein concentrate developed by the DIVISION OF DAIRY RESEARCH) will be used in the manufacture of the biscuits.

Keeping milk fresh

Milk and cream can be sterilized by what is known as the U.H.T. (ultra-high-temperature) process. This involves heating the milk or cream to about 270°F for one or two seconds, then flash cooling it in a vacuum chamber. There is very little change of flavour and if the product is packaged so as to maintain its sterility it will keep for weeks or months.

In practice, the life of U.H.T.-sterilized milk is usually determined by how long it lasts before the protein in it starts to coagulate. An investigation by the DIVISION OF DAIRY RESEARCH into possible causes of this coagulation has revealed enzyme activity in U.H.T.-sterilized milk, and the evidence so far suggests that this activity causes the coagulation. Milk contains enzymes that can break down protein, but one would expect them to be inactivated by the high temperatures used in the U.H.T. process. The results of the investigation suggest that these enzymes either partly survive the heat treatment or, more probably, become reactivated by temperature changes during subsequent storage.

Engineering and construction

Division of Forest Products

Location: South Melbourne
Finance: $1,403,042 (Treasury $1,311,689, contributory $91,353)
Staff: Research scientists 36, other professional staff 45, supporting staff 151

Fields of research:
Structure and properties of wood and wood fibres
Conversion of trees to final timber product
  Solid wood, cutting and seasoning
  Preservation ●
  Wood-based panels
  Operational research
Pulp, paper, and paper products
Engineering of timber structures

Division of Mechanical Engineering

Location: Highett, Melbourne
Finance: $585,504 (Treasury $532,703, contributory $52,801)
Staff: Research scientists 16, other professional staff 19, supporting staff 47

Fields of research:
Air conditioning and refrigeration ●
Utilization of solar energy
Industrial aerodynamics
Heat and mass transfer
Grain storage and agricultural machinery
Design and control by computer ●

Division of Building Research

Location: Highett, Melbourne, with an office in Port Moresby
Finance: $830,626 (Treasury $798,703, contributory $31,923)
Staff: Research scientists 22, other professional staff 37, supporting staff 58

Fields of research:
Building materials—ceramics and ceramic products, concrete, gypsum and gypsum products, paint, organic building materials ●
Concrete structures
Architectural acoustics
Heat comfort in buildings ●
Tropical building
Operational research ●
Systems research

Division of Soil Mechanics

Location: Syndal, Melbourne, with a laboratory in Adelaide
Finance: $369,864 (Treasury $354,540, contributory $15,324)
Staff: Research scientists 9, other professional staff 9, supporting staff 27

Fields of research:
Engineering materials science—physical and chemical properties of earthen materials in relation to engineering
Soil fabric, soil stabilization, mechanical properties of soils, defect structure mechanics, soil thermodynamics, soil and rock dynamics
Soil and rock engineering
Soil water, foundations on expansive soils, embankments and natural slopes, earth pressures and retaining structures, drilling and sampling, grouting
Use of land for engineering purposes
Site investigation, terrain evaluation for engineering

1. Round pine fence post treated with new, fire-retardant preservative.
2. Severe test fire burning about it.
3. When burning had stopped completely, only minor damage had resulted.

Fire-resistant fence posts

Round fence posts, properly treated with preservatives to protect them against termites and decay, can last more than 30 years. Over 1 million posts are commercially treated in Australia each year, mostly with preservatives of the waterborne copper–chrome–arsenic (CCA) type, and the number is growing steadily. CCA preservatives have a number of advantages: they can be transported readily in concentrated form, they are simple to use, no heating is needed during processing, and both the preservative and posts treated with it are clean and easy to handle.

CCA-treated posts do not catch fire readily and usually withstand a fire better than untreated hardwood posts, but once ignited they usually smoulder until completely consumed. While this peculiar 'after-glow' effect is the only disadvantage of the CCA treatment, it could seriously affect the future use of treated posts, even though the number destroyed by fire amounts to only a very small percentage of those installed each year. After experimenting with a number of preservatives and fire-retardant chemicals the DIVISION OF FOREST PRODUCTS has developed several formulations of the CCA type which eliminate this 'after-glow' problem. The new formulations protect timber against decay as effectively as earlier CCA preservatives and can withstand prolonged leaching by rain or even running water. They present no handling problems and are expected to add only a few cents to the cost of each treated post.

Keeping rooms cool

A room in a house can be kept cool in hot weather by using an evaporative cooler which draws warm outside air into the room over a moist surface. Water evaporating from the moist surface lowers the temperature of the air. Evaporative coolers cost less than refrigerated air-conditioning units and are cheaper to run, but even in hot dry conditions their performance is limited because they increase the humidity of the air they cool.

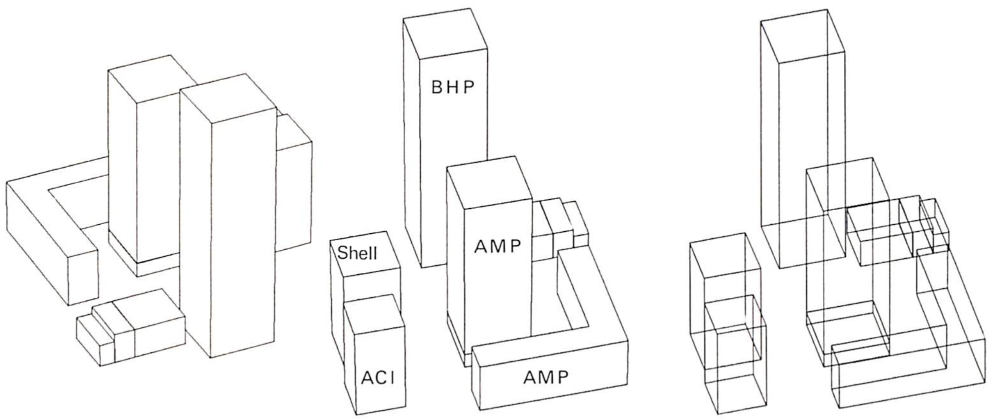
The DIVISION OF MECHANICAL ENGINEERING has devised a simple and compact evaporative cooler which gives lower temperatures and humidities than those obtainable with conventional evaporative cooling systems. The key to this improved performance is a plate heat exchanger made of plastic. Heat exchangers are normally made of metals, which are much better conductors of heat than plastic, but tests by the Division showed that with this particular heat exchanger, the poor conductivity of plastic was unimportant if plates of about 10/1000 of an inch were used.

In addition to the plastic plate heat exchanger, the cooling unit contains two fans, a water pump, and water spray nozzles. Exhaust air from the room being cooled is drawn over wet plates in the heat exchanger, and the evaporated water is carried through with the air and discharged outside. Evaporation of the water keeps the plastic plates cool, and fresh air blown past the dry side of the plates is cooled before entering the room without any increase in absolute humidity.

The unit is expected to give satisfactory cooling in most parts of Australia except in the humid tropics. Prototype units have been installed in Melbourne and Adelaide to check performance and servicing requirements. Although the construction of the cooler is novel, it should be adaptable to mass production methods.

Measuring shadows

From a knowledge of the Sun's position at different times of the year, an architect designing a house or an office building can work out the best positions and dimensions of the windows and the positions and angles of any shading devices he may decide to use. The same knowledge also helps the engineer to determine air-conditioning requirements. In making these calculations, however, The figures below show the process for an array of buildings surrounding the new A.M.P. tower (St. James project) on the corner of Bourke and William Streets, Melbourne. The tower is 378 ft high, including a 30 ft high lobby (drawn in). On its north side, lying across Bourke Street, are the Shell (222 ft high) and A.C.I. (195 ft high) buildings, while the L-shaped building to the west and south is the 106 ft high second building of the project. To the east, across William Street, are the 500 ft high projected B.H.P. building and three other much smaller buildings. The diagrams shown are for the Sun positions at 0800 and 1600 hours on December 22. In order to determine the shaded areas accurately a complementary drawing including hidden lines is produced (Fig. 3) to facilitate the location and dimensioning of any of the regions of interest which may lie in shadow.



1. 0800 hours 2. 1600 hours 3. 1600 hours

the architect and the engineer must consider not only the position of the Sun but also the extent to which the building is shaded by others nearby.

These calculations have now been made easier by a computer program developed jointly by the DIVISION OF BUILDING RESEARCH and the DIVISION OF MECHANICAL ENGINEERING. The program enables a digital computer to draw a picture of a group of buildings from a predetermined viewing point. If the viewing point lies on a line joining the Sun and the centre of the building array and is sufficiently far away, then those parts of the buildings not visible are in shadow.

Several pictures may be drawn corresponding to different positions of the Sun as it moves across the sky between sunrise and sunset. In this way a complete sun/shadow history of any part of the building can be determined. The technique has also been applied on a smaller scale to shading devices so that the shadows of individual louvres may be projected.

How long does a building take to build?

Unexpected delays in the construction of buildings are annoying and frustrating to all concerned and can be costly. A recent survey by the DIVISION OF BUILDING RESEARCH of some 350 buildings, ranging in price from \$10,000 to over \$10,000,000 and excluding houses, has shown that the time taken to construct a building is on the average nearly half as long again as the time originally allowed in the contract. The excess time varies according to the type of building; for example, the average time taken to complete an office block was about 25% greater than that specified in the contract while for schools in some areas it was over 80%. The Division found, however, that, contrary to what is commonly believed, there is little relationship between actual construction time and the type of building. Thus, a building costing \$1,000,000 is likely to take about 350 working days to complete irrespective of whether it is an office block or a school. The administrative procedures adopted by any of the parties to the contract can, however, affect the results.

There are a number of factors responsible for the widespread failure to specify construction times correctly in contracts, but the basic cause appears to be lack of information on the relationship between the size of a building, the contractual procedure, and construction time. The information being obtained by the Division on these relationships is making it possible to define standards of performance that can be regarded as normal. These standards should enable all parties involved in a building contract, including the client, to assess the likely construction time of a project on a more realistic basis.

Longer life for sealed roads

Australia uses about half a million tons of bitumen, worth around $30 million, annually. Most of this bitumen is for road-making, but some is also used in the building industry as a sealant, particularly in the construction of waterproof membranes built up from alternate layers of bitumen and reinforcing fabric. Failures in these membranes caused by the bitumen becoming brittle and cracked with age as a result of oxidation in sunlight have been investigated by the DIVISION OF BUILDING RESEARCH. A study of the chemical reactions involved showed that some bitumens were more susceptible to oxidation than others. The study also enabled the Division to suggest types of chemicals that would be most effective in retarding oxidation in bitumen. A number of compounds of this sort were supplied by ICIANZ Limited for testing. The Division found that the useful life of bitumen could be increased, and in some cases doubled, by adding 1–2% of one of these compounds, zinc diethyl dithiocarbamate, an additive widely used in the rubber industry.

Subsequent laboratory and field studies conducted in conjunction with the Australian Road Research Board showed that the same oxidative reactions were involved in the deterioration of bitumen on road surfaces. Different paving bitumens are now being examined to assess their response to dithiocarbamate additive and the construction of road test sections is being planned by State road authorities in collaboration with the Board. Using additive could increase the cost of a bitumen seal by about 10%, but if it doubled the life of the seal, 90% of the cost of resealing would be saved.

Predicting soil behaviour

In designing structures such as road pavements, building foundations, and earthen dams, engineers need to predict the mechanical behaviour of the soil under load. In doing this they usually assume that the soil is homogeneous and isotropic, or uniform in composition and structure, and that the magnitude of any particular mechanical property is the same in all directions. Experiments suggest that few soils are like this.

The difficulty has been to describe the structure of a soil so that structure can be related to the mechanical behaviour of the soil. The DIVISION OF SOIL MECHANICS has now developed techniques for describing and measuring both the spatial distribution and the spatial orientation pattern of the individual particles or units of each of the three main soil components—sand and silt grains, clay particles, and pores filled with air or water or both. As a result a relationship reflecting soil anisotropy has been established between the structure of certain arbitrarily chosen soils and their mode of failure under load.

Chemistry and mineralogy

Division of Mineral Chemistry

Location: Garden City, Port Melbourne, with a laboratory in Sydney
Finance: $1,705,164 (Treasury $1,603,606, contributory $101,558)
Staff: Research scientists 46, other professional staff 60, supporting staff 134

Fields of research:
Chemical aspects of mineral exploration
  Borehole logging
  Coal survey
  Ore genesis
  Sedimentary chemistry ●
Chemistry of mineral treatment
  Molten salts
  Carbon ●
  Mineral sands
  Halide metallurgy
  Iron ore treatment
Chemical aspects of fuel technology
  Fuel cell
  Combustion
  Flames
  Inorganic combustion products
Chemistry of solids and surfaces
  Catalysis
  Plasma processes
  Structures
  Sulphide oxidation

Division of Applied Chemistry

Location: Fishermen's Bend, Port Melbourne, with a microanalytical laboratory at the University of Melbourne
Finance: $961,915 (Treasury $909,435, contributory $52,480)
Staff: Research scientists 37, other professional staff 29, supporting staff 57

Fields of research:
Chemistry of natural products—alkaloids and hormones
Synthetic organic chemistry and organometallic chemistry ●
Chemical thermodynamics, reaction mechanisms, and catalysis
Bush fires ●
Desalting of water
Surface chemistry
Nucleation and crystallization
Microanalytical laboratory

Division of Chemical Physics

Location: Clayton, Melbourne
Finance: $809,635 (Treasury $796,785, contributory $12,850)
Staff: Research scientists 32, other professional staff 13, supporting staff 51

Fields of research:
Spectroscopy
  Atomic absorption and resonance spectroscopy
  Diffraction gratings and specialized optical instruments ●
  Molecular spectroscopy
  Mass spectroscopy
Electron diffraction, electron microscopy, X-ray diffraction
Solid state research
Theoretical chemistry

Division of Chemical Engineering

Location: Fishermen's Bend, Port Melbourne
Finance: $534,671 (Treasury $511,551, contributory $23,120)
Staff: Research scientists 17, other professional staff 18, supporting staff 31

Fields of research:
Particle mechanics
  Grinding and classification
  Flotation
  Fluidization
Diffusional operations
  Heat transfer
  Crystallization
  Mixing and rheology
  Reversed osmosis
Metallurgical processes ●
  Tin smelting
  Ore roasting
High-pressure chemical reactions
Desalting of water
Process design and evaluation ●
Analogue computation and simulation

The Divisions of Applied Chemistry, Applied Mineralogy, Chemical Engineering, Chemical Physics, and Mineral Chemistry comprise the CHEMICAL RESEARCH LABORATORIES.

Division of Applied Mineralogy

Location: Fishermen's Bend, Port Melbourne, with a mineragraphic laboratory at the University of Melbourne and laboratories in Canberra, Perth, and Sydney
Finance: $676,523 (Treasury $640,181, contributory $36,342)
Staff: Research scientists 26, other professional staff 18, supporting staff 39

Fields of research:
Geology and geochemistry of ores
- Distribution of elements in mineralized areas
- Formation of sulphide ores
- Experimental mineralogy
- Mineragraphy

Industrial treatment and use of rock and mineral raw materials
- Cements, concretes, rock aggregates
- Refractories, engineering ceramics, foundry materials
- Mineral–organic systems

Ore Dressing Investigations

Location: Parkville, Melbourne
Finance: $126,018 (Treasury $115,094, contributory $10,924)
Staff: Research scientists 3, other professional staff 7, supporting staff 5

Fields of research:
Flotation
Hydrometallurgy
Physical separation processes—gravity, electrostatic, magnetic
Grinding and sampling

New leads in oil search

Drilling for oil and gas is an expensive operation and in the off-shore sedimentary basins around Australia a typical well can cost between 3 and 4 million dollars. Exploratory wells have located commercial reservoirs of oil and natural gas, notably in the East Gippsland Basin, but in many other areas wells have been drilled which have turned out to be dry or have yielded only traces of hydrocarbon. Research by the DIVISION OF MINERAL CHEMISTRY on the formation of hydrocarbons in rocks should enable exploration companies to improve the success of their drilling operations. The Division has shown that chemical examination of coals and carbonaceous material encountered during drilling can be used to help identify potential source beds of petroleum and natural gas, to estimate the probable depth at which oil and gas might occur, and to predict whether a particular area is likely to yield oil and gas, gas-condensate, or dry gas.

It is commonly assumed that the only source rocks for oil are those containing remnants of marine life, but the Division's research indicates that the Gippsland and Moonie oil and the natural gas at Gidgealpa are probably derived from the fossilized remains of the waxy coatings of leaves, pollen, and spores of land plants. These are often found as components of coal seams.

The Division's work also shows that the maturity of a coal deposit is related to its depth of burial rather than its geological age. The rising temperatures that accompany increasing depth of burial bring about a progressive chemical alteration resulting in the formation of gaseous and liquid hydrocarbons. These first appear in sedimentary rocks containing coal at the sub-bituminous stage. The Division found that hydrocarbons extracted from these rocks and from immature black coals had the same composition as the oil from one of the wells in the Gippsland Basin. The Division also found that it could generate the same hydrocarbons in the laboratory by taking pollen coal, consisting of waxy pollens and leaf cuticles, from the Yallourn seam of the Gippsland Basin, and heating it with water. Gaseous hydrocarbons corresponding to the main components of natural gas were also formed. The effect of heating the pollen coal was to accelerate the geological process and to bring about in a few days chemical reactions that would have taken millions of years in rocks under natural conditions.

An examination of coals and traces of hydrocarbons in cores and cuttings provided by various petroleum exploration companies indicated that oil was not formed unless the coaly material had been buried sufficiently deep in present off-shore sediments. On the other hand, in most older basins now on the land, the coal has been buried for a longer time and at higher temperatures. Where such coal has reached the bituminous coking stage large petroleum reservoirs appear less likely to occur, but as in the Gidgealpa and Moonie fields large amounts of natural gas may still be tapped.

Filter aids and activated carbons from coal

Filter aids are used in industry for such purposes as water purification, mineral dressing, effluent treatment, filtration of vegetable oils and petroleum products, and the clarification of beverages. A filter aid added to a liquid before filtering forms a porous layer on the filter which stops it from becoming blocked with sludge and removes fine particles that might otherwise leave the filtered liquid cloudy. The most widely used filter aid is diatomaceous earth which costs about $200 a ton. Australia imports several thousand tons of this material a year from the United States.

A few years ago the DIVISION OF MINERAL CHEMISTRY found that filter aids could be produced from coal by controlled carbonization in a fluidized bed. In many cases the new materials were equal in performance to good grades of diatomaceous earth and had the advantage that after being used they could be disposed of by burning. A further advantage was that they could be activated for use in applications where it was necessary to remove dissolved colouring matter as well as filter out suspended particles. By varying the type and particle size of the coal, and the temperature and rate of heating, the Division has been able to make a range of products differing in filtering speed and decolourizing activity and tailored to the specific requirements of different applications. The process of manufacturing these filter aids and activated carbons is simple, and the Division expects the cost of production to be low.

Apart from finding a use in industry as an alternative to existing filter aids, the new materials have a number of other potential applications. Tests carried out in conjunction with industrial firms in recent years have shown that activated coal-based filter aids provide an excellent alternative to bone char in sugar refining and in the production of glucose. They could also provide a worth-while alternative to active carbon and diatomaceous earth for the recovery and treatment of solvent in dry-cleaning plants. One of the biggest outlets for coal-based filter aids, however, may be in the aluminium industry, where they appear to have considerable promise for handling the red mud which is left behind when crude bauxite is purified by treatment with caustic soda.

New insecticides show promise

Last year's Annual Report described the development by the DIVISION OF APPLIED CHEMISTRY of several new compounds that were comparable with DDT in their toxicity to insects and were of low toxicity to humans and animals. Unlike most conventional insecticides the new compounds contain no chlorine or phosphorus.

The Division has found that the new insecticides are active against some strains of insects which are resistant to DDT, dieldrin, and other commonly used insecticides. Moreover, the Division has found a way to interfere with the mechanism by which insects break down and detoxify the new compounds. As a result the activity or potency of these compounds can be increased many times. For example, the Division was able to increase the activity of one of its compounds against the common house fly so that it gave much better control of the insect than DDT. The activity of the compound was the same against DDT-resistant flies as it was against DDT-susceptible flies. In preliminary tests carried out on dieldrin-resistant sheep blowflies the Division of Entomology recorded a marked increase in activity of the same compound. Research on the activity of the new insecticides against different insects is continuing.

In conjunction with the Commonwealth Department of Customs and Excise the Division is developing tests for detecting minute traces of the new compounds and experiments are planned to find out if they are transmitted to milk, meat, and other foods when applied to pastures and crops. Samples of the compounds have been submitted to the World Health Organization which will make an independent assessment of their value as insecticides in public health programmes and of any possible health hazards associated with their use.

Diffraction gratings

Optical diffraction gratings commonly take the form of extremely flat metal-coated glass plates with large numbers of closely spaced grooves (up to 32,000 per inch) ruled on them. They are used in a variety of optical instruments to separate light into its component colours. As a result of the work of the DIVISION OF CHEMICAL PHYSICS over the last 10 years, Australia is now one of the few countries in the world where first-quality diffraction gratings are produced commercially.

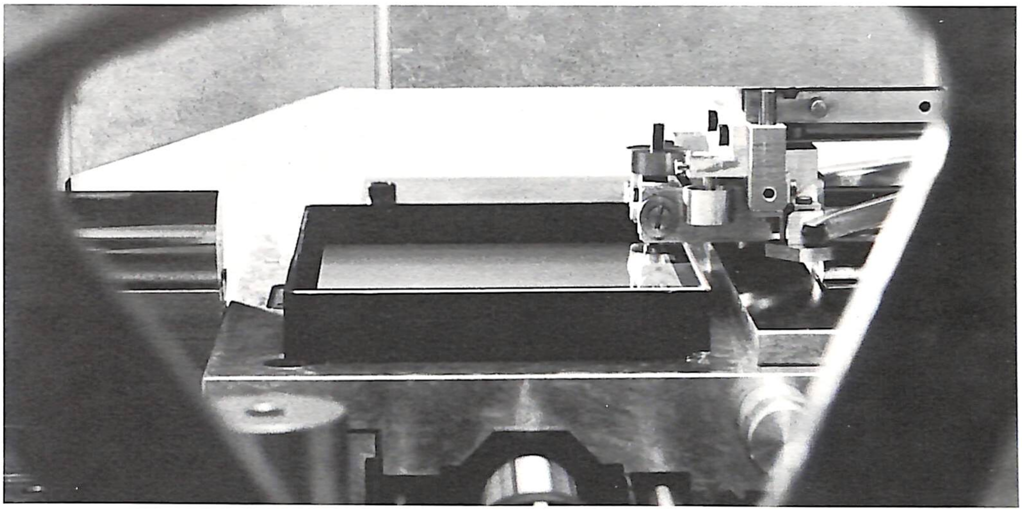
In high-quality gratings, the grooves must be straight to within one-millionth of an inch and parallel to better than 0·1 second of arc, all grooves must be well within one-millionth of an inch of their correct position with respect to the first groove, and the grooves must be of the same shape, width, and depth to within one-millionth of an inch. These tolerances are about a thousand times more exacting than those used in tool-making and special techniques are involved. Even today there are only about half a dozen ruling machines in the world capable of producing first-class gratings. The machine designed, constructed, and operated by the DIVISION OF CHEMICAL PHYSICS ranks high among them. Since 1960, when it was commissioned, the machine has ruled about 250 master gratings.

Master gratings made on the machine are too valuable to be used in commercial instruments. Replicas of these gratings are produced under licence to CSIRO by Varian Techtron Pty. Ltd., using a technique developed in the Division. Up to 50 perfect replicas of the parent grating have been made in this way. The company's production capacity is some 2000 gratings a year. At present the company uses most of the gratings it produces in the atomic absorption apparatus which it makes under licence to CSIRO.

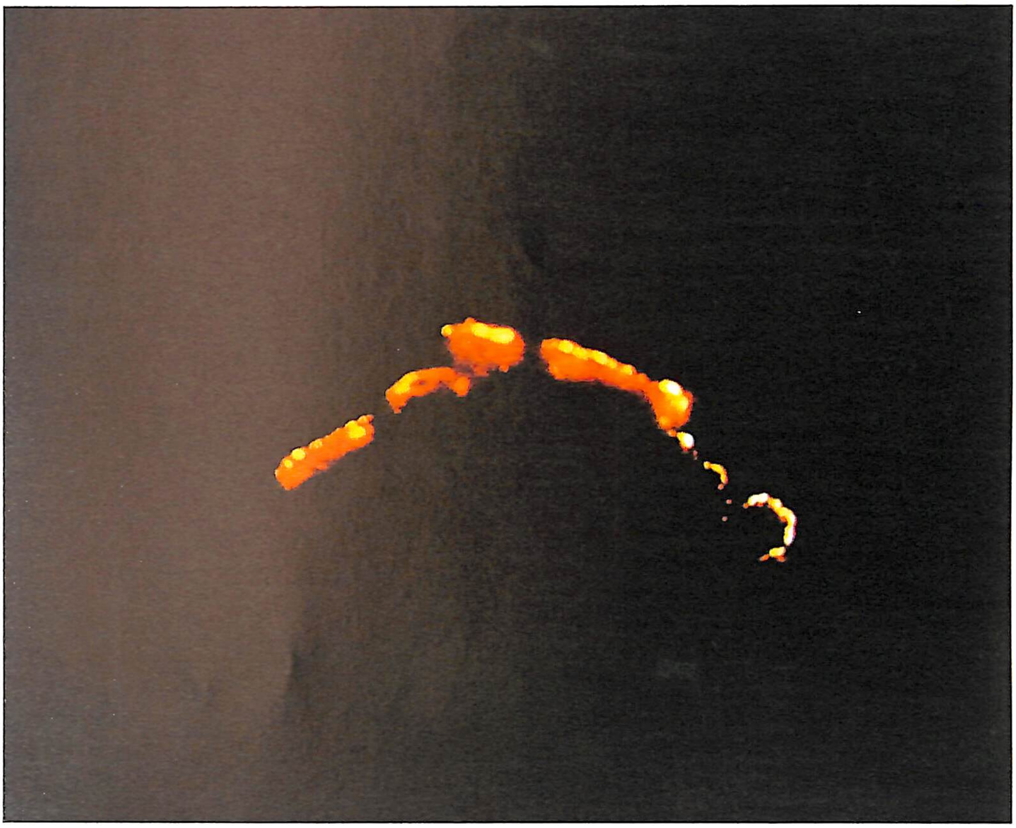
The Division is now building a new ruling machine capable of ruling gratings up to $8\frac{1}{2}$ in. by $4\frac{3}{4}$ in. as compared with 6 in. by 4 in. for the present machine. The new machine incorporates a number of improvements and should be operating by early 1970.

Mapping bush fires from the air by night

Keeping track of the course of bush fires and detecting new outbreaks is a major problem for anyone directing operations against fires in inaccessible country. Attempts to observe fires during the day from light aircraft have met with only limited success. The flames are often so obscured by smoke that accurate mapping of the fire edges is impossible. An infrared detector developed a few years ago by the DIVISION OF APPLIED CHEMISTRY enables aerial observers to view many flame fronts that would otherwise be invisible,



Ruling a master grating on a machine built by the Division of Chemical Physics.



Aerial photograph of a bush fire in the Snowy Mountains area.
The photograph was taken at night using infrared film.

but it cannot be used when the smoke is dense.

At night, on the other hand, an aerial observer can see fire edges and spot fires quite clearly through the thickest smoke, but he is then faced with the problem of trying to determine his exact position. The Division has been able to solve this problem by using precision dead-reckoning navigation and a portable radio beacon located at a known position near the fire area. The aircraft flies known tracks from the beacon and fire edges are mapped as the observer passes over them. This method has already been used successfully to map wild fires in Victoria and the Northern Territory.

The Division is also investigating the use of fast infrared films for photographing fires from the air at night. If the position and orientation of the aircraft can be fixed accurately with the help of the navigational techniques developed by the Division, the photographs obtained can easily be transferred onto a map. Fire maps prepared at night enable those directing fire-fighting operations to deploy their men and equipment so that they will be strategically placed to tackle the fire at first light before high temperatures and hot winds make it harder to control.

More efficient power generation

Although modern large steam power stations operate at steam temperatures around 1050°F and pressures up to 3500 lb/in^2, only about 40% of the energy in the fuel is converted into electrical energy. Any further increase in efficiency would require the use of still higher temperatures and pressures, for which suitable construction materials are not available. On the other hand, with gas turbine cycles the pressures are much lower but the efficiency is limited by the difficulty of recovering the low-grade heat from the turbine exhaust.

In an attempt to overcome these disadvantages, engineers have proposed combining the two cycles, using a carbonizer to provide a gaseous fuel for a gas turbine and burning the residual char with the turbine exhaust in a steam boiler. A combined-cycle power station with an output of 110 megawatts went into operation in West Texas at the end of 1968 and is now regarded as the most efficient power station in the United States. Its capital cost was slightly less than that of a conventional steam power station.

The DIVISION OF CHEMICAL ENGINEERING has been examining the operational requirements of a 275-megawatt combined-cycle power station for Australian conditions. Using the Organization's digital computer to investigate a mathematical model of such a station, the Division was able to study the performance of the station with respect to operating variables such as gas turbine inlet temperature, boiler excess air, allocation of secondary heat recovery, and fuel type. Cost capacity indices applied to the main equipment items were then used to calculate the total station cost and energy costs, and by successive trials all the major operating variables were examined so that the station giving minimum cost of electrical power could be defined.

The results indicated that with a gas turbine inlet temperature of 1400°F, which is within the range currently used, the cost per unit of energy would be reduced by 1·7%. However, if this temperature were increased to 2000°F, a value which could well become possible in the future, the energy cost reduction would be 5%. Such a reduction would certainly make the system worthy of further consideration.

Refining metals

A common way of removing a dissolved impurity from a molten metal during refining is to add a reagent that will precipitate the impurity as an insoluble compound which can be removed as a slag or dross. Although metallurgists can determine what reagent will be best in a particular situation and how much of it should be used, they have been able to do this only after long and difficult experiments followed by expensive plant-scale trials.

The DIVISION OF CHEMICAL ENGINEERING has now developed a method of solving this problem which should reduce the need for laboratory experiments and plant-scale trials. This method involves calculating the chemical behaviour of reagents and impurities in metal refining processes on the basis of the limits of their solubility in metal solution. These limits are often known accurately or can be determined experimentally without much difficulty. The Division's approach requires further testing, but on present indications it should simplify the task of improving the efficiency of existing metal refining procedures and of devising new metal refining processes.

Physics

Division of Radiophysics

Location: Epping, 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.
Finance: Treasury $1,671,014
Staff: Research scientists 38, other professional staff 30, supporting staff 164

Fields of research:
Solar radio astronomy
Galactic radio astronomy
Experimental cloud seeding
Cloud and rain physics

Division of Physics

Location: Chippendale, Sydney, with an optical observatory at the CSIRO Solar Observatory, Culgoora, N.S.W.
Finance: $945,261 (Treasury $883,097, contributory $62,164)
Staff: Research scientists 21, other professional staff 24, supporting staff 58

Fields of research:
Maintenance and development of standards of temperature, humidity, viscosity, light, and radiation, and associated research
Solid state physics
Fluid physics
Solar physics

Division of Applied Physics

Location: Chippendale, Sydney
Finance: $1,604,594 (Treasury $1,602,357, contributory $2,237)
Staff: Research scientists 36, other professional staff 49, supporting staff 129

Fields of research:
Maintenance of standards of direct current, length, mass, power frequency, radio frequency and microwave, vibration, and audio frequency, and associated research
Magnetic and dielectric properties of materials
Applied mechanics

The Divisions of Applied Physics and Physics comprise the NATIONAL STANDARDS LABORATORY.

Division of Tribophysics

Location: Parkville, Melbourne
Finance: Treasury $386,598
Staff: Research scientists 22, other professional staff 8, supporting staff 24

Fields of research:
Identification, classification, and properties of crystal defects in metal crystals
Defects in molecular crystals and their effect on properties such as strength and plasticity
Effect of crystal defects on properties such as adsorption and catalysis on the surface of metals

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Physical Metallurgy Section

Location: Parkville, Melbourne
Finance: Treasury $57,711
Staff: Research scientists 3, other professional staff 2, supporting staff 1

Fields of research:
Grain boundaries in metals
Changes in metals during deformation
Field ion microscopy
Metallurgical analysis

Upper Atmosphere Section

Location: Camden, N.S.W.
Finance: Treasury $136,925
Staff: Research scientists 5, supporting staff 11

Fields of research:
Physics of the upper atmosphere and ionosphere
Chemistry of upper atmospheric gases and ions

Cloud seeding by pyrotechnics

The DIVISION OF RADIOPHYSICS is trying a new method of cloud seeding in which silver iodide and a pyrotechnic mixture are loaded into cartridges and shot into the tops of clouds from an aircraft instead of being released into the bases as is usual. The material in the cartridge weighs only about 7 ounces, but as it burns and falls through the cloud it produces high concentrations of active silver iodide nuclei.

Experience of the method is limited as yet, but it appears particularly suitable for seeding individual clouds or the most active clouds in a given area. Dramatic cloud growth and heavy rain have often followed seeding.

The accompanying photographs show

1 minute
before seeding

7 minutes
after seeding

38 minutes
after seeding

79 minutes
after seeding

42 minutes
after seeding
(below cloud)

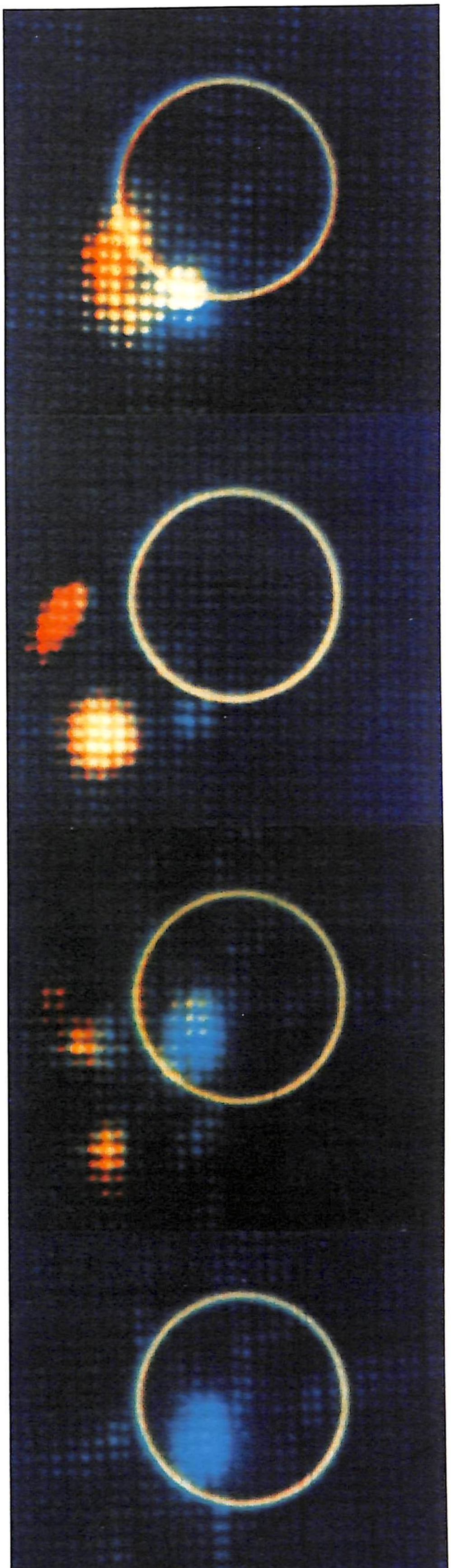
a cumulus cloud near Charleville, Queensland, 1 minute before seeding and 7, 38, and 79 minutes afterwards. When seeded, the cloud top changed from water drops to ice crystals and grew into the anvil shape of a large cumulo-nimbus. Heavy rain covered several square miles when the cloud was photographed 42 minutes after seeding and was still falling when last seen three-quarters of an hour later. No rain fell from similar clouds in the vicinity which were not seeded.

Radio pictures of the Sun

The radioheliograph operated by the DIVISION OF RADIOPHYSICS at the CSIRO Solar Observatory at Culgoora, New South Wales, is a unique instrument which gives a rapid sequence of detailed pictures of the Sun in the 'light' of radio waves of 3·75 metres wavelength. These 'radio pictures' are displayed on two picture tubes. One tube shows radiation that is circularly polarized in the left-handed sense, the other shows radiation that is circularly polarized in the right-handed sense. Unpolarized radiation produces identical images on both tubes.

The Division has now developed a novel method of displaying these observations in colour. The photographs opposite show different phases of an outburst observed on November 22, 1968. In these pictures, red, blue, and white regions correspond to sources of left-handed, right-handed, and zero circular polarization respectively. The circles indicate the visible disk of the Sun. North is on top, east to the left.

The radio event began at 11 a.m. with an unpolarized white source just inside, and a weakly red-polarized source just beyond, the south-east edge of the visible Sun. During the first 10 minutes this source puffed out into an arch of weak, mixed polarization (1),



1

2

3

4

seemingly anchored at the edge of the visible disk. For the next half-hour this arch continued to expand. The radiation was dominated by three compact sources (2): the red and blue polarized sources near the feet of the arch, the unpolarized white source at the top. Ten minutes later the arch sources were fading while a new, strongly blue-polarized source appeared on the disk (3) and near the original flare position. The blue source gained in intensity while the arch disappeared; it was still emitting strongly (4) when observations finished about $2\frac{1}{2}$ hours later.

The observed polarizations and positions of the radio sources indicate that the arch is magnetic in origin. The arch is activated by a flare explosion, becomes radio-emitting, and expands to about half a million miles above the Sun's surface.

Measuring high pressures

Very high fluid pressures can be measured accurately by observing their effect on the melting point of mercury. At atmospheric pressure the melting point of mercury is $-38 \cdot 87$°C, but at a pressure of 7470 atmospheres it is 0°C. Established forms of apparatus used to measure pressures of the order of 10,000 atmospheres are massive. Because of this there is typically a delay of 20 minutes or more before temperature effects resulting from changes in the pressure of the working fluid diminish to the point where an accurate measurement can be made.

The DIVISION OF PHYSICS has developed a technique for determining the melting point of mercury under pressure which involves only a small amount of mercury housed in polyethylene within a steel capillary tube. The onset of melting is observed by detecting the small amount of heat absorbed in the melting process. With this technique, highly reproducible results can be obtained quickly. In one series of measurements, the Division made fifteen determinations in an hour with a reproducibility of 1 part in 30,000.

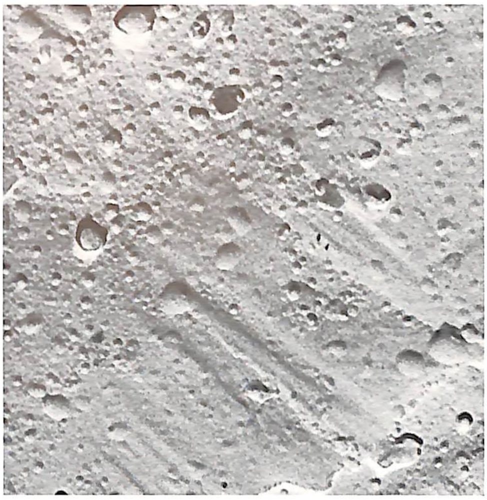
Promoting corrosion with an inert gas

The gases helium, neon, argon, krypton, xenon, and radon are known as the inert gases because of their chemical

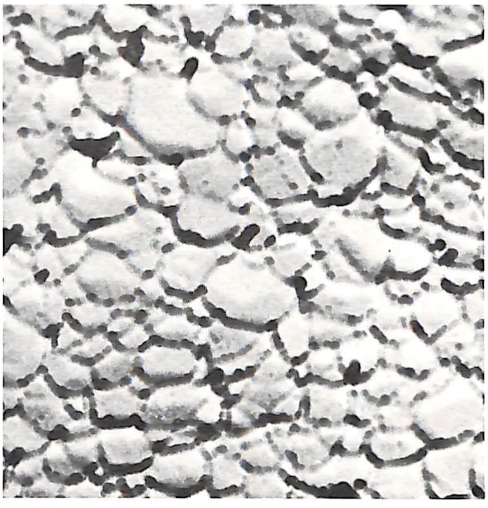
1

1. Untreated nickel surface.
2. Nickel after attack by fluorine only. Corrosion is slight.
3. Nickel after attack by fluorine in the presence of xenon. Considerable corrosion has occurred.

inactivity. In recent years, however, it has been found that they can combine with fluorine. Xenon, for example, combines with fluorine to form xenon fluoride. The DIVISION OF TRIBOPHYSICS has shown that the formation of xenon fluoride is catalysed by a variety of metals, one of the most active being nickel. An interesting finding was that xenon actually promotes corrosion of a nickel surface by fluorine. This effect can be seen in the following pictures which were taken with the Division's electron microscope. The magnification is about 40,000.



2



3

Crystals that don't obey the rules

Early last century John Dalton propounded his law of definite proportions which states that in every sample of a given compound the constituent elements are always present in the same proportions. Towards the end of last century, however, a number of inorganic crystalline compounds were found which apparently did not obey this law. Such compounds are said to be non-stoichiometric. Many of these compounds are of interest to metallurgists because minerals go through a non-stoichiometric stage during smelting. They are also of considerable interest to solid-state physicists and chemists since non-stoichiometry leads to unusual electrical properties in semiconductors and also to useful optical properties in various materials.

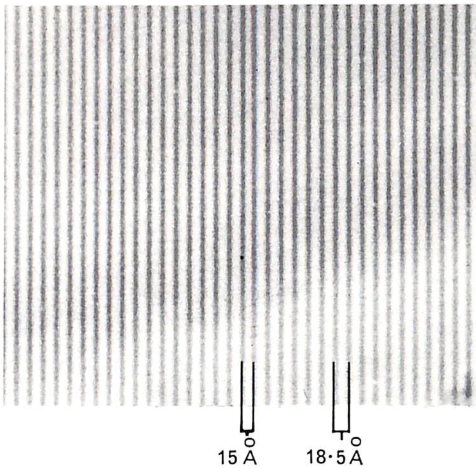
For some years it was thought that all non-stoichiometric compounds contained 'holes' or vacant sites in their crystal lattice which should have been occupied by atoms but weren't. More recently the DIVISION OF MINERAL CHEMISTRY has shown that many non-stoichiometric compounds have quite a different structural basis. X-ray diffraction studies of complex oxides formed by high-temperature solid-state reactions showed that large families of closely related structures are quite common in oxide systems. One such family which was investigated by the Division contains niobium oxide as a major constituent and has at least 20 members. Each member consists of very thin slabs of well-defined structure and composition, stacked together in a regular way.

Many of these materials have been examined by the DIVISION OF TRIBOPHYSICS under the electron microscope. In this way, the individual slabs could be observed directly and the detailed structure of small crystals determined.

Figure 1 is an electron micrograph of part of a crystal of $W_5Nb_{16}O_{55}$, magnified one million times. The fringes show that most of the slabs are 18·5 ångström units ($1{\cdot}85 \times 10^{-6}$ mm) thick, but this regular structure is interrupted by a single slab only 15 Å thick, corresponding to a closely related structure with a different composition, $W_3Nb_{14}O_{44}$. The presence of this fault alters the average composition very slightly, so that overall the crystal is non-stoichiometric.

Figure 2 is an electron micrograph of an oxide fragment with the composition $TiNb_{52}O_{132}$ magnified one million times. In this case slabs 17 Å and 15 Å thick alternate regularly through the structure, their compositions being $Nb_{28}O_{70}$ and $TiNb_{24}O_{62}$ respectively. In this way the non-stoichiometry introduced by the presence of even very small proportions of titanium is accommodated in a regular manner and a new compound has been made.

The type of structure illustrated in the two micrographs is thought to be typical of many oxides of chromium, niobium, titanium, tungsten, vanadium, and zirconium, and considerable evidence to support this view is being obtained in laboratories throughout the world.



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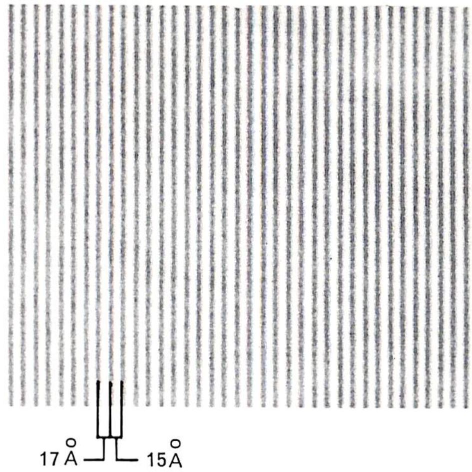

2

Measuring gravity

The absolute measurement of force, pressure, and many other physical quantities requires a knowledge of the local value of g, the gravitational acceleration. Absolute determinations of g have been made at a few sites in North America and Europe. Instruments calibrated at these sites have then been used elsewhere to obtain local values for g, but the local values obtained in this way do not have the same degree of accuracy.

For the last few years the DIVISION OF APPLIED PHYSICS has been working on an absolute determination of g. Although the method used employs a number of novel techniques it is simple in theory and consists essentially of timing the rise and fall of a body when it is thrown up. In practice, however, a number of technical difficulties have had to be overcome to achieve the desired accuracy. Although some possible sources of systematic error still have to be investigated, preliminary results indicate that the required accuracy of 1 in 10 million should be achieved.

Statistics and computation

Division of Computing Research

Location: Canberra, with subsidiary installations at Adelaide, Brisbane, Melbourne, Perth, Sydney, and Griffith, N.S.W.
Finance: Treasury $902,297
Staff: Research scientists 9, other professional staff 26, supporting staff 51

Fields of research:
Improvement of operating systems ●●
Development of classification methods
Picture interpretation
Numerical meteorology

Division of Mathematical Statistics

Location: Glen Osmond, Adelaide, with officers stationed at a number of Divisions and Sections and at the University of Melbourne
Finance: Treasury $411,997
Staff: Research scientists 22, other professional staff 22, supporting staff 30

Fields of research:
Computing with particular reference to statistics
Analysis of climatological data
General distribution theory
Experimental design
Multivariate analysis
Statistical inference

In addition to conducting their own research programmes, the Divisions of Computing Research and Mathematical Statistics help scientists in other Divisions and Sections in the design of experiments and in the analysis and interpretation of research results.

Helping the programmer

Scientific research is always dealing with fresh problems and new computer programs are continually being evolved to handle them. In CSIRO, probably as much computer time is spent on developing new programs as on using these programs to process data. To help programmers in the preparation, editing, and testing of their new programs, the DIVISION OF COMPUTING RESEARCH has designed and implemented a monitor system for its Control Data 3600 computer. This system incorporates six keyboard display consoles located in the Division's computing laboratory in Canberra. The consoles provide programmers with direct access to the central processor so that they can check and test their programs during the course of their preparation. There is now a considerable demand for the use of these facilities and some programmers have even found it worth while to visit Canberra for program development. Unfortunately the display consoles are expensive and are difficult to operate over long distances from the computer.

Recently the system has been extended by the addition of five teleprinters. Although the teleprinters have the same functions of entry and control of programs and data as the display consoles, they are much cheaper and can be operated over telephone lines. Four of the teleprinters are being operated in the Division's computer building but will later be installed in other laboratories in Canberra. The fifth teleprinter is already installed in the Canberra laboratory of the DIVISION OF LAND RESEARCH.

The teleprinters are on-line to a small computer that is connected to the main computer by an interface designed and constructed as a Divisional research project. A novel technique used in this design not only simplified the design work but meant that in several months

One of the keyboard display consoles used at the Division of Computing Research to help programmers in the preparation and testing of new programs.

of operation only one design error came to light. Advantage was taken of the symbol matching ability and other features already present in the normal machine language assembler program of the 3600 computer. The assembler was made to generate a wiring list and to keep a running check on the cost, space, and power requirements of the design. A special program drew circuit diagrams and calculated the best wiring layout. The interface logic was checked out by simulation on the 3600. By also simulating the small computer with the large one it was possible to have programs prepared and a completely error-free system ready for the small computer when it was delivered.

Saving time on computers

Each day the DIVISION OF COMPUTING RESEARCH processes over one thousand jobs on its computer in Canberra. Most of these jobs are short—usually less than one minute. Before a program can be run, however, it must be translated into a language that can be understood by the particular computer being used and it must also be loaded into the computer. These two steps can take longer than the time taken to run the program so that a significant fraction of the time of short jobs and of total available computing time is used up in this unproductive manner.

By modifying the translation program supplied by the manufacturer and by implementing a new loading technique that uses the random access storage available in the magnetic drums, the Division has been able to speed up the translation of programs by about five times and to free the computer for several hours more computing time each day. The Division has named this new system KWIKTRAN.

Staff

Executive Changes

Mr. W. Ives, M.Ec., resigned from the Executive at the end of 1968 to take up appointment as Secretary of the Department of Primary Industry. Mr. Ives graduated B.Ec. in 1938 and M.Ec. in 1942 from the University of Sydney. He joined C.S.I.R. in 1946 as Technical Secretary of the Division of Plant Industry. He was made an Assistant Secretary at Head Office in 1949 and Secretary (Biological Sciences) in 1952. From 1954 to 1956 he occupied the post of Chief Scientific Liaison Officer in London. He was appointed Executive Officer in 1959, Associate Member of the Executive in 1962, and Member of the Executive in 1965.

Mr. Ives has worked closely with a number of primary industry organizations and has been a member of the Australian Wool Board's Production Research Committee and the Australian Dairy Produce Research Committee.

Mr. W. Ives

Mr. L. Lewis, B.Met.E., was appointed to the Executive in December 1968. Mr. Lewis graduated in metallurgical engineering from the University of Melbourne in 1933. He spent the next six years as a member of the research staff of Broken Hill Associated Smelters at Port Pirie.

In 1940, Mr. Lewis joined C.S.I.R. as Secretary of the newly formed Division of Industrial Chemistry and in 1946–47 he served in London as the Australian Scientific Liaison Officer. In 1955 he was appointed Officer-in-Charge of the Industrial Research Liaison Section. Mr. Lewis was made Executive Officer in 1964 and an Associate Member of the Executive in 1966.

Mr. Lewis is a member of a number of industrial research councils and committees including: Manufacturing Industries Advisory Council, Australian Industrial Research and Development Grants Board, Council of the Australian Mineral Development Laboratories, Council of the Bread Research Institute of Australia, and Council of the Australian Welding Research Association.

Mr. L. Lewis

Mr. V. D. Burgmann, B.Sc., B.E., was appointed Associate Member of the Executive in March 1969. A graduate in science and electrical engineering from the University of Sydney, Mr. Burgmann joined the Division of Radiophysics in 1939 to work on radar. During the war he spent some time as liaison officer in London and Washington where he was responsible for collecting information for Australia on developments in radar research. He also spent a period at the Radiation Laboratory of the Massachusetts Institute of Technology.

After the war Mr. Burgmann led a research team which developed navigation aids for civil aviation. The team's main achievement was Distance Measuring Equipment, which is now a standard installation on all domestic airlines. Mr. Burgmann shared the 1951 Bronze Medal of the Institute of Navigation in Britain for a paper entitled 'An Investigation into Air Traffic Control by a Simulation Method'.

In 1949 he became Officer-in-Charge of the Physics and Engineering Unit of the newly formed Wool Textile Research Laboratories. The Unit became the Division of Textile Physics in 1958 with Mr. Burgmann as its Chief.

Mr. V. D. Burgmann

Obituaries

Dr. J. Griffiths Davies, C.B.E., Ph.D., D.Sc., Chief of the Division of Tropical Pastures, died in Brisbane on March 15, 1969. Dr. Davies, who has been described as 'the father of Australian pasture research', was born at Aberystwyth, Wales, in 1904. After obtaining his Ph.D. from the University of Wales, Dr. Davies came to Australia in 1927 to take up a position as agrostologist at the Waite Agricultural Research Institute at Adelaide.

Dr. J. Griffiths Davies

In 1938 he was appointed by C.S.I.R. to establish an Agrostology Section in the Division of Plant Industry and in the next fourteen years he established groups of pasture workers at Canberra, Perth, Deniliquin, Armidale, and Brisbane. Dr. Davies transferred his headquarters to Brisbane in 1952 to devote his energies to building a programme of pasture research for the tropics and subtropics of Australia. He became an Associate Chief of the Division of Plant Industry in 1951 and was appointed Chief of the Division of Tropical Pastures on its formation from the Division of Plant Industry in 1959.

Dr. Davies was Federal President of the Australian Institute of Agricultural Science in 1951–52, its medallist in 1957, and one of its foundation Fellows. In 1964 he was awarded the Britannica Australia award for natural and applied sciences for 'his outstanding contributions to pasture science and hence to the pastoral industry and economy of Australia'. He was created a Commander of the Order of the British Empire in the New Year Honours in 1969.

In a eulogy delivered on the occasion of the conferment on Dr. Davies of the honorary degree of Doctor of Science of the University of New England in 1958, Professor McClymont said, 'It is given to few men, in their lifetime, to develop a new philosophy of approach to a major scientific and economic problem, to put that philosophy into practice, see it so widely accepted that it becomes difficult for later workers to conceive that it was not always so accepted, and see the practical application of that philosophy result in immeasurable benefits to mankind. John Griffiths Davies has been one of such few'. It is noteworthy that this could be said of him before the success of his work in the tropics was fully apparent.

Dr. A. D. Wadsley

Dr. A. D. Wadsley, D.Sc., Assistant Chief of the Division of Mineral Chemistry, suffered a severe coronary occlusion while chairing the opening session of the International Conference on the Chemistry and Physics of the Earth's Mantle in Canberra on January 6, 1969. He died later that day in hospital.

Dr. Wadsley was a brilliant scientist of international standing. He gained his M.Sc. at the University of Tasmania in 1941 and, after a period as physicist at the Munitions Supply Laboratories, joined the Division of Industrial Chemistry in 1943. He was awarded the degree of D.Sc. by the University of Tasmania in 1956 and in 1965 he received the H. G. Smith Memorial Medal of the Royal Australian Chemical Institute. Dr. Wadsley became Assistant Chief of the Division of Mineral Chemistry in 1967.

Mr. J. C. M. Fornachon, B.Ag.Sc., M.Sc., Director of the Australian Wine Research Institute, died in Adelaide on August 25, 1968. A graduate in agricultural science from the University of Adelaide, Mr. Fornachon joined the staff of the Waite Agricultural Research Institute in 1935. He joined the C.S.I.R. Oenological Section in 1945 and ten years later was appointed Director of the Wine Research Institute.

Mr. Fornachon achieved an international reputation for his research on the microbiology of wines and in 1955 undertook the task of producing an English translation of the international dictionary of viticultural and oenological terms under the auspices of F.A.O.

Mr. J. C. M. Fornachon

Retirements

Dr. W. Boas, Chief of the Division of Tribophysics, retired in February 1969 after twenty-two years with CSIRO. One of the pioneers of metal physics, Dr. Boas has received international recognition for his work on plastic flow in metals. A text-book on crystalline plasticity of which he was joint author has become a classic in its field.

Dr. Boas obtained his Diploma of Engineering at the Technische Hochschule of Berlin in 1928 and his Doctor of Engineering degree from the same institution in 1930. From 1928 to 1938 he carried out research in Berlin, Fribourg, Zurich, and London.

In 1938 he became Carnegie Lecturer in Metallurgy at the University of Melbourne and in 1940 Senior Lecturer in Physical Metallurgy. He gained his M.Sc. at Melbourne in 1943 and in the same year was elected a Fellow of the Institute of Physics. Dr. Boas became engaged in part-time collaboration with the Division of Tribophysics the following year and at the end of 1946 joined the Division. He became Chief of the Division in 1949.

Dr. Boas was made a Fellow of the Australian Academy of Science in 1954 and served as a member of the Academy's Council from 1964 to 1966. In 1962 he became Federal President of the Australian Institute of Metals and in 1965 he was elected a foreign scientific member of the Max-Planck Institut für Metallforschung and of the Max-Planck Gesellschaft. He was elected to the Executive Committee of the International Union of Pure and Applied Physics in 1966.

Dr. W. Boas

Dr. F. N. Ratcliffe, O.B.E., B.A., D.Sc., retired from the position of Assistant Chief of the Division of Entomology in February 1969. After graduating with first-class honours in Zoology from Oxford University, Dr. Ratcliffe spent a year at Princeton University as a Proctor Fellow before coming to Australia to work for C.S.I.R. in 1929. Since then he has been involved in a wide range of investigations, including studies of mosquitoes, rabbits, giant fruit bats, and soil erosion of the inland. The last two subjects formed the basis of his well-known book 'Flying Fox and Drifting Sand'.

As a member of the Division of Entomology from 1937 to 1949, he worked on termites and pests of stored wheat. He also served for some time with the RAAMC as a malariologist investigating mosquito control techniques. In 1949 the Wildlife Section (now the Division of Wildlife Research) was established under his leadership. During the next 10 years he worked closely with Professor Fenner of the John Curtin School of Medical Research on myxomatosis.

For the past eight years Dr. Ratcliffe has been Assistant Chief of the Division of Entomology. He was awarded an honorary D.Sc. degree by the Australian National University in 1968. Dr. Ratcliffe is Honorary Secretary of the Australian Conservation

Dr. F. N. Ratcliffe

Foundation and was a member of the original committee that organized the establishment of the Foundation.

Tropical Pastures Chief

Dr. E. M. Hutton, B.Ag.Sc., D.Sc., was appointed Chief of the Division of Tropical Pastures following the death of Dr. J. Griffiths Davies in March 1969. After graduating B.Ag.Sc. from the University of Adelaide in 1933, Dr. Hutton joined the South Australian Department of Agriculture to carry out field investigations of pastures. Two years later he became Assistant Plant Breeder at Roseworthy Agricultural College.

He was awarded the degree of M.Sc. by the University of Adelaide in 1940, and in 1941 he joined the Division of Plant Industry, where he began research on the genetics and mechanism of virus resistance in the potato and the tomato. This work led to the development of high-yielding virus-resistant potato and tomato hybrids and, in 1950, to his being awarded the degree of D.Sc. by the University of Adelaide. Dr. Hutton also undertook work on the breeding of temperate pasture species.

Dr. E. M. Hutton

In 1954 he transferred from Canberra to Brisbane where he began a programme of plant breeding aimed at the improvement of subtropical pasture species, particularly legumes. One of his most outstanding achievements was the breeding of the new tropical legume Siratro. In 1959 the Division of Plant Industry's pasture research team in Queensland became the Division of Tropical Pastures, and in 1964 Dr. Hutton was appointed Assistant Chief of the Division.

Dr. Hutton was Federal President of the Australian Institute of Agricultural Science in 1966–67. He was elected a Fellow of the Institute in 1967 and in 1968 was awarded the Farrer Memorial Medal.

Wheat Research Leader

Dr. D. H. Simmonds, B.Sc., Ph.D., was appointed Leader of the Wheat Research Unit in March 1969. He succeeds Mr. M. V. Tracey who was appointed Chief of the Division of Food Preservation in 1967.

Dr. D. H. Simmonds

Dr. Simmonds graduated B.Sc. with honours from the University of Adelaide in 1946 and Ph.D. from the University of London in 1951. From 1949 to 1958 he worked with the Division of Protein Chemistry on the development of suitable techniques for estimating amino acids in proteins. He then spent three years as a senior lecturer in the Department of Agricultural Chemistry at the Waite Agricultural Research Institute, Adelaide, before joining Castlemaine Perkins Ltd. in 1961 as a research scientist.

One of his principal research interests in the last few years has been the separation and characterization of barley proteins and their behaviour during the malting and brewing process.

Academy President

Dr. D. F. Martyn, Officer-in-Charge of the Upper Atmosphere Section, was elected President of the Australian Academy of Science in April 1969. Dr. Martyn gained his Ph.D. at the University of London in 1929. He came to Australia in 1930 to take up an appointment with the Radio Research Board, and in 1936 was awarded the degree of D.Sc. by his old university.

Early in 1939 Dr. Martyn was sent to England by the Commonwealth Government to obtain full information for Australia on the development of radar, then a matter of the highest secrecy. On his return, C.S.I.R. established its Radiophysics Laboratory in Sydney to carry out research and development on radar, and Dr. Martyn was appointed Chief of the Laboratory. In 1942 he was seconded to the Department of Army as Director of Operational Research. Two years later he returned to the Radio Research Board and began a programme of research on atmospheric and solar physics at the Commonwealth Solar Observatory, Mt. Stromlo, near Canberra. In 1956 he transferred his research activities to Camden and established a small laboratory there. This became the CSIRO Upper Atmosphere Section in 1958 with Dr. Martyn as Officer-in-Charge.

Dr. Martyn has received a number of high honours for his contributions to our knowledge of the propagation of radio waves and to the physics of the upper atmosphere and the ionosphere. In 1947 he was awarded the T. K. Sidey Summer-Time Medal

Dr. D. F. Martyn

and Prize by the Royal Society of New Zealand for research on electromagnetic radiation, and the Sir Thomas Ranken Lyle Medal by the Australian National Research Council for research on the ionosphere. He was elected a Fellow of the Royal Society of London in 1950. In 1951 he was awarded the Walter Burfitt Medal and Prize of the Royal Society of New South Wales and in 1954 the Charles Chree Medal of the Physical Society of London. He became a Foundation Fellow of the Australian Academy of Science on its creation in 1953 and has served on many of its committees. For the last ten years he has been Chairman of the Australian National Committee for Space Research.

Since the war Dr. Martyn has played a leading role in the work of various international scientific organizations. He has been Chairman of the United Nations Scientific and Technical Sub-Committee on the Peaceful Uses of Outer Space since 1962. He is also a member of the Executive Committee of the International Council of Scientific Unions, and has been a Vice-President of the International Union of Radio Science, as well as president of its commissions on radio astronomy and the ionosphere. In 1962 he was elected the first Australian Fellow of the International Academy of Astronautics.

Deaths

Mr. A. L. Gunn, HEAD OFFICE
Mr. H. Irzykiewicz, ENTOMOLOGY

Retirements

Miss M. C. Clark, MINERAL CHEMISTRY
Mr. R. W. Crabtree, EDITORIAL AND PUBLICATIONS
Mr. A. J. Higgs, RADIOPHYSICS
Mr. K. L. Loftus Hills, HEAD OFFICE
Mr. S. E. Powell, CHEMICAL PHYSICS
Dr. D. L. Serventy, WILDLIFE RESEARCH
Mr. H. H. Wilson, ANIMAL HEALTH

Professorships

Dr. T. R. A. Davey, CHEMICAL ENGINEERING, has been granted leave of absence for two years to take up an appointment as Professor of Metallurgical Engineering, Colorado School of Mines, U.S.A.
Mr. J. W. Holmes, SOILS, has been appointed Professor of Earth Sciences at Flinders University. Under an arrangement between the University and CSIRO, Professor Holmes will combine his university role with his duties in CSIRO.
The following officers resigned during the year to accept appointment to university chairs.
Dr. G. F. Bennett, ENTOMOLOGY; Research Professor of Avian Haematozoa, Memorial University of Newfoundland, Canada.
Mr. M. Feughelman, TEXTILE PHYSICS; Professor of Textile Physics, University of New South Wales.
Dr. F. J. Kerr, RADIOPHYSICS; Professor of Astronomy, University of Maryland, U.S.A.
Dr. E. T. Linacre, IRRIGATION RESEARCH; Associate Professor, School of Earth Sciences, Macquarie University.
Dr. J. S. Shannon, ENTOMOLOGY; Professor of Chemistry, University of New South Wales.

Honours and Awards

Dr. K. Baird, TEXTILE PHYSICS; Fellow of the Textile Institute.

Mr. R. Birtwhistle, MATHEMATICAL STATISTICS; Engineering Applied to Agriculture Award of the Institution of Mechanical Engineers (shared).

Mr. J. D. Boyd, FOREST PRODUCTS; Fellow of the Institution of Engineers, Australia.

Dr. W. F. Cole, BUILDING RESEARCH; Doctor of Science, University of Western Australia.

Mr. J. L. Corbett, ANIMAL PHYSIOLOGY; Doctor of Science, Massey University, New Zealand.

Dr. E. A. Cornish, MATHEMATICAL STATISTICS; Honorary Fellow of the Royal Statistical Society.

Dr. H. McL. Gordon, ANIMAL HEALTH; Doctor of Veterinary Science, University of Sydney.

Mr. A. F. A. Harper, PHYSICS; President of the Australian Institute of Physics.

Mr. G. D. Hubble, SOILS; President of the Australian Society of Soil Science.

Mr. G. B. Jones, NUTRITIONAL BIOCHEMISTRY; Doctor of Science, University of Auckland, New Zealand.

Dr. F. G. Lennox, PROTEIN CHEMISTRY; Deputy Chancellor, Monash University.

Mr. R. E. Loughhead, PHYSICS; Doctor of Science, University of Sydney.

Mr. J. D. Mellor, FOOD PRESERVATION; Chairman, Vacuum Physics Group, Australian Institute of Physics.

Mr. R. N. Morse, MECHANICAL ENGINEERING; Mechanical Engineering Prize of the Institution of Engineers, Australia (shared).

Dr. D. O. Norris, TROPICAL PASTURES; Fellow of the Australian Institute of Agricultural Science.

Dr. K. R. Norris, ENTOMOLOGY; Doctor of Science, University of Western Australia.

Mr. A. Packham, ANIMAL GENETICS; Fellow of the Australian Veterinary Association.

Mr. W. R. W. Read, MECHANICAL ENGINEERING; Mechanical Engineering Prize of the Institution of Engineers, Australia (shared).

Mr. J. A. Redpath, PLANT INDUSTRY; Imperial Service Medal.

Dr. A. L. G. Rees, CHEMICAL PHYSICS; Secretary (International Relations), Australian Academy of Science.

Mr. E. P. S. Roberts, MEMBER OF THE EXECUTIVE; Companion of the Order of St. Michael and St. George.

Dr. R. C. Rossiter, PLANT INDUSTRY; Fellow of the Australian Institute of Agricultural Science.

Dr. D. L. Serventy, WILDLIFE RESEARCH; R. M. Johnston Memorial Medal, Royal Society of Tasmania.

Dr. F. H. C. Stewart, PROTEIN CHEMISTRY; Doctor of Science, University of Belfast.

Dr. F. G. Lennox

Mr. E. P. S. Roberts

Mr. J. V. Sullivan, CHEMICAL PHYSICS; David Syme Research Prize (shared).

Dr. G. H. Taylor, MINERAL CHEMISTRY; Doctor of Science, University of Melbourne.

Mr. P. A. Taylor, MECHANICAL ENGINEERING; Engineering Applied to Agriculture Award of the Institution of Mechanical Engineering (shared).

Professor E. J. Underwood, MEMBER OF THE EXECUTIVE; Doctor of Agricultural Science, University of Western Australia.

Mr. R. W. Viney, FINANCE MANAGER; Member of the Order of the British Empire.

Dr. A. Walsh, CHEMICAL PHYSICS; Fellow of the Royal Society, Royal Society of Victoria Medal, and Talanta Gold Medal.

Sir Frederick White, CHAIRMAN; Doctor of Science, Monash University.

Dr. J. P. Wild, RADIOPHYSICS; Henryk Arctowski Medal of the United States National Academy of Sciences.

Dr. A. Walsh

Dr. J. P. Wild

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L. Lewis, B.Met.E.
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E. P. S. Roberts, C.M.G.
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K. L. Sutherland, Ph.D., D.Sc., F.A.A.
Professor E. J. Underwood, C.B.E., Ph.D., D.Rur.Sc., D.Sc.(Agric.), F.A.A.

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WESTERN AUSTRALIA—E. H. Lee-Steere, C.B.E.

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Professor D. C. Blood, M.V.Sc.
C. W. Bridges-Maxwell, M.H.R.
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W. J. D. Shaw, O.B.E.
G. Sheil, B.Sc., B.C.E., B.M.E.
Professor J. M. Swan, D.Sc., Ph.D.
R. G. Ward, M.A., Ph.D.
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State Committees

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Division of Textile Industry

See Wool Research Laboratories

Division of Textile Physics

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Division of Tribophysics

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Division of Textile Industry

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Miss S. H. Allen, B.Sc.

Finance

The following table summarizes sources of CSIRO funds and categories of expenditure.

Source of funds	Investigations	Grants for Studentships and grants to outside bodies	Capital works and services, including major items of equipment	Total
Treasury appropriation, including revenue	33,569,099	1,353,491	1,228,558	36,151,148
Wool Research Trust Fund	6,048,007		507,279	6,555,286
Meat Research Trust Account	1,041,958		420,936	1,462,894
Wheat Research Trust Account	239,515		—	239,515
Dairy Produce Research Trust Account	284,807		1,980	286,787
Tobacco Industry Trust Account	190,864		—	190,864
Other contributors	1,410,540		295,240	1,705,780
Total	**$42,784,790**	**$1,353,491**	**$2,453,993**	**$46,592,274**

Annual Expenditure

The following summary gives details of expenditure by CSIRO Divisions and Sections on other than capital items from July 1, 1968 to June 30, 1969.

DIVISION OR SECTION	Funds ($) Treasury	Funds ($) Contributory	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 and Washington, and general office expenditure.	2,572,040	35,750	2,607,790
Research Programmes			
Animal Health and Reproduction			
Animal Genetics	879,945	418,889	1,298,834
Animal Health	1,289,396	420,360	1,709,756
Animal Physiology	216,012	1,504,133	1,720,145
Nutritional Biochemistry	374,288	199,428	573,716
Plant Industry	2,530,761	1,242,607	3,773,368
Entomology and Wildlife			
Entomology	1,600,048	460,553	2,060,601
Wildlife	504,976	250,426	755,402
Soils	1,396,626	127,834	1,524,460
Horticulture and Irrigation			
Horticultural Research	438,594	28,203	466,797
Irrigation Research	436,605	20,429	457,034
Tropical Pastures	1,202,219	287,224	1,489,443
Land Research	1,202,391	260,129	1,462,520
Processing of agricultural products			
Food Preservation	1,293,367	303,139	1,596,506
Dairy Research	330,422	172,064	502,486
Wheat Research	22,328	46,213	68,541
Textile Industry	81,641	1,091,367	1,173,008
Textile Physics	—	837,818	837,818
Information and publications			
Central Library	234,721	—	234,721
Editorial and Publications Section	701,702	—	701,702
Film Unit	67,709	2,227	69,936
Chemical research of industrial interest			
Administration of Chemical Research Laboratories	436,903	865	437,768
Chemical Engineering	511,551	23,120	534,671

Applied Chemistry	909,435	52,480	961,915
Chemical Physics	796,785	12,851	809,636
Protein Chemistry	48,089	872,640	920,729
Fisheries and Oceanography	727,737	29,274	757,011
Processing and use of mineral products			
Mineral Chemistry	1,603,606	101,557	1,705,163
Applied Mineralogy	640,181	36,343	676,524
Physical Metallurgy	57,711	—	57,711
Ore Dressing Investigations, Melbourne	115,094	10,924	126,018
Ore Dressing Investigations, Kalgoorlie	6,450	—	6,450
Baas Becking Geobiological Group	8,000	51,564	59,564
Physical research of industrial interest			
Physics	883,097	62,164	945,261
Applied Physics	1,602,357	2,237	1,604,594
General physical research			
Radiophysics	1,671,014	—	1,671,014
Meteorological Physics	561,029	—	561,029
Upper Atmosphere	136,925	—	136,925
Radio Research Board	40,000	46,419	86,419
Commonwealth Meteorology Research Centre	6,478	—	6,478
General industrial research			
Building Research	798,703	31,923	830,626
Tribophysics	386,598	—	386,598
Soil Mechanics	354,540	15,326	369,866
Mechanical Engineering	532,703	52,801	585,504
Processing of forest products			
Forest Products	1,311,689	91,352	1,403,041
Research services			
Computing Research	902,297	—	902,297
Mathematical Statistics	411,997	—	411,997
Western Australian Laboratories	197,341	—	197,341
Extramural investigations	39,844	—	39,844
Australian Mineral Development Laboratories	60,355	—	60,355
Development projects	108,920	—	108,920
Miscellaneous	325,879	13,058	338,937
Grants			
Research Associations	326,500	—	326,500
Research Studentships	337,043	—	337,043
Other grants and contributions	689,948	—	689,948
Total expenditure	34,922,590	9,215,691	44,138,281

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 SECTION	Funds ($) Treasury	Funds ($) Contributory	Total ($)
Head Office	4,623	—	4,623
Animal Health and Reproduction			
Animal Genetics	63,675	19,224	82,899
Animal Health	78,389	—	78,389
Animal Physiology	25,112	20,089	45,201
Nutritional Biochemistry	—	—	—
Plant Industry	97,993	27,776	125,769
Entomology and Wildlife			
Entomology	61,976	8,955	70,931
Wildlife	6,827	—	6,827
Soils	51,333	35	51,368
Horticulture and Irrigation			
Horticultural Research	21,699	64	21,763
Irrigation Research	6,194	—	6,194
Tropical Pastures	174,984	18,263	193,247
Land Research	—	—	—
Processing of agricultural products			
Food Preservation	42,418	523,919	566,337
Dairy Research	6,454	100,000	106,454
Wheat Research	—	—	—
Textile Industry	86,926	211,291	298,217
Textile Physics	—	187,944	187,944
Information and publications			
Film Unit	649	—	649
Chemical research of industrial interest			
Administration of Chemical Research Laboratories	2,148	—	2,148
Chemical Engineering	7,262	—	7,262
Applied Chemistry	1,514	—	1,514
Chemical Physics	—	—	—
Protein Chemistry	—	57,072	57,072
Fisheries and Oceanography	9,520	—	9,520
Processing and use of mineral products			
Mineral Chemistry	86,435	312	86,747
Applied Mineralogy	41,079	—	41,079
Physical Metallurgy	—	—	—
Ore Dressing Investigations, Melbourne	1,319	—	1,319
Physical research of industrial interest			
Physics	79,920	—	79,920
Applied Physics	52,608	—	52,608
General physical research			
Radiophysics	96,350	—	96,350
Meteorological Physics	386	—	386
General industrial research			
Building Research	30,635	—	30,635
Mechanical Engineering	25,001	54,354	79,355
Processing of forest products			
Forest Products	54,698	—	54,698
Research Services			
Computing Research	934	—	934
Mathematical Statistics	1,206	—	1,206
Western Australian Laboratories	3,022	—	3,022
Miscellaneous	5,269	−3,863	1,406
Total capital expenditure	1,228,558	1,225,435	2,453,993

Contributions

This table summarizes receipts and disbursements during 1968/69 of funds provided by contributors and recorded in a special account entitled 'Special Research Account'. The largest amounts contributed for specific research projects are provided from joint Commonwealth–Industry Research Funds such as the Wool Research Trust Fund and the Meat Research Trust Account. However, sums which are quite substantial in total are contributed by industrial organizations and other bodies, including several United States Government agencies.

DIVISION OR SECTION	**Receipts 1968/69 and balances brought forward** ($)	**Expenditure 1968/69** ($)
Animal Genetics		
Wool Research Trust Fund	324,796	328,134*
Meat Research Trust Account	87,300	77,886
Other contributors	70,162	32,093
Animal Health		
Wool Research Trust Fund	238,944	230,624
Meat Research Trust Account	202,988	166,914
Dairy Produce Research Trust Account	17,949	15,379
Other contributors	20,640	7,444
Animal Physiology		
Wool Research Trust Fund	1,376,228	1,408,179*
Meat Research Trust Account	122,350	107,948
Other contributors	14,981	8,094
Nutritional Biochemistry		
Wool Research Trust Fund	210,369	199,429
Meat Research Trust Account	15,000	—
Plant Industry		
Wool Research Trust Fund	1,003,822	862,158
Meat Research Trust Account	39,574	36,166
Wheat Research Trust Account	35,867	33,403
Dairy Produce Research Trust Account	15,395	15,184
Tobacco Industry Trust Account	225,154	190,864
Other contributors	180,882	132,606
Entomology		
Wool Research Trust Fund	76,366	62,575
Meat Research Trust Account	189,273	177,887
Wheat Research Trust Account	53,078	50,907
Other contributors	201,944	178,140
Wildlife Research		
Wool Research Trust Fund	209,579	207,248
Meat Research Trust Account	33,740	32,692
Other contributors	11,905	10,487
Soils		
Wheat Research Trust Account	57,579	51,052
Other contributors	114,544	76,817
Horticultural Research		
Other contributors	38,999	28,266
Irrigation Research		
Other contributors	48,878	20,429
Tropical Pastures		
Meat Research Trust Account	188,879	176,299
Dairy Produce Research Trust Account	84,006	78,442
Other contributors	93,360	50,745
Land Research		
Meat Research Trust Account	32,490	29,510
Other contributors	251,849	230,619
Food Preservation		
Meat Research Trust Account	664,444	647,920
Wheat Research Trust Account	4,430	4,052

* Expenditure in excess of receipts will be recovered in 1969/70.

DIVISION OR SECTION	Receipts 1968/69 and balances brought forward ($)	Expenditure 1968/69 ($)
Other contributors		
Dairy Research	212,432	175,086
Dairy Produce Research Trust Account	192,465	172,064
Other contributors	100,000	100,000
Wheat Research Unit		
Wheat Research Trust Account	55,384	46,213
Textile Industry		
Wool Research Trust Fund	1,341,443	1,273,491
Other contributors	47,140	29,167
Textile Physics		
Wool Research Trust Fund	1,049,380	1,020,732
Other contributors	2,053	5,030*
Film Unit		
Other contributors	4,359	2,227
Administration of Chemical Research Laboratories		
Other contributors	1,786	865
Chemical Engineering		
Meat Research Trust Account	10,801	8,395
Dairy Produce Research Trust Account	7,500	5,718
Other contributors	20,517	9,006
Applied Chemistry		
Wool Research Trust Fund	43,419	38,982
Meat Research Trust Account	272	—
Other contributors	49,195	13,498
Chemical Physics		
Other contributors	18,639	12,851
Protein Chemistry		
Wool Research Trust Fund	917,679	888,714
Other contributors	11,556	40,998*
Fisheries and Oceanography		
Other contributors	685	29,274*
Applied Mineralogy		
Other contributors	104,096	36,343
Mineral Chemistry		
Other contributors	214,706	101,869
Ore Dressing Investigations		
Other contributors	3,871	10,924*
Baas Becking Geobiological Group		
Other contributors	115,331	51,564
Applied Physics		
Other contributors	6,443	2.237
Physics		
Other contributors	60,047	62,165*
Radiophysics		
Other contributors	13,933	—
Radio Research Board		
Other contributors	53,736	46,419
Building Research		
Other contributors	89,489	31,923
Tribophysics		
Other contributors	4,521	—
Soil Mechanics		
Other contributors	36,550	15,326
Mechanical Engineering		
Wheat Research Trust Account	67,931	52,801
Other contributors	75,300	54,354
Forest Products		
Other contributors	133,295	91,352

* Expenditure in excess of receipts will be recovered in 1969/70.

Mathematical Statistics		
Other contributors	10	—
Head Office—agricultural liaison		
Wool Research Trust Fund	47,956	34,855
Other contributors	646	895*
Miscellaneous		
Wool Research Trust Fund	165	165
Meat Research Trust Account	1,278	1,278
Wheat Research Trust Account	1,087	1,087
Other contributors	369,650	6,666
	12,044,490	10,441,126
Cash advance received to meet expenditure in July 1969 against 1969/70 allocations for research financed from joint Commonwealth–Industry Research Funds:		
Wool Research Trust Fund	521,656	
Meat Research Trust Account	73,501	
Wheat Research Trust Account	23,883	
Tobacco Industry Trust Account	17,100	
Total contributions	12,680,630	10,441,126

* Expenditure in excess of receipts will be recovered in 1969/70.

General revenue

During 1968/69, general revenue amounting to $801,717 was received by the Organization. Details of the receipts are as follows:

Sale of publications	33,696
Sale of equipment purchased in former years, and other receipts	60,594
Sale of produce, including livestock	84,046
Royalties from patents	151,483
Testing fees	61,256
Computing charges to outside users	379,999
Miscellaneous receipts	30,643
Total	801,717

Of the above sum $781,590 was spent as part of the general Estimates for 1968/69 approved by the Minister for Education and Science and the Treasurer.

Financial Statements

In compliance with Section 30(1) of the Science and Industry Research Act 1949–1968 the Organization has prepared the following financial statements for the year ending June 30, 1969:

- Receipts and payments from all sources
- Consolidated statement of expenditure
- Statement of payments from Special Account
- Statement of payments from Specific Research Account

These statements are published as a separate document.

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