Commonwealth Scientific and Industrial Research Organization, Australia

Mr. J. J. Russell

CSIRO Nineteenth Annual Report 1966-67

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Contents

General Review

SCIENCE THRIVES ON NEEDS, problems and difficulties. Man's need to navigate ships put astronomy on a scientific basis and stimulated the development of mathematics. Louis Pasteur's discovery of bacteria arose from attempts to solve the problems of the brewing and silk industries in France.

The Commonwealth Government made its debut as a patron of scientific research just fifty years ago. The step was not taken from philanthropic or altruistic motives, or for reasons of national prestige. It was taken because the Government recognized that Australia was beset with technical problems for which no solutions were in sight. Most of these problems were agricultural, but by 1916 all the Allied powers were discovering their lack of self-sufficiency in industrial knowledge and technique.

In many ways the 1926 Act which established the Council for Scientific and Industrial Research (CSIRO's immediate predecessor) was ahead of its time. The Bruce Government defined the Council's main purpose, which was 'the initiation and carrying out of scientific researches and investigations in connexion with, or for the promotion of, primary or secondary industries . . . .' The Government wisely left it there, allowing the new Organization to respond in its own way to the stimulus of national needs and problems.

And the young Council did respond. Its achievements, rated in proportion to manpower and expenditure, were remarkable. Diseases of livestock were conquered, insect pests controlled and a new paper-pulp industry was founded. The successes of that era have now passed into the history of science and of Australian progress.

The situation today is as it was then. Very properly, it is largely left to scientists to decide where lie the best opportunities for scientific research. And the needs of Australian industry are still CSIRO's sources of stimulation. These needs are constantly changing as new mineral discoveries are made and as science itself opens up new possibilities. Every year the Executive of CSIRO reviews its research program, and every year the possibilities for productive and useful research grow more numerous. The program's state of continual change reflects the health and responsiveness of the Organization.

The next decades of scientific research promise to be no less exciting and productive; indeed they promise an even greater challenge from the stimulating problems arising in the new era of great industrial developments. The undeveloped north, the limitation of water resources and a rapidly rising tide of technology all make increasing demands upon Australian ingenuity.

Seen in perspective, Australian research is just a part of the international world of scientific endeavour. Australian scientists deal in the same ideas, read the same journals, use the same techniques as scientists anywhere. Naturally enough, their achievements must be judged by the same standards. If our scientific work is second rate then our industrial efficiency and the quality of our products will also be second rate. This is something we cannot afford. The Executive therefore has a heavy responsibility to see that CSIRO's research is first-class by world standards.

Some of our recent ideas and achievements are described in Chapter 2 of this Annual Report. Most of them hold significance for 'the promotion of our primary and secondary industries'. The present generation of CSIRO scientists is keenly appreciative of national problems and believes that research can continue to make valuable contributions to their solution.

A scientific jubilee

In 1966 CSIRO celebrated a fiftieth anniversary. It was in 1916 that the Commonwealth Government set up an Advisory Council of Science and Industry. The original Council was later replaced by the Institute of Science and Industry (1920–26) and the Council for Scientific and Industrial Research (1926–49). These bodies were the predecessors of CSIRO.

To commemorate the occasion the Executive commissioned an exhibition and a book.

The exhibition was displayed first in King's Hall, Parliament House, from 26th September to 3rd October 1966, and later at other venues in Canberra, Sydney and Melbourne.

Half of the forty-two panels cover the period from 1916 to 1949 and trace the history of CSIRO's predecessors. The other twenty-one panels are designed to show the wide scope and variety of the Organization's work today.

The book, entitled 'The Origins of CSIRO', was published on 30th September 1966. The authors were Sir George Currie, formerly a research scientist in C.S.I.R., and Mr. John Graham, presently Officer-in-Charge of the Organization's Head Office Records Section.

It is a history of the increasing involvement of the Commonwealth Government in the application of scientific research to the problems of primary and secondary industry during the years 1901 to 1926.

Sir George Currie (left) and Mr. John Graham (standing) showing a copy of 'The Origins of CSIRO' to Senator J. G. Gorton and Sir Frederick White.

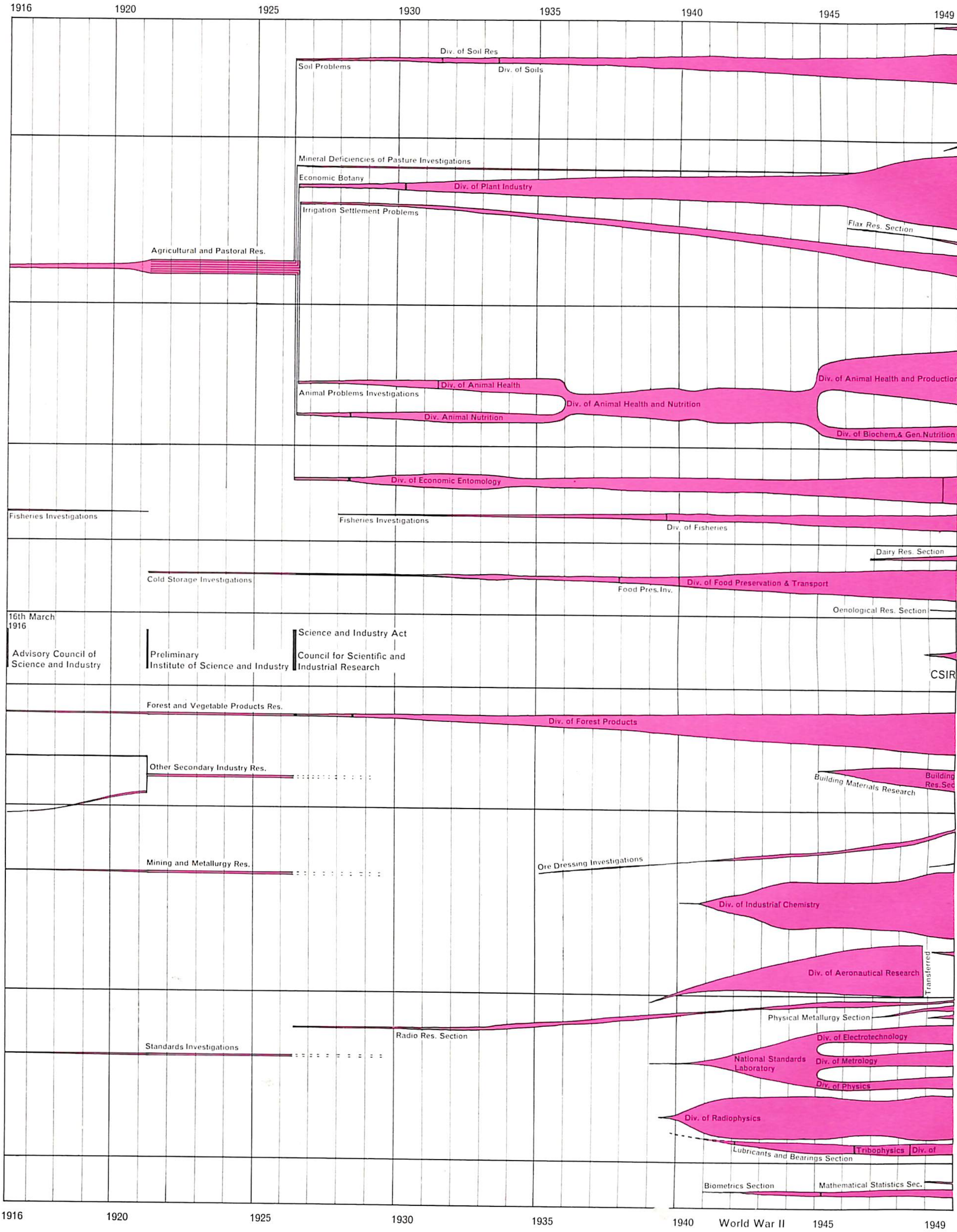
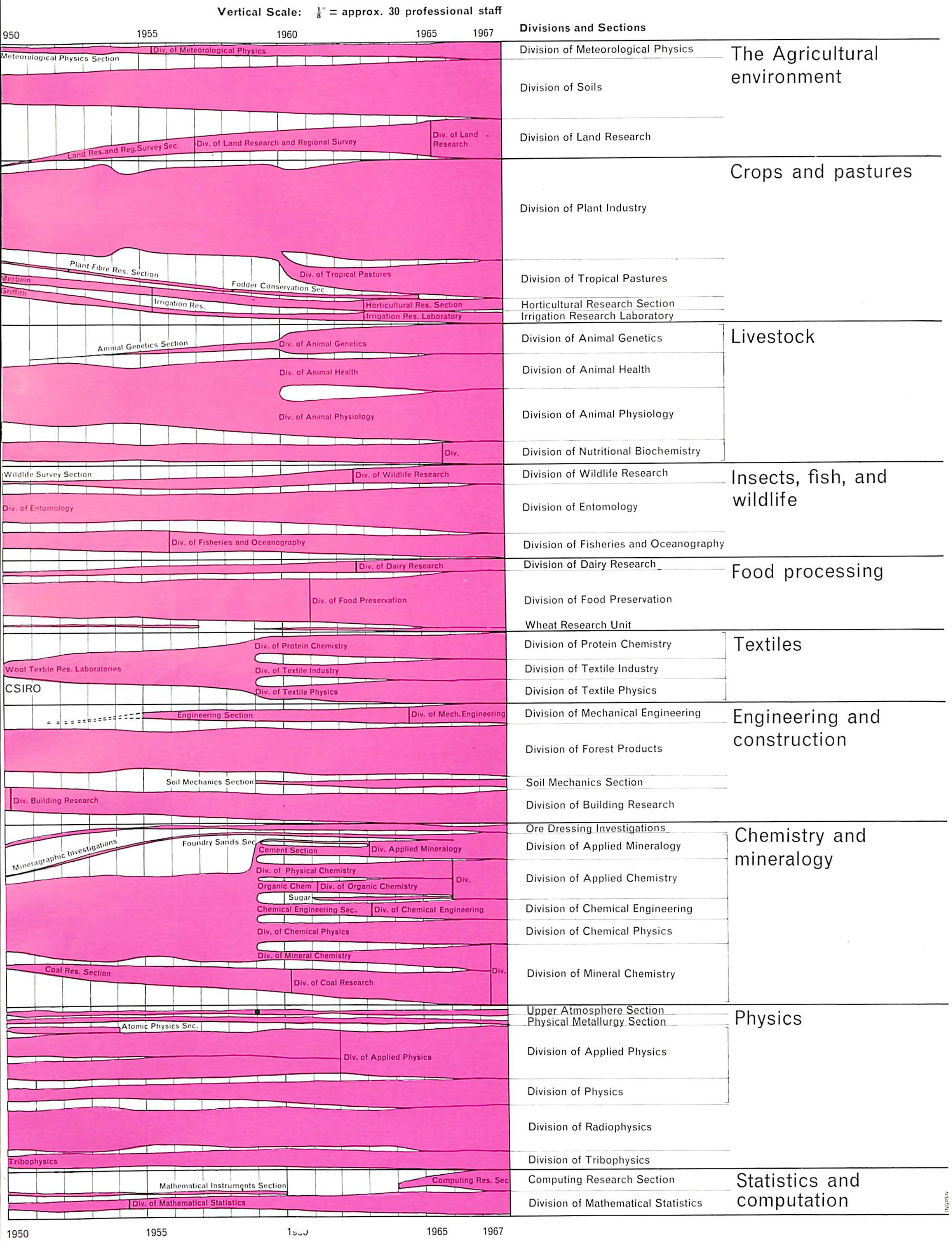
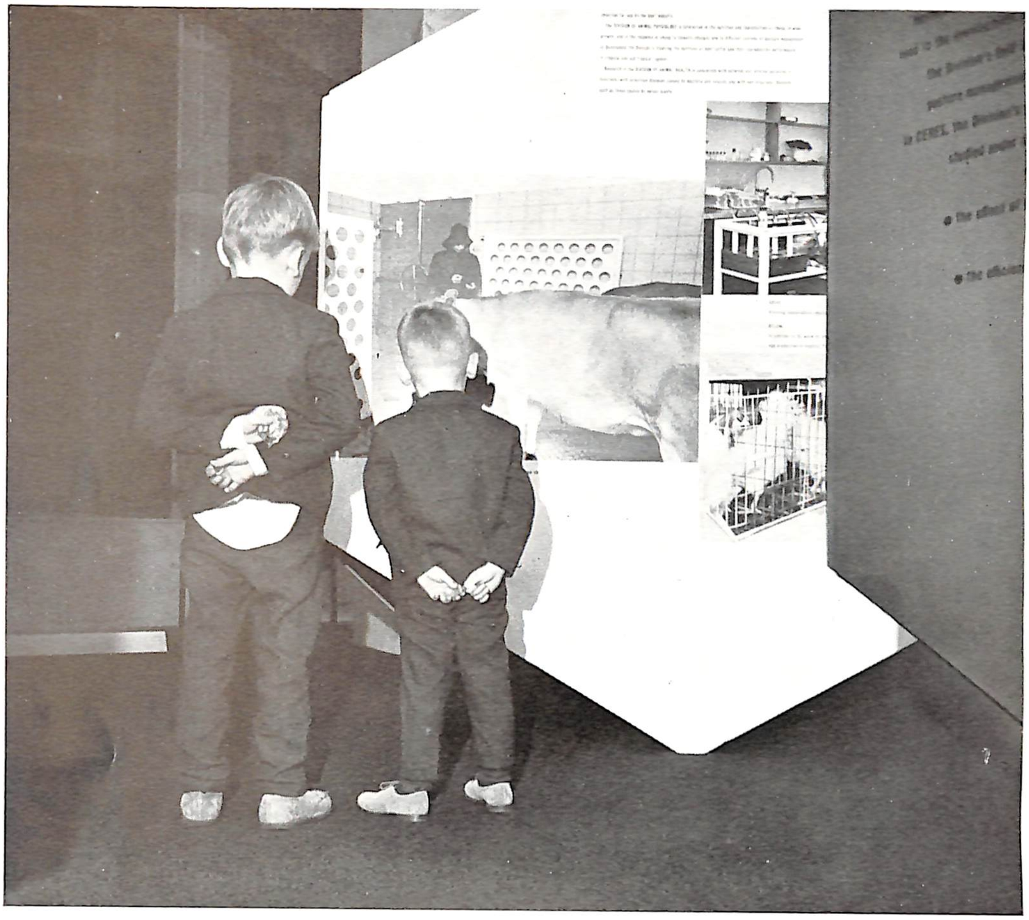

1916
1920
1925
1930
1935
1940
1945
1949
Div. of Soil Res.
Soil Problems
Div. of Soils
Mineral Deficiencies of Pasture Investigations
Economic Botany
Div. of Plant Industry
Irrigation Settlement Problems
Flax Res. Section
Agricultural and Pastoral Res.
Div. of Animal Health
Animal Problems Investigations
Div. Animal Nutrition
Div. of Animal Health and Nutrition
Div. of Animal Health and Production
Div. of Biochem.& Gen.Nutrition
Div. of Economic Entomology
Fisheries Investigations
Fisheries Investigations
Div. of Fisheries
Dairy Res. Section
Cold Storage Investigations
Food Pres. Inv.
Div. of Food Preservation & Transport
Oenological Res. Section
16th March 1916
Advisory Council of Science and Industry
Preliminary Institute of Science and Industry
Science and Industry Act
Council for Scientific and Industrial Research
CSIR
Forest and Vegetable Products Res.
Div. of Forest Products
Other Secondary Industry Res.
Building Materials Research
Building Res.Sec
Mining and Metallurgy Res.
Ore Dressing Investigations
Div. of Industrial Chemistry
Div. of Aeronautical Research
Transferred
Physical Metallurgy Section
Radio Res. Section
Standards Investigations
Div. of Electrotechnology
National Standards Laboratory
Div. of Metrology
Div. of Physics
Div. of Radiophysics
Lubricants and Bearings Section
Tribophysics
Div. of
Biometrics Section
Mathematical Statistics Sec.
World War II

Diagram of the growth of research activities in CSIRO and its predecessors over the past fifty years.



The exhibition held interest for people of all ages. It was devised by Mr. David Kimpton of the Organization's Head Office, and designed and built by the firm of Peter Hutchison and Associates.



Ministry of Education and Science

The following paragraph appeared in the 1965/66 Annual Report of CSIRO.

'There is now a noticeable move within Australia towards the fashioning of a policy for science. The situation today is both interesting and encouraging, and thoughts about the support of science in all its aspects must form an important element of Government policy considerations for the future.'

During the past year the Government's interest in science policy found expression in the establishment of a new ministry. The Ministry of Education and Science was established on 13th December, 1966, and on the same day Senator J. G. Gorton was appointed Minister. On 11th January, 1967, it was announced that Sir Hugh Ennor would become Secretary of the new department.

The Executive welcomes these developments and believes that they will assist the growth of Australian science and the provision of sound policy advice to the Government.

The Executive will in future report to the Minister of Education and Science instead of as in the past to a Minister acting on behalf of the Prime Minister. In no other way is the position of CSIRO affected.

Divisional changes

Two divisional mergers have taken place during the year. The former DIVISIONS OF PHYSICAL CHEMISTRY and ORGANIC CHEMISTRY have been combined into a new DIVISION OF APPLIED CHEMISTRY. The Chief is Dr. S. D. Hamann, previously Chief of the DIVISION OF PHYSICAL CHEMISTRY.

The DIVISION OF COAL RESEARCH has been absorbed into the DIVISION OF MINERAL CHEMISTRY, under Mr. I. E. Newnham.

The development of promising ideas

In the course of their researches, scientists often hit on ideas for new processes, methods, products, machines or instruments. Sometimes the ideas seem promising, but their proper evaluation calls for additional resources of money and manpower.

In organizations like CSIRO, where annual budgeting is practised, it has always been difficult to provide resources for short-term development. A step taken in 1966–67 is designed to overcome this difficulty. The Executive has established a pool of staff positions and money from which allocations can be made at short notice and for short terms (typically one to two years). In the first year, the pool contained ten staff positions and $60,000.

Several allocations to Divisions have already been made. The projects concerned include one new process for smelting tin from low-grade ore and another for freeze-drying foodstuffs more efficiently. These are typical of ideas which appear promising and prove workable in the laboratory or in pilot plant. It is not possible to assess their industrial significance without further developmental work.

The development pool will, it is hoped, enable CSIRO laboratories to take more ideas to a stage where their commercial potential can be appreciated by industry.

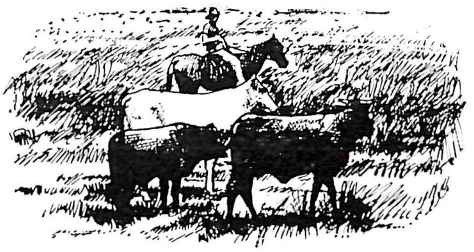
Starting new programs

The number of problems which could be tackled by CSIRO is enormous, but the Organization's ability to take up new lines of work is necessarily limited by manpower and money. It is nevertheless important that some new research projects should be started every year, some stopped, and others expanded. The development pool idea is one way of financing strategic short-term expansion.

In its considerations of the 1965/66 and 1966/67 estimates the Executive gave special attention to the development of specific research areas of particular promise. Each year Divisions are asked to nominate (in a supplement to their draft estimates) what new or expanded programs they believe would repay support.

The proposals of the Divisions are examined by the Executive. The most promising of them are short-listed and the list is included in the Organization's annual budgetary estimates. The Government is thus able to see for what purpose it is making real (as distinct from inescapable) increases in CSIRO's allocation of funds.

During the last two years approval has been given for the commencement of several new programs. The DIVISION OF ENTOMOLOGY, for instance, has been able to develop some new ideas for pest control. The DIVISION OF TROPICAL PASTURES has begun to tackle the problem of tree and shrub re-growth which follows land clearing in Queensland. The DIVISION OF LAND RESEARCH has been able to start a new study of pasture and cereal agronomy in the Kimberleys.



On the industrial side, a 'hardware' group for larger scale experimentation has been started in the DIVISION OF MINERAL CHEMISTRY. The DIVISION OF MECHANICAL ENGINEERING is greatly expanding its work on methods for reducing the costs of comfort cooling houses in the tropics.

These programs are new, and don't simply replace others. The Executive does, of course, encourage the winding-up of completed programs, and the reallocation of resources within Divisions. For example work on irrigated crops and pastures at Deniliquin is now being heavily reduced, and some $100,000 worth of resources are being diverted to dry-land agronomic research. And the DIVISION OF WILDLIFE RESEARCH, having completed a study of the Tasmanian native hen, is diverting resources to a study of eagles and emus in Western Australia.

Rainmaking goes operational

The first artificially induced rain ever to hit the ground fell in New South Wales after a cloud seeding experiment by the DIVISION OF RADIOPHYSICS in 1947. The Division has continued to carry out rainmaking experiments through the succeeding twenty years, gradually extending its knowledge and experience.

There is always a drought, or at least a prolonged dry spell somewhere in Australia. Over the years CSIRO has received a steady stream of requests to stimulate rainfall in one region or another. In cases where prospects were good and resources were available the DIVISION OF RADIOPHYSICS has mounted cloud-seeding operations.

By 1964 the Division had arrived at the conclusion that rainmaking operations (as distinct from research) could and should be taken over by state authorities concerned with agriculture, forestry and water supply. So a 'School for Rainmakers' was held in 1965 and attended by representatives of several state departments.

A large-scale state operation was conducted by the Victorian Department of Agriculture over the Wimmera and Mallee wheat growing areas in the spring of 1966. An aircraft based at Nhill made 34 'seeding' flights between August and October. The Department has reported that rainfall in the seeded area was higher than in the surrounding unseeded areas, the ratio for seeded to unseeded areas having been exceeded only once in the last 41 years. The Department's Journal reported that:

'A conservative estimate of the increase in wheat production in the area where cloud seeding operations were conducted in 1966 is 1,800,000 bushels, valued at $2,000,000 gross to growers.'

Two aircraft were sent to Horsham in May, 1967, to seed clouds over the wheat country during the 1967 season.

Research associations

The Science and Industry Research Act lists among the functions of CSIRO

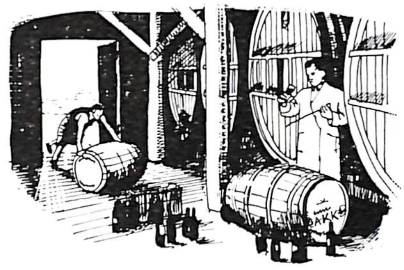
'the recognition or establishment of associations of persons engaged in any industry for the purpose of carrying out industrial scientific research . . . and the making of grants to such organizations . . .'

The Organization makes annual grants to four research associations which have previously been recognized. In each case the grant is equal to or less than the industry contribution.

The Bread Research Institute of Australia, which is based in Sydney and provides research and extension services to bakers throughout Australia, receives an annual grant of $42,500.

The Leather Industry Research Association uses its annual grant of $44,000 to provide financial support for the work of a Leather Research Section recently established in CSIRO's DIVISION OF PROTEIN CHEMISTRY.

The Australian Wine Research Institute, which is located in Adelaide, carries out long-term research on wine growing and wine making. Its grant is $15,000 a year.



The Australian Coal Industry Research Laboratories, serving colliery proprietors and coal users, receives an annual grant of $40,000.

During the year CSIRO recognized two new research associations.

The Australian Welding Research Association was formed in 1965 by 42 companies and organizations to undertake research in welding and associated activities. The members include a steel maker, steel fabricators, users of welded structures and manufacturers of welding supplies. The Association will not establish its own laboratory, but will sponsor research projects in existing laboratories. CSIRO's grant will be on a dollar for dollar basis up to a maximum of $40,000 a year. The Association is eligible for the maximum grant in 1967.

CSIRO has also recognized Sugar Research Ltd. This research association was set up eighteen years ago by a group of 26 sugar mills in Queensland who between them crush more than 80 per cent of Australian cane.

Research in the laboratory at Mackay, Queensland, is concerned with improving the efficiency of raw sugar milling and the quality of the product. At present the industry subscribes $300,000 a year, and the CSIRO grant will be on the basis of one dollar for each two subscribed by the industry. Maximum grants of $100,000, $150,000 and $200,000 have been fixed for the first three years.

CSIRO and the universities

In recent years the Executive has been giving thought to the respective roles of CSIRO and the universities in scientific research. A lively discussion on the subject took place at a 1965 meeting of the Advisory Council. At the conclusion, the Council appointed a twelve-man committee 'to examine co-operation between CSIRO and the universities and to make suitable recommendations'.

Chairman of the committee was Professor G. M. Badger, a member of the CSIRO Executive who has since become Vice-Chancellor of the University of Adelaide. The committee consisted of two vice-chancellors, four professors, two members of the CSIRO Executive, two senior members of the CSIRO research staff and two other members of the Advisory Council. A report was presented to the Advisory Council in May, 1967.

The main thesis of the report is that there *is* a need for increased co-operation between CSIRO and the universities. Seven ways of achieving co-operation were recommended.

Undergraduate teaching
CSIRO scientists should be encouraged to accept invitations to give courses of lectures or supervise practical classes at universities. The teaching load on university staff would be slightly reduced and many members of the CSIRO staff would find the experience stimulating.

Graduate training
CSIRO laboratories should be encouraged to provide accommodation and facilities for students proceeding to higher degrees in cases where university regulations allow credit for off-campus work. CSIRO scientists could be joint supervisors of Ph.D. students working in their laboratories.

Joint research
The establishment of joint CSIRO–university research units should be encouraged. The committee emphasized that this would be more feasible if there were fewer barriers obstructing the transfer of staff. It welcomed present moves by the Government towards simplifying the transfer of superannuation rights.

Study leave
CSIRO scientists should be permitted and encouraged to undertake study leave in Australian universities; conversely university staff should be encouraged to spend part of their study leave, or even long vacations, in CSIRO laboratories. Direct exchange between CSIRO and university staff for one academic year should also be encouraged.

Vacation schools
CSIRO and the universities should co-operate in arranging special schools for undergraduates or graduates during university vacations.

Consultants
University scientists should be encouraged to take an interest in CSIRO research projects and invited to act as consultants. Similarly, CSIRO scientists should take an interest in university research.

Equipment and facilities
CSIRO and the universities should co-operate in the purchase and use of expensive equipment and facilities. This is already being done in some instances with computers.

The Advisory Council report pointed out that none of the recommendations were entirely novel; many of them were being implemented to some degree. But the present collaboration between CSIRO and the universities needed to be extended if Australia was to make the best use of its resources of money and manpower.

The report is being widely circulated among senior members of CSIRO and university staffs.

Buildings and land

In recent reports the Executive has expressed concern at the slow rate of progress being made in providing satisfactory accommodation for the Organization's work. Though many problems still exist, progress has been made this year with the planning of a number of new laboratories. It is particularly gratifying to record progress with two of the biggest projects, the rehousing of the CHEMICAL RESEARCH LABORATORIES and the NATIONAL STANDARDS LABORATORY. By the middle of 1969 half of the CHEMICAL RESEARCH LABORATORIES will have been relocated, and a start on the NATIONAL STANDARDS LABORATORY project is planned for 1969–70.

Treasury funds available increased from \$2.4 million in 1965/66 to \$2.9 million in 1966/67 and substantial grants were received from industrial and private benefactors. As a result, four new laboratories were completed and a cattle station was acquired.

The biggest of the new buildings is a laboratory to house most of CSIRO's research activities in Western Australia. This laboratory is built on a 27 acre site in the Perth suburb of Floreat Park, overlooking the Commonwealth Games site. It houses 85 members of the staff of the DIVISIONS OF PLANT INDUSTRY, SOILS, ENTOMOLOGY, MATHEMATICAL STATISTICS and APPLIED MINERALOGY. Eventual capacity is 115 people.

The laboratory has 38,000 square feet of space in the three-storey, air-conditioned main building. There are also a number of small service buildings. The whole project was designed by the Department of Works and cost \$1,245,000. It was opened on 8th April, 1967, by His Excellency the Governor-General, Lord Casey.

The DIVISION OF FOOD PRESERVATION acquired the first stage of a new meat research laboratory at Cannon Hill, Brisbane. The new two-storey laboratory cost \$580,000, of which over 90 per cent was provided by the Australian Cattle and Beef Research Committee. The building is air-conditioned and has extensive cold room facilities. It provides space and facilities for a considerably expanded research program. The laboratory was formally opened on 31st May, 1967, by the Chairman of the Australian Meat Board, Mr. J. L. Shute.

In 1963 the Organization was given a very valuable benefaction by Mr. F. C. Pye, a prominent New South Wales grazier. Some \$265,000 of the benefaction was used to build a laboratory which will be a centre for research on the field environment of plants. Designed by Ancher, Mortlock, Murray and Woolley, it is a three-storey square building of about 16,000 square feet, built on the DIVISION OF PLANT INDUSTRY'S site at Black Mountain, Canberra. The laboratory is built around an attractive naturally lit courtyard, flagged with white terrazzo. It was formally opened by Lord Casey on 31st August, 1966.

A new laboratory for the DIVISION OF LAND RESEARCH has been built at Katherine in the Northern Territory. It provides for the first time modern air-conditioned laboratory facilities for the station, which was established in 1945. The building was designed by the Department of Works and cost \$100,000. It was opened on 11th April, 1967, by the Administrator of the Northern Territory, Mr. R. L. Dean.

At Mundubbera, 190 miles north-west of Brisbane, a 22,500 acre cattle station has been acquired for the DIVISION OF TROPICAL PASTURES. It was made available to CSIRO by the Government of Queensland. The Organization has paid \$38,000 in compensation for improvements, and \$221,000 has so far been expended on development. Total development costs will be about \$600,000. The property is especially valuable for research purposes because it contains tracts of spear grass and brigalow country, both of which are being studied by the Division. It has been named "Narayen Research Station".

1 The new F.C. Pye Field Environment Laboratory is built around an attractive central courtyard, which gives access to the offices and laboratories.

2 The first stage of the new meat research laboratory at Cannon Hill, Brisbane. This building will be used mainly for research on beef. The second stage, scheduled to commence in 1968, will house work on lamb, mutton and other meats.

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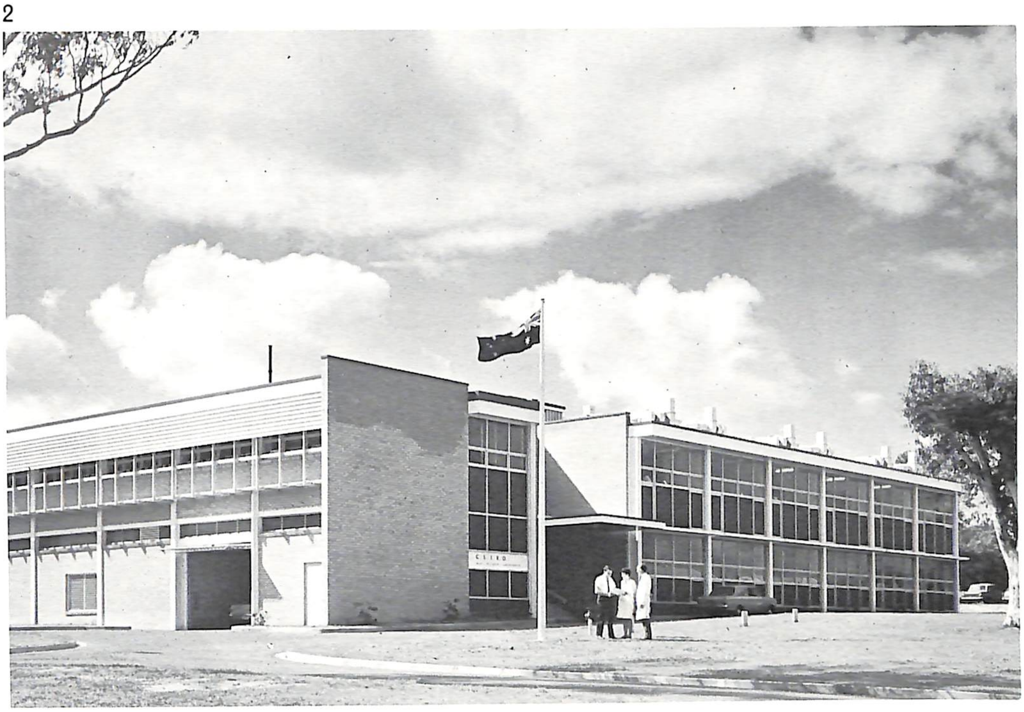


CSIRO on television

On 26th June, 1967, an estimated television audience of 400 million people in some twenty-four countries watched CSIRO scientists at work in 'Ceres', the Controlled Environment Research Laboratory at Canberra, and in the control room of the 210-ft. radiotelescope at Parkes, New South Wales.

The occasion was the world's first multinational live television program.

It was shown on the A.B.C. network in all Australian States except Western Australia between 5.00 a.m. and 7.00 a.m., Eastern Standard Time.

Entitled 'Our World', the program included live telecasts from fourteen countries around the world.

Australia was the only contributor from the Southern Hemisphere.

The program, which had as its theme Man in His World, was shown in six sequences —This Moment's World, This Hungry World, This Crowded World, Aspiration to Physical Excellence, Aspiration to Artistic Excellence, and The World Beyond.

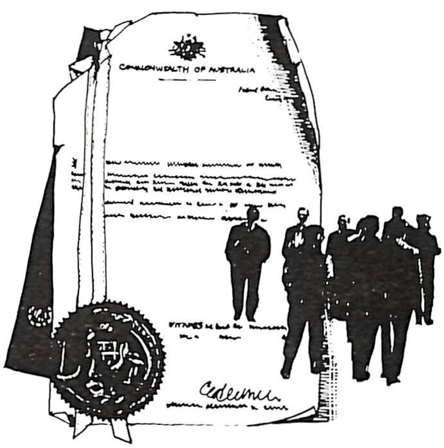
In This Hungry World viewers saw how 'Ceres' was being used by CSIRO scientists and by visiting scientists from other countries to find out more about the way in which environment controls the growth and development of the plants which provide our food.

The World Beyond showed radioastronomers at Parkes recording signals from one of the most distant objects yet discovered in the Universe.

Contact with industry

If CSIRO is to do effective research for the benefit of secondary industry it must understand industry's needs. Furthermore, the Organization must encourage industry to interest itself in promising discoveries. So it is necessary to maintain close contacts with industry.

Most of this contact is at the Divisional level; the DIVISIONS OF BUILDING RESEARCH, FOOD PRESERVATION and TEXTILE INDUSTRY are typical of those which are in close touch with the industries which they serve. For some of the subject Divisions, like APPLIED CHEMISTRY, contact is more difficult because its research results may have implications for half a dozen different industries. There are many different ways in which contact is fostered—through open days, special courses for industry technicians, calibration services and information services. Several Divisions publish periodicals and circulate them without charge to the appropriate industries, and a leaflet entitled *Industrial Research News* is made available to all Australian manufacturers.



In recent years CSIRO has made increasing use of patents to promote the use of research results by industry. Patents are applied for:

- When there is a danger of others obtaining patents covering the results of the Organization's work.
- When it seems likely that an invention will only be developed and exploited commercially if covered by patent.
- When it is desirable for the Organization to maintain an interest in the quality and technical efficiency of production through the licensing of patents.

- When an invention may assist in maintaining or extending the use of Australian products overseas.
- When substantial royalties are likely to be collected from overseas licensees.

The Organization is now patenting inventions at a rate of one a week, and about one licence a week is being issued for the use of CSIRO inventions.

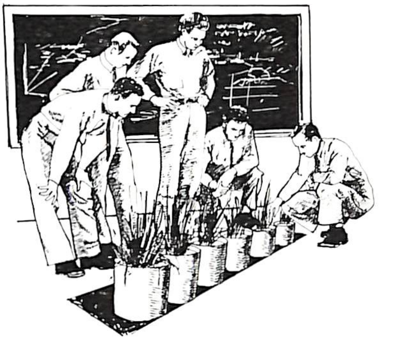
Agricultural liaison

Though CSIRO is the largest Australian body engaged in agricultural research it is only one of many. Substantial contributions are made by State Departments, Universities and others.

It is important for the Organization to maintain close, cordial and co-operative relationships with other agricultural bodies, especially the State Departments which are responsible for adapting the results of CSIRO research to local needs.

There are nowadays many avenues for cooperation. CSIRO and Departmental representatives sit together on several committees which consider possible research projects and advise on priorities. There is the Animal Production Committee, for example, for which CSIRO provides a secretary. The latest committee of this type, formed this year, is the Australian Weeds Committee.

CSIRO has established in its Head Office an agricultural liaison unit which fosters close relationships with other agricultural organizations. The unit publishes a quarterly journal called *Rural Research* which presents practical aspects of the more important findings arising from the Organization's agricultural and biological research. Another of its responsibilities is the organization of conferences. Last year the unit organized a meeting between wool industry representatives and CSIRO scientists engaged in wool production and textile research. Conferences on cereal and pasture plant breeding, potato agronomy, plant pathology and agricultural extension were arranged on behalf of the Australian Agricultural Council.



There is an increasing tendency for cooperation to occur in the laboratory as well as across the conference table. The DIVISION OF PLANT INDUSTRY, for example, has taken part in an increasing amount of collaborative work over the past few years. The Division has about half a dozen people from State Departments working in its Canberra laboratories on joint projects. Similar schemes are in force at Deniliquin and Perth, and are planned for Mareeba. The Division has also been running plant breeding courses for State officers for the last three years. Each year four of them come to the Division to participate in seminars and to undertake a research project.

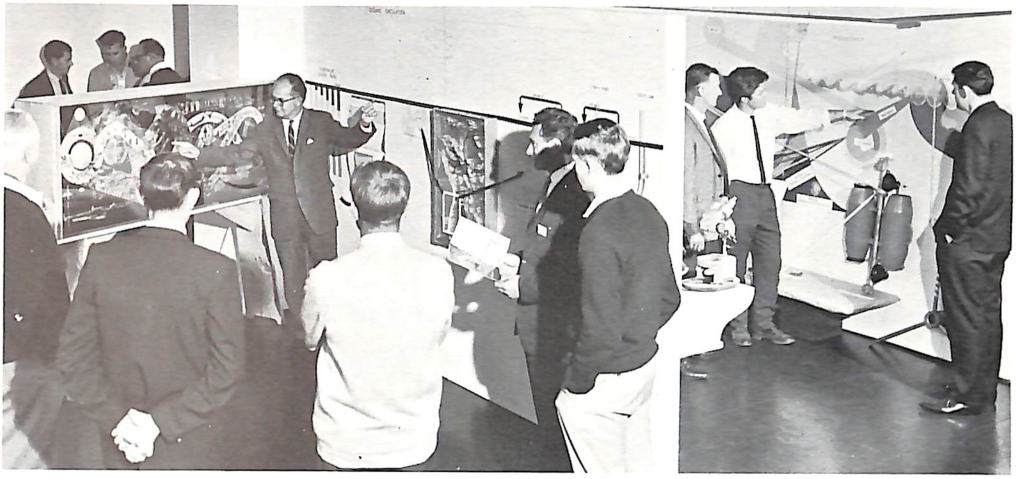
Film productions

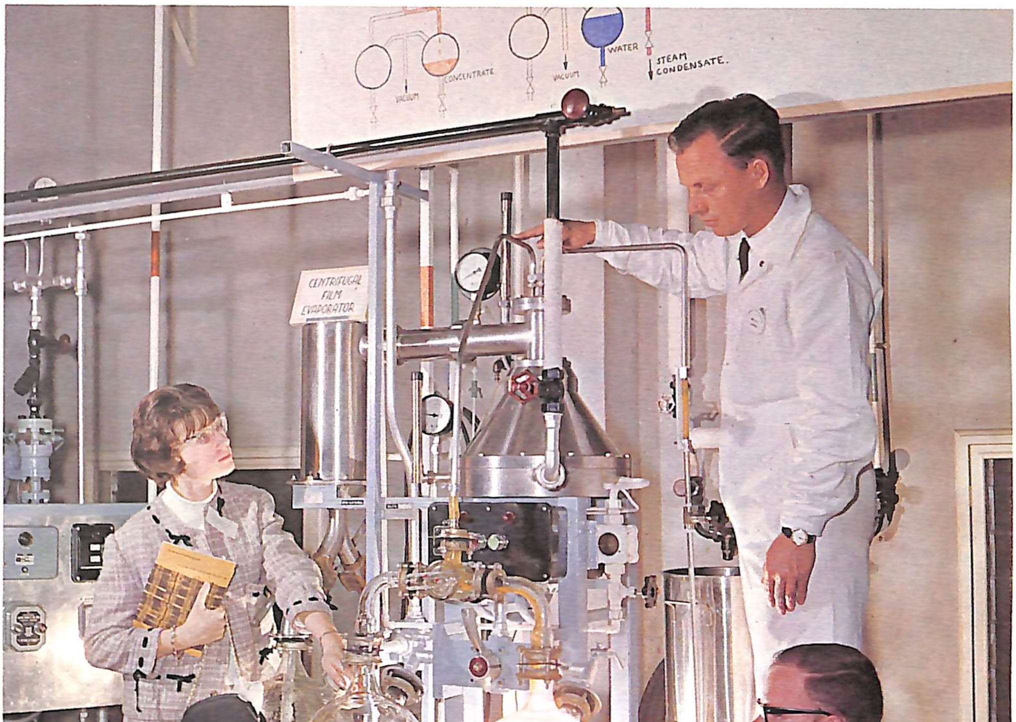
The Film Unit produced five new 16-mm films, and a number of segments of film were taken for historical or record purposes. The new films are:

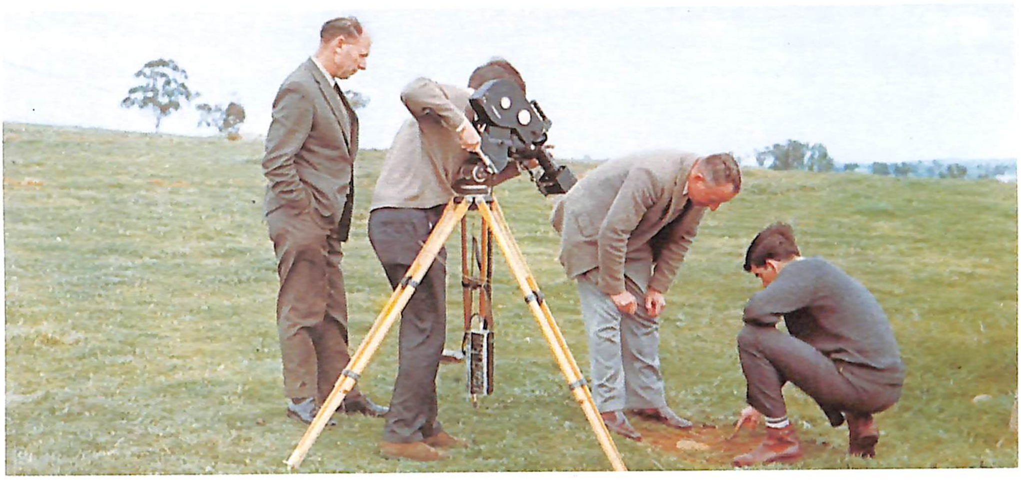
Design for climate (COLOUR, 20 MINUTES)
An account of how research results can help designers to create agreeable indoor climates by overcoming problems of heat, glare, noise and ventilation.

Water from the sun (COLOUR, 15 MINUTES)
A description of the principle of solar distillation, and how it has been applied in the CSIRO designed still at Coober Pedy, South Australia.

Demonstrations, open days, and courses of instruction, are held from time to time in many CSIRO laboratories. An annual fisheries school is held at the Cronulla laboratory of the Division of Fisheries and Oceanography. The top photograph shows a member of the Division's staff explaining a marine science exhibit to a group of fisheries field officers.
The Division of Food Preservation held open days in August, 1966. The lower photograph shows visitors inspecting a demonstration plant for concentrating fruit juice.







Members of the Film Unit shooting
'A Skeleton in the Crop'
on location in northern Victoria.

Crystallographers in conference (COLOUR, 43 MINUTES)
The history of the modern science of crystallography is recalled by several of the pioneers of the subject at a meeting in Melbourne in 1965.

Classifying by computer (BLACK AND WHITE, 10 MINUTES)
How the computer is used to unravel complex relationships between plants in their natural surroundings, and to find out how they can be grouped in a meaningful way.

A skeleton in the crop (COLOUR, 31 MINUTES)
How skeleton weed spread through the wheatlands of New South Wales and Victoria and how farmers and scientists together tackled the problem.

The opening of the David Rivett Laboratory in 1966 was recorded on film.

On forty occasions during the year CSIRO films were shown on television. Several more films were shown in part.

A 1965 CSIRO production, 'Birth of the Red Kangaroo' was the Grand Prix winner (best film) at the fourth International Festival of Scientific and Technical Films held in 1967 at Brussels.

Photograph acknowledgments

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The Report is set in ten and eight point Monotype Baskerville and printed on international size B5 Gemini Ballarat Art paper in letterpress and litho by the CSIRO printery, Melbourne.

Organization

The Office of the Chairman of CSIRO is in Canberra and the central administration is in Melbourne. Regional administrative offices are located in Melbourne, Sydney, Canberra and Brisbane.

The Organization's research work is carried out in a number of Divisions and Sections. Some of the Divisions are associated as groups known as the Animal Research Laboratories, the Chemical Research Laboratories, the National Standards Laboratory and the Wool Research Laboratories. The Sections are smaller in size than Divisions, or in earlier stages of development.

Location of CSIRO Laboratories and Field Stations

The list of Divisions and Sections is as follows.

ANIMAL RESEARCH LABORATORIES, consisting of the following four Divisions:

Animal Genetics,	with headquarters in Sydney, laboratories in Sydney and in Rockhampton, Qld., and field stations at Badgery's Creek, N.S.W., and Rockhampton.
Animal Health,	with headquarters and laboratories in Melbourne, laboratories in Sydney and Brisbane, and field stations at Werribee, Vic., and Amberley, Qld.
Animal Physiology,	with headquarters and main laboratories at Prospect, N.S.W., a laboratory with field station at Armidale, N.S.W., and a laboratory at Brisbane.
Nutritional Biochemistry,	with headquarters and laboratories in Adelaide and a field station at O'Halloran Hill, S.A.

CHEMICAL RESEARCH LABORATORIES, Melbourne, consisting of the following five Divisions:

Applied Chemistry,	with a microanalytical laboratory at the University of Melbourne.
Applied Mineralogy,	with a branch laboratory in Perth and a small laboratory in Sydney.
Chemical Engineering,	
Chemical Physics,	
Mineral Chemistry,	with a Coal Research Laboratory in Sydney.

NATIONAL STANDARDS LABORATORY, Sydney, consisting of the following two Divisions:

Applied Physics,	
Physics,	with a Solar Physics Observatory at Culgoora, N.S.W.

WOOL RESEARCH LABORATORIES, consisting of the following three Divisions:

Protein Chemistry,	Melbourne.
Textile Industry,	Geelong, Vic.
Textile Physics,	Sydney.

OTHER DIVISIONS ARE:

Building Research,	with headquarters in Melbourne and an office in Port Moresby.
Dairy Research,	Melbourne.
Entomology,	with headquarters and main laboratories in Canberra, laboratories in Sydney, Perth and Brisbane, and field stations at Albury, Armidale, Trangie, and Wilton, N.S.W., Cambridge, Tas., Ascot, England and Montpellier, France.
Fisheries and Oceanography,	with headquarters and main laboratories at Cronulla, N.S.W., and laboratories in Melbourne, Brisbane, and Perth.

Food Preservation,	with headquarters and laboratories in Sydney and laboratories in Brisbane and Gosford, N.S.W.
Forest Products,	Melbourne.
Land Research,	with headquarters in Canberra and field stations and laboratories at Alice Springs, Katherine and Darwin, N.T., and Kununurra, W.A.
Mathematical Statistics,	Adelaide, with officers stationed at a number of Divisions and Sections and at the University of Melbourne.
Mechanical Engineering,	Melbourne.
Meteorological Physics,	Melbourne.
Plant Industry,	with headquarters and main laboratories in Canberra, laboratories in Brisbane, Perth, Hobart and Deniliquin, N.S.W., field stations and experimental farms at Canberra and Deniliquin and at Pinjar, Kelmscott, Kojonup, and Baker's Hill, W.A., and the Tobacco Research Institute at Mareeba, Qld.
Radiophysics,	with headquarters and laboratories in Sydney, the Australian National Radio Astronomy Observatory at Parkes, N.S.W., and the Solar Physics Observatory at Culgoora, N.S.W.
Soils,	with headquarters and laboratories in Adelaide and laboratories in Canberra, Perth, Hobart, Brisbane and Townsville, Qld.
Tribophysics,	Melbourne.
Tropical Pastures,	with headquarters in Brisbane, main laboratories in Brisbane and Townsville, a laboratory at Lawes, Qld., and field stations at Townsville, Samford, Woodstock and Mundubbera, Qld.
Wildlife Research,	Canberra, with a laboratory at Helena Valley, W.A.

SECTIONS

Computing Research,	Canberra, with subsidiary installations at Adelaide, Melbourne and Sydney.
Editorial and Publications,	Melbourne.
Horticultural Research,	Adelaide, and Merbein, Vic.
Irrigation Research,	Griffith, N.S.W.
Ore Dressing,	Melbourne.
Physical Metallurgy,	Melbourne.
Soil Mechanics,	Melbourne.
Upper Atmosphere,	Camden, N.S.W.
Wheat Research,	Sydney.

REGIONAL CENTRES, Officers from a number of Divisions are located at:

Tasmanian Regional Laboratory, Hobart.

Western Australian Regional Laboratory, Perth.

Chapter 2

Research activities

THE FIRST of the functions of CSIRO, as defined in the *Science and Industry Research Act*, is to carry out scientific research 'in connexion with, or for the promotion of, primary or secondary industries . . .' Over nine-tenths of the Organization's resources are committed to this job of carrying out scientific research.

CSIRO has always been decentralized and today the forty Divisions and Sections are spread throughout the Commonwealth. As envisaged in the Act, the Organization's work has spread to the territories and several Divisions are conducting research in New Guinea. Nearly all the primary and secondary industries of Australia are now benefiting in some way from CSIRO's work.

There are many different ways of dividing up the complex structure of the Organization. It reflects, in microcosm, the whole structure of Australian industry. In this chapter it has been found convenient to subdivide the research under ten headings.

It used to be practicable to review all of the Organization's research every year. This is no longer the case. A full account of all the research programs, with appropriate notes on their relevance to the economy, would fill a thousand page volume. In recent years it has been the practice to select a few significant advances for mention in the Annual Reports.

This has been done again this year. A special effort has been made to select programs which lend themselves to description in terms which are intelligible to the general reader. This condition inevitably introduces a bias, as a good deal of fundamental work in the basic sciences is excluded by it. Often the significance of such research can be appreciated only by specialists in the same field. Limitations of space and style have also made it necessary to omit many of the subtleties; in almost every case only the bold outline is sketched.

The picture of CSIRO's work presented here is therefore restricted and to some degree over-simplified. The sacrifices in accuracy have been deliberately made in the interests of readability. Scientists in search of comprehensive information about CSIRO's work should consult the separate annual reports of the individual Divisions and Sections.

The agricultural environment

THREE CSIRO DIVISIONS are especially interested in the environment of plant growth. This is an important field of study for an Australian research organization, since our soils and our climate are different from those in other countries.

The DIVISION OF SOILS studies the chemistry, physics, biology, geology and mineralogy of Australian soils. Practical objectives include the classification of soils to ensure their best use and the treatment of soils (by tillage or fertilizer application, for example) to increase fertility.

The DIVISION OF METEOROLOGICAL PHYSICS is concerned with climate and weather processes. Areas of study include the differences between weather patterns in the northern and southern hemispheres and the study of heat balance and evaporation close to the surface of the ground, the micro-climate in which plants grow.

The interests of the DIVISION OF LAND RESEARCH include all environmental factors—soil and climate included. The Division's main job is to find out how best to use the land in the relatively undeveloped regions of Australia and New Guinea.

Computing superphosphate needs

How well a plant grows depends on quite a number of soil factors. The roles of these various factors are becoming better understood.

In a recent experiment at Coleambally (New South Wales), 95 per cent of the differences in yield between clover plots could be explained in terms of them.

This sort of knowledge is now being exploited by the DIVISION OF SOILS. A scientist can take a soil sample from a wheat field and readily measure various things—the nitrogen content, acidity and so on. He can then look up tables to get more relevant information about growing wheat in that field, such as the average pattern of rainfall distribution throughout the year.

These factors (all of which affect fertilizer requirements) can then be incorporated in a computer program devised by the Division. The computer will calculate the right amount of superphosphate to add for maximum yield, or perhaps maximum profit.

The program is very flexible. All sorts of things, including economic factors like the cost of superphosphate, can be incorporated in it.

Some of the fertilizer companies plan to use the program in conjunction with their advisory services. One company, which has its own computer, has estimated the cost of computation at $1\frac{1}{2}$ cents a recommendation. This is insignificant in relation to the cost of collecting a sample and making an analysis.

Keeping the soil moist

There are many ways of keeping soil moist. One can apply a mulch of straw or leaves. Farmers keep moisture in the soil by leaving stubble in the ground or by cultivating the surface in certain ways.

Scientists in the DIVISION OF SOILS have been measuring the effect of these moisture-retention treatments in theory, in model soils, and in the field. Experimental evidence suggests that surface treatment is useless in deep sandy soils, but it can be effective in soils which have impenetrable subsoils, such as clay. One of the aims of the research has been to find how best to modify the soil surface. Studies on model soils showed that breaking them into one-eighth inch diameter clods produced the best mulching effect.

Tests under field conditions showed that stubble and straw weren't very effective mulches on red-brown earths (typical wheat belt soils). It was also shown that clod sizes could be bigger than an eighth of an inch in practice. This is just as well, as fine-grain surfaces are very susceptible to rain-drop damage and subsequent erosion.

This work is of great significance to agriculture in the north, where high evaporation rates obviously create scope for improved mulching treatments.

Rainfall and sea surface temperature

As the surface temperature of the sea rises, evaporation will increase and more moisture will enter the atmosphere. It therefore seems likely that more rain will fall in nearby regions when the sea surface temperature is higher than usual.

This theory has been tested experimentally by the DIVISION OF METEOROLOGICAL PHYSICS.

The only source of good temperature records was CSIRO's DIVISION OF FISHERIES AND OCEANOGRAPHY, which has recorded sea surface temperatures at Port Hacking (near Sydney) since 1943. Rainfall records were obtained from 13 weather stations in northern New South Wales and southern Queensland.

It was found that higher-than-average sea surface temperatures occurred during wet spells at a number of stations. Similarly, lower-than-average surface temperatures occurred in drought periods.

Much more research is needed to find out whether sea surface temperature variations *cause* rainfall or drought, or whether the two things are merely associated. More good surface temperature records will be needed. When there is no cloud cover, surface temperature measurements can be made from satellites but so far the accuracy obtainable is not good enough. When sea temperatures are generally available, from whatever source, the weather forecaster will have a useful new weapon in his armoury.

Radio-active rain

The DIVISION OF METEOROLOGICAL PHYSICS began measuring radio-activity in rainfall just after the American nuclear tests at Bikini Atoll in 1958. Measurements have been continued through the years of further testing by Britain, the United States, Russia, China and France.

The pattern of radio-active fallout after each of the explosions has helped meteorologists to learn more about air movement in the higher levels of the atmosphere. Radio-activity in rain increases after an explosion and then varies with the seasons. Calculations from the data show that the radio-active particles at high-levels are transferred from the equator to the poles. In the southern hemisphere, this takes place in winter. The nature of the transfer process is not quite the same in both hemispheres, a fact which is attributed to differences in the size ratio and configuration of the land and sea masses.

Radio-active fallout in Melbourne's rain rose to high levels after the 1966 French tests. The levels were, however, far below those considered to be hazardous.

Lake George and the Ice Age climate

The mystery of the origin of Lake George, near Canberra, has encouraged scientists in the DIVISION OF LAND RESEARCH to study the lake's surroundings. As often happens in scientific work, the research led to some quite unexpected conclusions.

For many years scientists have believed that the weather during the Ice Age in Australia (some tens of thousands of years ago) was wetter than it is today. The LAND RESEARCH study has cast considerable doubt on this theory.

During the Ice Age frost affected soils and vegetation down to much lower altitudes in the Snowy Mountains. By comparing the former and present extent of frost action, it can be worked out that average temperatures were colder in the Ice Age by 15 degrees Fahrenheit.

Now Lake George is a closed basin; the water running into it from rainfall is balanced by the water leaving it through evaporation. There is clear evidence that the shore-line of the lake was higher in the

Ice Age. This level is related to the ratio of rainfall to evaporation, and evaporation at 15 degrees less than today's temperatures can easily be calculated. And if evaporation is known, the rainfall which balances it can be calculated. It was actually between half and two-thirds of today's rainfall. Since world climates are interrelated, findings like this help scientists to understand the tremendous changes in climate, soil and vegetation which have taken place in recent geological times.

Soil moisture and crop yield

Efforts to relate crop yield to climate and weather have never been very successful. In the DIVISION OF LAND RESEARCH scientists have been trying to find out just how wetness and dryness do influence crop yield.

The early experimental work used growth and yield records for wheat and grain sorghum at the Queensland Department of Primary Industries Research Station at Biloela, about 100 miles south-west of Rockhampton. The results were remarkably clear-cut. Grain yields were very closely related to soil moisture content at a critical stage of growth. In the case of both wheat and grain sorghum this was at flowering and early grain filling. These findings were further tested using growth and yield records of peanuts and sorghum at Katherine (Northern Territory). Though the environment was different the result was the same.

At first actual measurements of soil moisture content were used but good estimates were obtained using rainfall and evaporation figures (and a computer program).

The findings have interesting consequences for plant breeders, who may now select varieties which flower when soil moisture content is high.

The results also give scientists a measure of the cropping potential of under-developed areas.

Pastures for the Northern Territory

The development of the Australian cattle industry depends on increasing the acreage of improved pastures. Plant scientists have a number of grasses which will grow well in the Australian tropics. The key to pasture improvement in the north is the availability of suitable legumes to go with them. Legumes build up soil fertility by increasing the amount of nitrogen in the soil.

The most promising legume for a large part of the north is Townsville lucerne. This rather insignificant looking small dark green plant is neither a lucerne nor a native of Townsville. It grows well in a wide range of conditions and is very appetizing and nutritious to stock.


Townsville lucerne

Scientists in the DIVISION OF LAND RESEARCH have been trying to find ways of establishing Townsville lucerne in perennial native pastures in the Northern Territory. Simply dropping seed on to vigorous native pasture gives poor results—the seed cannot establish because the competition is too great.

While Townsville lucerne can be established by clearing and ploughing, cheaper methods are being sought. The Northern Territory Administration introduced Townsville lucerne successfully into annual pastures with early wet season burning. The difficult task of establishment into perennial native pastures is being tackled by the DIVISION OF LAND RESEARCH. Both heavy grazing in the early wet season and burning have given good establishment.

These methods may help to accelerate pasture improvement in the Northern Territory, where some 25 million acres are estimated to be suitable for development.

Crops and pastures

THE DIVISION OF PLANT INDUSTRY is CSIRO's largest Division and one of the biggest plant research institutes in the world. Its fields of enquiry encompass all the botanical sciences.

The DIVISION OF TROPICAL PASTURES has the job of finding out how to improve pastures in Australia's tropical and sub-tropical regions. This research is showing the way to dramatic increases in beef production and is being followed closely by other tropical countries.

The IRRIGATION RESEARCH LABORATORY, located in the Murrumbidgee Irrigation Area, is concerned with the problems of growing crops under irrigation.

The HORTICULTURAL RESEARCH SECTION's field of investigation is the growing of horticultural crops, especially grapes.

The uses of the phytotron

The phytotron, an artificial climate facility attached to the DIVISION OF PLANT INDUSTRY, is giving outstandingly good value. Since its opening in 1962 its facilities have been in keen demand. It has been used by over fifty scientists from outside the Division, including fifteen from abroad. As many as 100 different sorts of plants have been studied in the phytotron in one year. Some recent findings are of great interest.

Plants measure day-length Very small differences in length of the light period can be very significant. Some rice varieties will flower or not flower depending on an additional five minutes of day length. Plants have special light receptor pigment which senses day-length. This pigment somehow changes its structure as a result of illumination and sends messages to points of growth and differentiation in the plant. Research in the phytotron has identified the way in which messages are sent. They move at the rate of about an inch an hour. The investigators could detect increases in the rate of protein formation at special 'target' cells found at the growing points.

Rates of grass growth Scientists have used the phytotron to study the growth rates of temperate zone and sub-tropical grasses. The temperate grasses grow best at about 70 degrees Fahrenheit, while the growth rate of the sub-tropical varieties continues to increase all the way up to 113 degrees. Under the best conditions, temperate grasses will grow at the rate of 17 per cent a day, while sub-tropical grasses often exceed a growth rate of 40 per cent a day. Surprisingly, all grasses belong to one group or the other, and there seem to be no intermediates between them.

Sterility in rice Sterility in rice flowers, resulting in heads not filling with grain, is a serious problem encountered by growers in the irrigation areas of New South Wales. Efforts to find the cause by experiments in the field were unsuccessful. A scientist from the Department of Agriculture, using the phytotron, was able to discover that the trouble is due to low night temperatures at certain stages during formation of the flowering head. He is now crossing local varieties with some Japanese varieties known to be unaffected by cold nights. His crosses will be tested in the phytotron to see which of them stand up best to cold temperatures.

Testing for blue mould

The tobacco plant is grown as an annual and many millions of seedlings are planted out every year by growers. In Queensland and Victoria, where Australia's tobacco crop is grown, there are breeding programs aimed at improving quality and disease resistance.

The main disease is blue mould. Scientists in CSIRO and the State Departments are constantly seeking blue mould resistant tobacco plants. At best these only remain resistant for a few seasons, so new resistant varieties are always needed.

Present laboratory tests for blue mould involve the infection of whole plants. Scientists in the DIVISION OF PLANT INDUSTRY have devised a much better test. They cut cent-sized disks out of the leaf, infect them with mould, and float them on water under controlled conditions of temperature and illumination. There are several advantages. First, it's not just a yes–no test; degrees of resistance can be determined only 48 hours after inoculation. A number of blue mould strains (four are known in Australia) can be tested on the sample plant. Moreover, the plant is still available for breeding afterwards.

The test will not only be useful in Australia, but also in Europe where blue mould has recently broken out with devastating effect.

The taste and scent of pasture

Grazing animals, like people, don't always know what's good for them. While they do tend to select a good diet, their choice is to some degree affected by the palatability of the different herbage plants. Scientists in the DIVISION OF PLANT INDUSTRY have been studying the preferences of sheep. Several methods can be used, including simple observations, dung analysis, and withdrawing samples through fistulas or plug-holes surgically fitted to the animal.

The findings were not always in accord with expectations. Opinions about which plants are eaten by sheep at different times of the year are often not correct. These results will change our attitude to the importance of some species.

The Division is also looking into the reasons why sheep prefer some plants to others. The sheep has four ways of assessing the pasture—by sight, smell, taste and feel on the lips and tongue. By depriving experimental sheep of different senses—taste, smell, feeling and sight—one can find out what it is about a plant that makes it attractive or repellent. Once it is known which characters, chemical or physical, grazing animals like, then plant breeders can try to incorporate these features in new varieties.

Carbohydrate from irrigation water

In sunlight, plants make carbohydrate out of water from the soil and carbon dioxide from the air. The carbohydrate thus produced is the main source of man's food. As the leaves collect carbon dioxide they simultaneously lose water vapour. The ratio of carbon dioxide gain to water vapour loss is a useful measure of the efficiency of the plant's use of water. The plant is functioning most efficiently when this ratio is high.

It has been supposed that water shortage would reduce the efficiency of water use by plants. Experiments at the IRRIGATION RESEARCH LABORATORY have shown that this is not so, at least on a short-term basis. Moderate water shortage does *not* directly affect the rate of carbohydrate production. And experiments in controlled environment (phytotron) cabinets show that the efficiency of water use remains constant even though the rate of carbohydrate production varies considerably.

These findings have some interesting implications if the results in the phytotron cabinets can be applied to growth in the field. They suggest that plants kept a little short of water would use their water more efficiently. There would be no loss of efficiency in carbohydrate production and water loss from the soil surface would be very low. The optimum amount of irrigation water for a crop may be lower than we think.

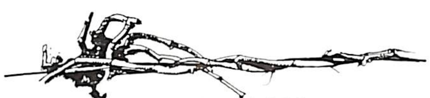
Better profits from sultanas

Four recent findings by scientists at the HORTICULTURAL RESEARCH SECTION will help sultana growers to improve yields and reduce costs.

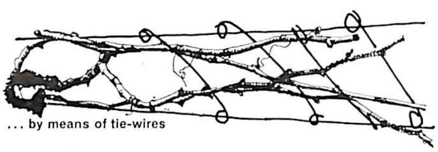
Firstly, in spite of beliefs to the contrary, it has been demonstrated that high yield in sultana vines is transmissible. Cuttings taken from high yielding vines will themselves yield well. The Section has already distributed some superior cuttings, and by 1968 expects to have enough of them to supply all comers.

Secondly, it was shown that the vertical canes which shoot from the vine are more fruitful than those which grow horizontally. This knowledge can be exploited at pruning time.

Thirdly, research has revealed that overcropping does not constitute a real risk. For years, heavy pruning has been practised in the years when heavy crops were predicted. It was feared that vines would suffer severely if overcropped. With this theory exploded, more fruit can be harvested in the bumper years.



Canes attached to the trellis wire ... by twisting



... by means of tie-wires

... by means of wire rings

Finally, another common belief was found to be untrue. This was the idea that canes should be tightly twisted around trellis wires to promote bud burst and the growth of fruiting wood. Tie wires or rings were used in the experiment but any other labour-saving method will achieve the same result.

Indigofera spicata

Fertilizer and cattle production

In the unimproved spear grass country near Townsville (Queensland) cows are carried at the rate of one beast to 15 or 20 acres. The calving rate is about 50 to 60 per cent and 10 to 15 per cent of these calves can die from malnutrition in the dry season.

The DIVISION OF TROPICAL PASTURES has been measuring the effects of adding Townsville Lucerne and fertilizer to the pasture. The most significant result was that cows could safely carry their calves when stocked at 1 beast to 6 acres on pastures dressed with 3 hundredweight of superphosphate to the acre. In the years 1964/65, 65/66, and 66/67 cows on these pastures had calving percentages of 100, 100, and 88. The calving percentages on similar pastures *without* superphosphate were 100, 19, and 69. The dramatic difference was in 1965/66, when only half the annual 34 inch rainfall was received. Cows and calves on the fertilized pasture gained weight well, and no calves suffered from malnutrition. Cows on the unfertilized pastures had to be given protein concentrates after calving to keep them alive.

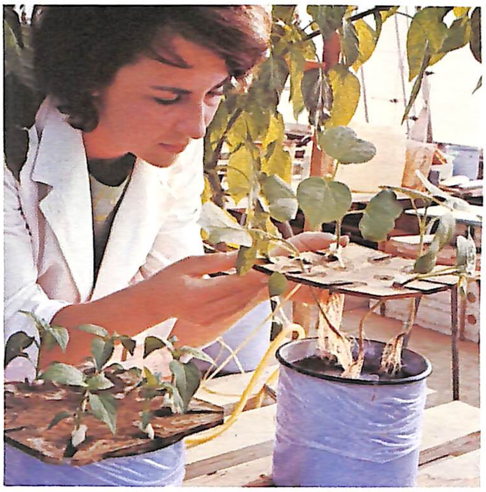
A promising plant for the tropics

The DIVISION OF TROPICAL PASTURES has been studying a legume called *Indigofera spicata*, sometimes called 'trailing indigo'. Introduced from Ceylon and other tropical areas, it grows well in south-east Queensland and is one of the best nitrogen fixers among tropical legumes. Unfortunately it is poisonous to sheep and horses, and causes abortions in cattle.

Research workers in other countries have been trying for some years to identify the poison and recently the Division has succeeded in isolating it from the plant. The poison, which has been called Indospicine, acts on the liver in a way which is not yet fully understood. The Division is collaborating with scientists in the Universities of Queensland and Melbourne to find out how it works. Meanwhile, the Division is trying to produce a poison-free variety of the legume.

The Canberra phytotron contains fifteen large naturally lit glasshouses, in which day and night temperature can be closely controlled. Research on over 100 plant species has been carried out in the building since its opening in 1962.

At the Irrigation Research Laboratory, pepper and cotton plants are used experimentally for measuring the effects of water shortage. The experiments are usually done in phytotron cabinets.



Cattle eating *Dolichos lab lab*, one of the legumes being grown at the Division of Tropical Pastures' research station at Samford, near Brisbane. This legume was introduced from Kenya in 1952.

THE GROUP OF FOUR Divisions known as the ANIMAL RESEARCH LABORATORIES are concerned with the health and productivity of domestic animals.

The work of the DIVISION OF ANIMAL GENETICS provides a scientific basis for breeding. It seeks to identify the genetic characters which are important for various purposes, like increasing wool production or adapting cattle to hot climates.

The DIVISION OF ANIMAL HEALTH studies animal diseases which are of importance to our livestock industries. Part of the research program involves serious diseases which are *not* here, so that they can be quickly suppressed if they enter Australia.

The DIVISION OF ANIMAL PHYSIOLOGY, by contrast, studies the body functions of the healthy animal. It is particularly concerned with the relationship between feeding and management and the growth, reproduction and productivity of sheep.

The DIVISION OF NUTRITIONAL BIOCHEMISTRY's field of study is animal nutrition. The Division has placed special emphasis on the part played by trace elements in the metabolism of sheep.

Picking the best dairy bulls

A cow inherits her milking propensities from both her parents. Twenty years ago scientists began to estimate the breeding value of bulls by measuring the milk yields of their daughters.

Soon afterwards consideration was given to the use of the sons of proven sires. It was presumed that the sons of proven bulls were more likely than the sons of bad bulls to sire high milk-yielding daughters.

But a good bull has many sons. Which ones should be selected for breeding purposes? And can a selection be made early in the bull's life?

One of the difficulties in herd improvement for the practical breeder is the long time taken for evaluating bulls. By the time the average milk yields of his daughters are known, the bull is 5 or 6 years old. With this generation time, improvement is slow. It would obviously be of great value if a bull's ability to sire good milkers could be predicted with accuracy earlier in his lifetime.

The DIVISION OF ANIMAL GENETICS has achieved a method for doing just this. The Division's method is based on the theory that because mammary tissue is a highly modified skin structure, the bull's skin may carry some indicators of his future daughter's mammary development.

Already it is possible to make good predictions on the basis of the sizes of hair follicles and sweat glands microscopically observed in samples of skin from 2-year old bulls. The method is at present being tested with the cooperation of two State Departments of Agriculture.

An artificial stomach

The rumen, or paunch, is the first of the four 'stomachs' of a ruminant animal. In the rumen the cellulose in pasture is broken down into digestible units by thousands of species of micro-organisms.

For obvious reasons, it is very difficult for scientists to study the biochemical reactions going on within the rumen of a live animal. The use of fistulas (surgically fitted plugholes) is of only limited help.

An artificial rumen has been built in the DIVISION OF NUTRITIONAL BIOCHEMISTRY. The great advantage of it is that one can vary some of the factors (such as the plant species) in a controlled way and observe what happens. The method has its limitations—the right microbial populations and environmental conditions can't be maintained for long.

Out of this work has come a valuable discovery. The important thing to measure in the rumen is the *rate* at which it produces digestible food from cellulose. Using the artificial rumen, the Division's scientists developed a tiny cellophane dialyser cell, no bigger than a thimble. Digestible food passes into the cell, and is carried out again by the water stream circulating through it. The device can be placed in a live sheep's rumen through a fistula so that one can quantitatively measure the rate of grass-into-food conversion in the rumen. This will help scientists to evaluate different pastures.

Electrocardiograms for lambs

The trace element selenium is essential in the nutrition of animals and man. The sign of its deficiency is muscular abnormality or dystrophy; in sheep this is recognized as 'white muscle disease'.

Exactly how selenium is involved in nutrition is something of a mystery. Its function appears to be related to that of Vitamin E. In some species either selenium or Vitamin E will relieve muscular dystrophy, and both are known to affect animal fertility.

A scientist in the DIVISION OF NUTRITIONAL BIOCHEMISTRY has managed to produce white muscle disease in lambs experimentally by maintaining them on selenium-free diets for 2 to 3 months. The disease has been found to affect the heart muscle as well as other muscles. It has also been found that the onset of selenium deficiency can be detected very early from the lamb's electrocardiograms. Electrocardiograms will be useful as a method of diagnosis and as an aid to research.

Marginal selenium deficiency is widespread, especially in Western Australia. The Division is now trying to find out whether there is a relationship between infertility due to selenium deficiency and infertility due to oestrogenic (hormone-containing) pasture. Does one intensify the other, for example?

Stimulating wool growth

A most interesting discovery emerged three or four years ago from basic research in the DIVISION OF ANIMAL PHYSIOLOGY. It was found that some proteins, when inserted into the fourth stomach (abomasum) of a sheep, caused a remarkable increase in wool growth. When two ounces of the milk protein, casein, were inserted each day into the abomasums of sheep fed on a mere survival diet the wool production rate jumped from 5 pounds a head to 15 or 20 pounds.

This discovery is not practically useful unless one can find a cheap and easy way of getting protein into the abomasum. When the sheep is fed by mouth, the food is fermented in the rumen. Only a small amount of the fodder protein gets through to the fourth stomach.

The Division is now studying ways of ensuring that protein fed by mouth can get through to the abomasum. There are four possible ways—

- Coating the feed with a bacteria-resistant substance which will dissolve on contact with the acid in the abomasum.
- Decreasing the time the food spends in the rumen, by making the sheep drink more, or by the use of drugs.
- By using drugs to inhibit those rumen bacteria which break down protein.
- Treating protein chemically to make it resist bacterial attack in the rumen.

All have been tried, and the last appears to be the most promising.

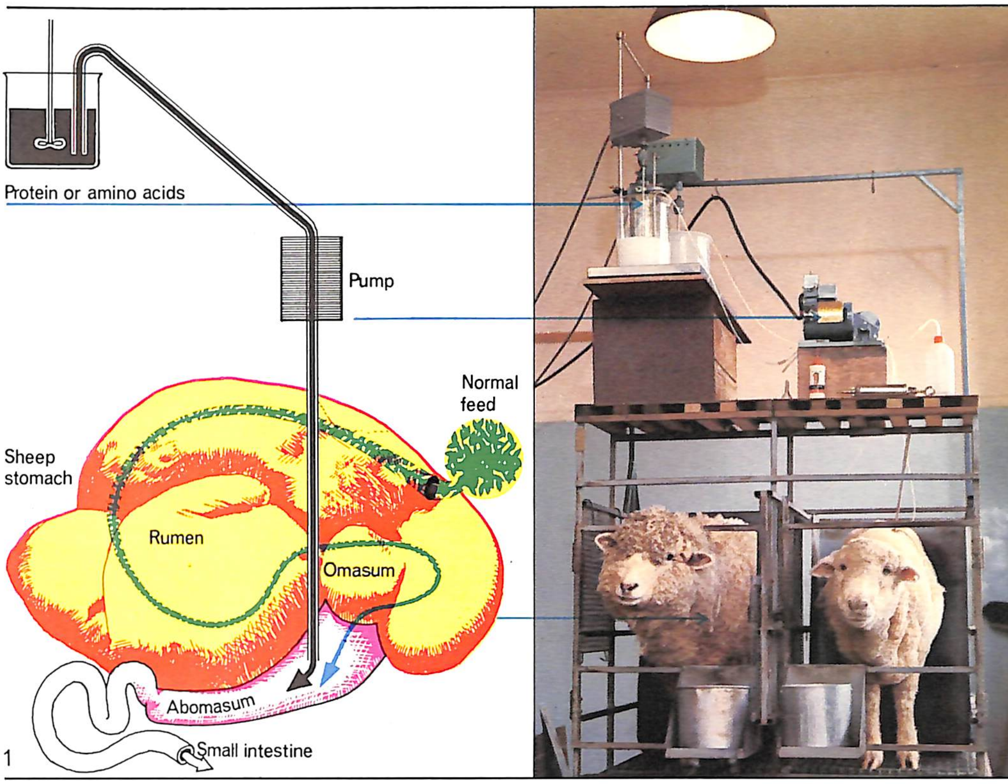
As little as one to two grams daily of certain sulphur-containing amino acids will exert the same effect as proteins in the abomasum. The amino acids can be coated with protein, treated chemically and given as a feed supplement. The ramifications of all this work are very wide, and a number of patent applications have been made in consequence.

Saving new-born lambs

Ten million new-born lambs, or one in five of the population, die every year. The DIVISION OF ANIMAL PHYSIOLOGY has been studying the causes of this for some years. The Division has found that infectious diseases are of minor significance. The

Research in the DIVISION OF ANIMAL PHYSIOLOGY has revealed that a remarkable increase in wool growth occurs when certain amino acids or proteins are put into the fourth stomach (abomasum) of a sheep. (**1**) A solution or slurry of the amino acids or protein is infused into the abomasum of the sheep through a roller pump.

(**2**) Instead of infusing the protein direct into the abomasum, it may be fed normally, provided it is treated to make it resistant to microbial digestion in the rumen. These processes are wasteful when sheep are fed diets rich in protein, but, treated protein gets through to the abomasum without destruction in the rumen.



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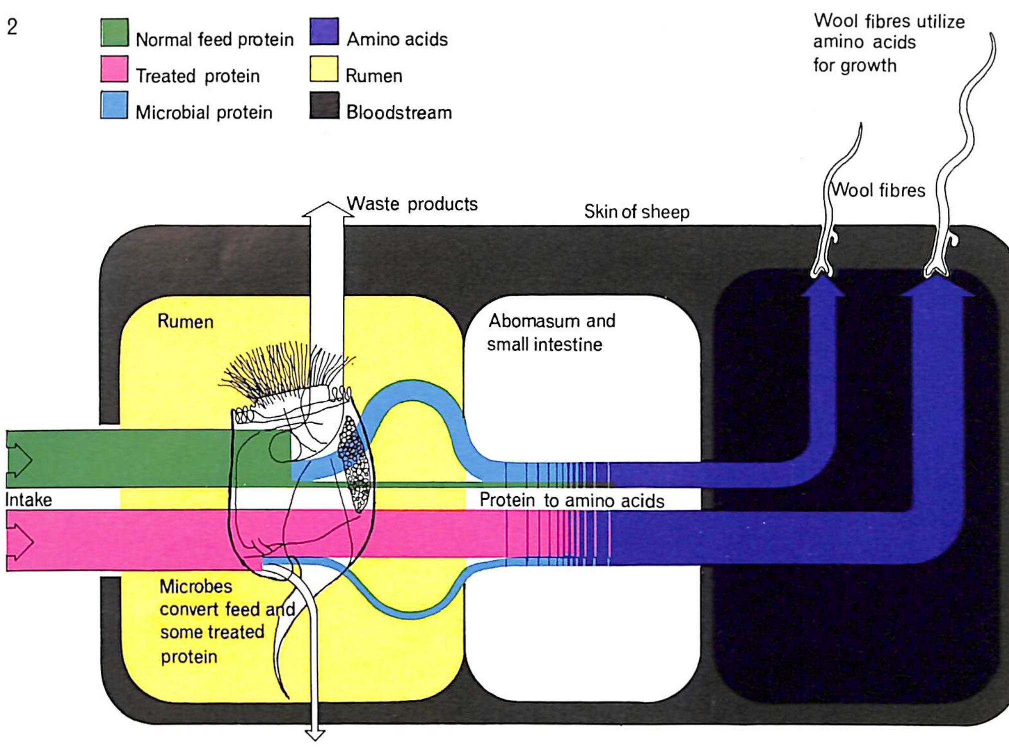


important things are the nutrition of the pregnant ewe, the severity of the climate, and the behaviour of the mother. In general, small lambs are endangered in bad weather. The Division has worked out in quantitative terms, how wind speed, temperature and wetness influence lambs of various birth weights.

From this information one can now predict quite accurately what weather conditions will jeopardize the survival of lambs. The Commonwealth Bureau of Meteorology is now including warnings to woolgrowers in broadcast weather forecasts. To an increasing degree graziers are taking advantage of the growing body of knowledge in their own husbandry practices.

The Division recently joined forces with the DIVISION OF WILDLIFE RESEARCH and the South Australian Department of Agriculture in a study of lamb predators. In this study foxes were mainly scavengers of dead lambs and afterbirth—there was only one attack on a healthy lamb. Crows made occasional attacks, but in no case succeeded in injuring a healthy lamb.

Newcastle disease is here

Newcastle disease is a dreaded disease of poultry, widespread throughout the world. It is highly infectious and generally fatal. In 1962 the British Government spent $20 million in trying to eradicate it.

Australia has always been free of the disease, except for an outbreak in Victoria 35 years ago which was quickly controlled. As recently as 1964 there was good evidence that the disease was still not in Australia.

In 1966 virologists in State Departments in Queensland, New South Wales and Victoria isolated a virus from fowls which seemed to be Newcastle disease. Yet the birds were not only alive, but symptom free. The DIVISION OF ANIMAL HEALTH examined the virus, identified it as Newcastle disease virus, and began to investigate the matter further.

It was found that the new virus was highly infectious and multiplied rapidly in day-old chickens. It survived in frozen, dressed poultry, and has no doubt been spread widely through the country. The interesting possibility was that birds infected with the harmless virus would be resistant to the virulent strain. An experiment performed in April, 1967, showed that this was indeed so. A group of chickens infected with the 35 year old virus (kept in deep freeze and passaged occasionally in chick embryos) all died. Another group, first infected with the new virus, survived attack from the virulent form. We may therefore be building up an immune national flock.

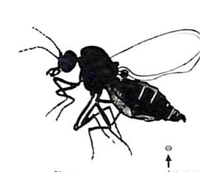
How the harmless virus entered the country is unknown. It may have been brought in by a migratory bird, or it may have entered the country illegally in fowl sperm or in a fertile egg.

Controlling the spread of disease

Australia is luckily free of some very serious diseases of livestock. Typical of these is blue tongue, a disease of sheep which has so far never been successfully eradicated from any country. This disease is spread from one animal to another by the bites of midges. So if an outbreak of blue tongue were to occur in Australia, it would not be good enough to slaughter the infected sheep—the midges would have to be killed as well.

The DIVISION OF ANIMAL HEALTH is conducting a study of these potentially important insects and of ways in which they could be controlled.

The study has so far resulted in the discovery of several new species and the acquisition of a lot of new information about their behaviour and movements. A scientist in the Division has devised a beautiful technique whereby he can discover what types of blood the midges have been eating by testing the gut contents. He can do 30 to 40 tests on a single midge.



CIVILIZED MAN is constantly seeking a greater degree of control over his environment. Among other things, he attempts to control wild populations, ridding himself of undesirables like the blowfly or the cattle tick while conserving the useful crayfish and the aesthetically appealing lyre bird and koala.

CSIRO's DIVISION OF ENTOMOLOGY is concerned with insect control, especially through what it calls 'pest management'. This refers to means of controlling pest populations by the strategic manipulation of nature rather than by heavy dependence on insecticides.

The DIVISION OF FISHERIES AND OCEANOGRAPHY studies the fishery resources of Australia, and is concerned with their conservation and possible extension. The Division also investigates the biological, chemical and physical oceanography of the waters around Australia.

The DIVISION OF WILDLIFE RESEARCH has two main tasks. One is to study means of conserving as much as possible of Australia's unique wildlife. The other is to show how pests like the fox, dingo or rabbit can be controlled. Some animals don't fall neatly into a classification. Kangaroos, for instance, are at the same time a pest, a species to be conserved, and a potentially economic source of meat and skins.

Orchard pests

Is it possible that orchard sprays are encouraging rather than controlling insect pests? The DIVISION OF ENTOMOLOGY has set up a three-year investigation to test this theory. The experiments are being run with the co-operation of State Departments of Agriculture in New South Wales, Victoria, Tasmania and South Australia. The work is financed in part by the Australian Apple and Pear Board.

There is a well established hierarchy of pests in an apple orchard. The five most important are codling moth, light brown apple moth, mites, scales and woolly aphis. Then come a number of others of only minor economic importance.

The experiments began in the 1966–67 growing season in seven orchards in the four co-operating states. The trees were subjected to uniform spray treatment aimed specifically at codling moth. No attempt was made to deal with the others, except to combat one attack of light brown apple moth at Hastings, Victoria. Pests other than codling moth were watched for in all orchards.

The trend everywhere was downwards—mites and woolly aphis almost vanished. A tentative conclusion is that broad spectrum insecticides were actually encouraging four of the five major pests by killing their natural predators. The picture will probably become clearer during the next two seasons.

Stick insects

Various outbreaks of stick insects, or phasmatids, occurred in the forests of New South Wales and Victoria during the 1940's and 1950's. In severe outbreaks thousands of acres of trees were stripped of their foliage. In 1959 CSIRO began a study of the insect, with financial support from the Snowy Mountains Authority and the Murray River Commission. This study has just been completed.

It was found that the insect ranges from southern Queensland right down to Powelltown, Victoria. It is most abundant on the western (inland) slopes of the ranges, at altitudes above 3,500 feet. Much of this country is covered with forests of alpine ash, a tree which is very susceptible to phasmatid attack. Trees are frequently stripped of their foliage, but rarely killed by the insect. For this reason it is not as formidable a pest as was feared.

Stick insects have an unusual pattern of population growth. The population reaches peaks every second year, numbers being relatively low in the intervening years. When a peak occurs, the forests are

1a A stick insect, or phasmatid, devouring a eucalytus leaf.
1b Among the natural enemies of the phasmatid is this parasitic wasp. It punctures the phasmatid's egg and sucks out some of the yolk. The wasp then lays its own eggs in the empty space.

2 An Australian raven *Corvus coronoides* feeding on the shot carcase of a red kangaroo.
Research has established that there are not one species of raven, but two. The newly identified species *Corvus mellori* is the top one in the inset.

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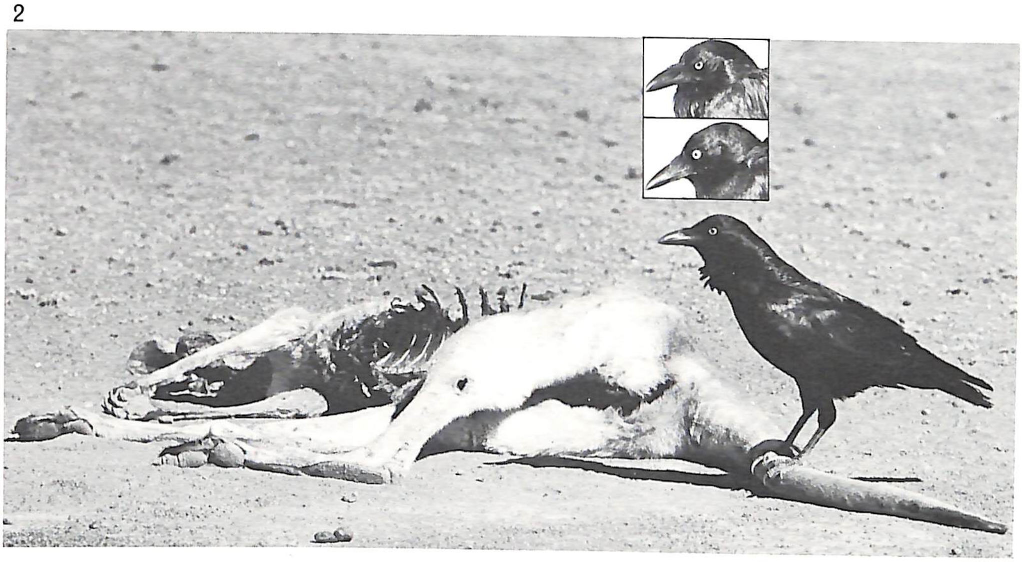
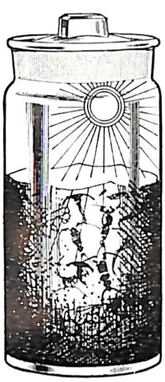


invaded by insects which prey on phasmatid eggs and by nomadic birds—magpies, crows, currawongs and wattle-birds—which feed on the phasmatids. The stick insects are also susceptible to a fungus disease which follows big population increases.

Controlled burning of forest floors destroys litter and removes cover and protection from the insect's eggs. Where control is needed, this seems to be the best way for foresters to exert it.

Ocean in the laboratory

Scientists in the DIVISION OF FISHERIES AND OCEANOGRAPHY have built apparatus which enables them to reproduce many features of the environment of the oceans in the laboratory.



One of the Division's research projects is a study of the rate of primary production in the sea. 'Primary production' is the biologist's term for conversion of inorganic, non-living material into living, microscopic forms of life. Some measurements are actually made at sea, but it is also desirable to study the process in the laboratory.

Primary production takes place in the upper levels of the ocean, where light penetrates. As one descends from the surface, the quantity of light diminishes, and at the same time the light quality changes, becoming bluer with increasing depth. With the aid of various light filters scientists have been able to reproduce exactly the light conditions in the depths. By balancing electric currents in photo-electric cells they can directly compare their laboratory illumination with underwater illumination. The 'light bath' they have built will be used for laboratory measurements of the productivity of natural plankton populations.

Another piece of apparatus reproduces the high pressures which are encountered in the oceans. It is a vessel which can be pressurized up to 60,000 pounds per square inch, which is considerably higher than the greatest ocean pressures. The vessel is contained in an oil bath which maintains constant temperature within very close limits, of the order of one-thousandth of a degree. The device will be used for studies of the chemistry of sea water under great pressure, and for research on the metabolism of plankton under various conditions of temperature, pressure and illumination.

Are kangaroos in danger?

In 1959, when the DIVISION OF WILDLIFE RESEARCH began a study of red kangaroos, the animals were very numerous in the inland. At about that time two developments occurred. The drought began, and the kangaroo meat industry began to grow rapidly. Over an eight-year period the populations in central Australia and western New South Wales have dropped to less than half. In some areas the kangaroo has been virtually wiped out.

The drought has had a number of effects on the kangaroo population. First the mortality of 'joeys' or pouch young increased until the point was reached where none survived. Then the females ceased to breed. The kangaroos, which normally don't move more than 30–40 miles from their home range, moved as far as 150 miles in search of grazing. Many of them perished, probably from malnutrition or starvation.

Kangaroo shooters in 1965–66 took about two million animals. Some $2,000,000 worth of meat was exported and the local market was at least as big. Observations by the DIVISION OF WILDLIFE RESEARCH indicate that shooters are having a significant effect on the population. The Division believes that there is a danger that shooters could eliminate the red kangaroo when its numbers are already heavily reduced by drought.

Research on the red kangaroo has indicated that sheep and kangaroos can be run together without seriously competing. If at any time State authorities seek to bring the kangaroo industry under control, the DIVISION OF WILDLIFE RESEARCH has enough knowledge to know how to begin appropriate management practices.

Ducks in decline

Research on wild ducks by the DIVISION OF WILDLIFE RESEARCH is summarized in a book called 'Waterfowl in Australia' published in April, 1967. The Division has been particularly interested in game species (black duck, grey teal, hardhead and pink-eared duck) and rare species or species unique to Australia (musk duck, freckled duck, blue billed duck).

All these species breed in the swamps, lagoons, and billabongs of the Murray–Darling river basin. The game ducks also need floodwaters every few years to build up their numbers. The others need heavily vegetated water, of which there is not much left.

In the summer, the ducks disperse to those coastal areas (see map) where freshwater lakes and swamps are found.

The duck population is constantly falling as the habitats disappear. Floodwaters are becoming rarer as flood mitigation schemes proceed. Irrigation authorities are draining the vegetated swamps. As more dams are built, river levels are brought under control and billabongs dry up. Coastal swamps are being drained. Only a few habitats, like the lakes of western Victoria, are being preserved.

Agricultural draining, irrigation and flood mitigation schemes all pose threats to the survival of duck species. 'Waterfowl in Australia' recommends that wildlife authorities should be consulted in the planning of such schemes.

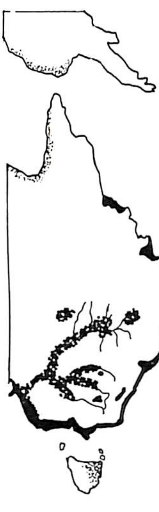
How many species?

In order to study the animal kingdom, the biologist classifies at several levels. His ultimate sub-division is the species, a group of individuals which can mate with one another to produce offspring of the same kind. It is important in biology to know if you are dealing with one or more species. Different species may react differently to changes in the environment or changes in management practice.

Scientists originally classified animals largely on the basis of appearance. But now taxonomy (the science of classification) has become more subtle and is leading biologists to new ideas.

There are about 50 species in the kangaroo family, for example, but nobody is quite sure how many are involved. The DIVISION OF WILDLIFE RESEARCH and the University of Western Australia have been studying speciation in the grey kangaroo. Study of blood proteins, skin structure and gestation periods provided the necessary clues, and it is now established that there are two species, one in eastern Australia, the other in the west. The populations overlap in the Riverina. The two species don't mate with one another in the wild, but can be crossed in captivity with difficulty. The study is now being extended to other members of the kangaroo family.

Another research project has shown up the fact that the common raven or crow (*Corvus coronoides*) is in fact two quite different species. A close study of the raven showed clear differences in calls, general behaviour (one type was more sociable than the other) and migratory behaviour. The more sociable type moves away from the inland when conditions become harsh. It breeds in the southern highlands, then moves back to the plains. The sociable, migratory type has been named *Corvus mellori*. Close inspection shows certain differences in the feathers of the throats of the two species. *Corvus mellori* eats more insects than his close relation, and is a less efficient predator of lambs.



Textiles

CSIRO's PROGRAM of textile research, which is almost entirely concentrated on wool, is carried out in three Divisions known as the WOOL RESEARCH LABORATORIES.

The DIVISION OF PROTEIN CHEMISTRY does research on the basic structure and chemistry of wool. This provides a better understanding of wool's properties and the changes that take place during processing. It also provides a scientific basis for the modification of the wool fibre to improve its properties.

The DIVISION OF TEXTILE PHYSICS studies the physical properties of wool fibres, with special attention to mechanical and water-absorption properties.

Most of the work on textile technology and wool processing is done in the DIVISION OF TEXTILE INDUSTRY which has a full range of mill processing equipment.

A new way of dyeing wool

When wool is made into yarn by the worsted process, it passes through a stage called 'top'. The 'top', a loose rope of clean, combed, aligned fibres, is the last stage before drawing and spinning into yarn. Most of the worsted wool in Australia is dyed at this point.

Conventional top dyeing is a lengthy ($1\frac{1}{2}$–2 hour) batch process. It is carried out at boiling point, and tends to weaken the wool fibres. The WOOL RESEARCH LABORATORIES have been looking for a better dyeing method for several years.

A few years ago the DIVISION OF PROTEIN CHEMISTRY invented a method in which formic acid was used to help dyes penetrate the wool fibres. The method was rapid, continuous, and did not require heat. The stumbling block is that formic acid is too expensive to discard after use.

Now the DIVISION OF TEXTILE INDUSTRY has come up with a method which uses urea to help dyes penetrate the wool fibres. Urea is superior to formic acid in that it is harmless and non-poisonous and cheap enough not to need recovering. It can be applied warm or cold, but the treated wool does need to be steamed.

The process seems to be better than conventional methods in several ways. Capital costs are smaller. Dyeing only takes five minutes, and can be operated on a continuous basis. The wool fibres are not damaged as much.

The process has been patented, and licences are being negotiated with machinery makers.

Making knitteds keep their shape

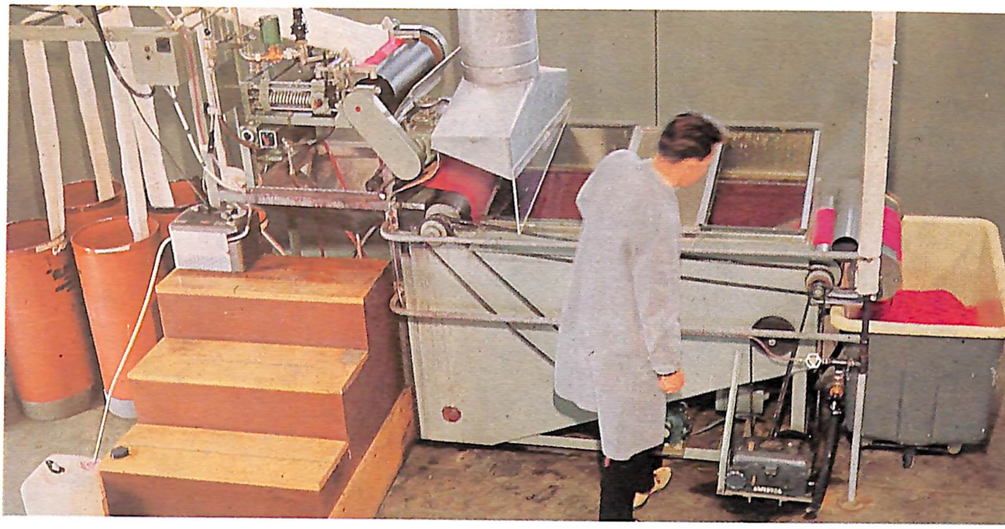
About half of the woollen goods produced in Australia are knitted, and the other half woven. At present, in common with a world trend, the output of knitted goods is increasing.

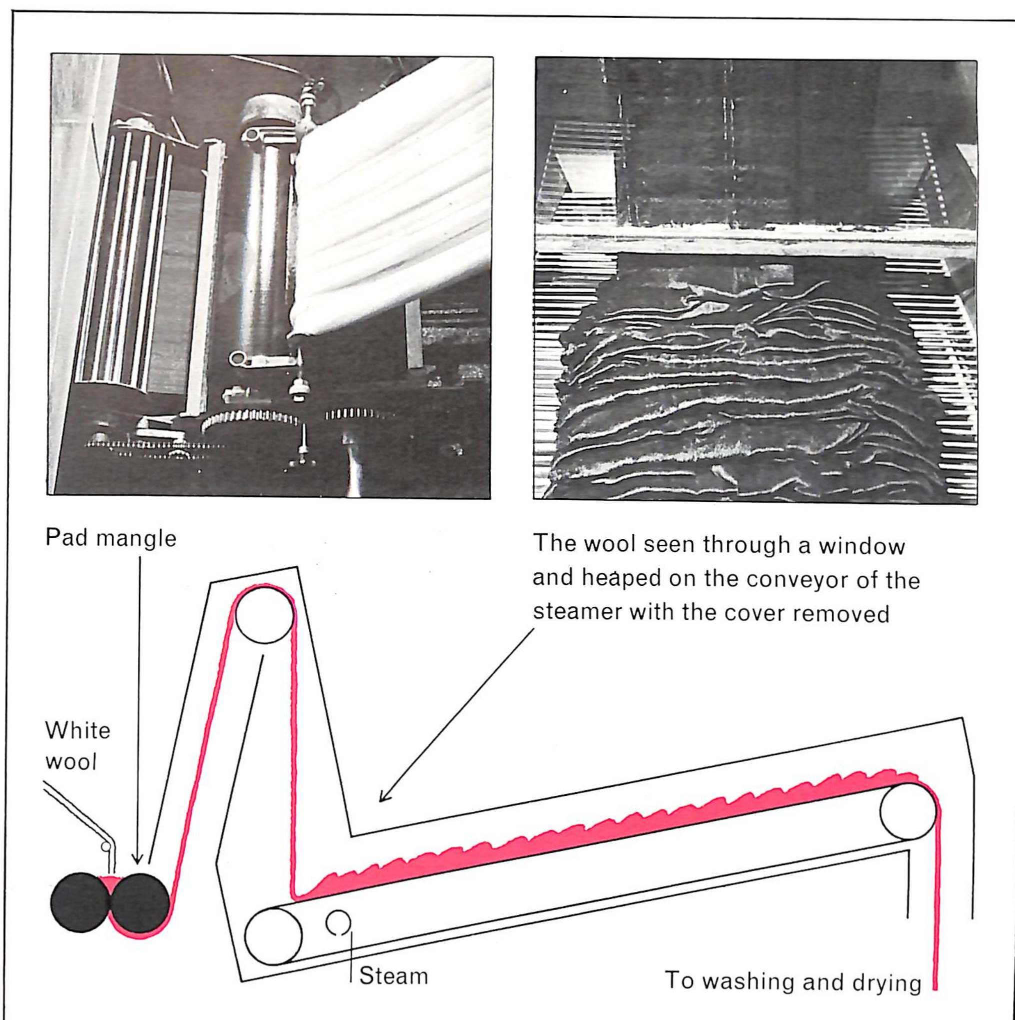
Each method of fabrication has its advantages and disadvantages. Knitteds are preferred when one wants a fabric that is extensible or stretchable, flexible, and resistant to wrinkling. But there are also problems with knitted goods. If not well made, they don't retain their shape properly; in the physicists terms they have poor dimensional stability. This is partly due to the fact that wool is under tension during knitting. The finished cloth or garment is 'relaxed' usually by steaming. As many manufacturers are still not using shrinkproofing processes some knitted woollens are also subject to some degree of shrinkage in washing.

The DIVISION OF TEXTILE PHYSICS is studying the knitting process so that it can help knitters to achieve a high quality of production when using wool. By use of the spinning and knitting machinery in the Division it is possible to knit fabrics with a wide range of constructions and to measure dimensional changes.

It has been found that the size of the loop in knitting has a crucial effect on washing shrinkage. If one compares two fabrics, knitted in the same stitch from the same shrinkproofed wool, the closer knit (small loop size) fabric will shrink less

The photograph shows a prototype of the plant used for the Division of Textile Industry's new dyeing process. The wool top is being drawn from the containers on the left and impregnated with cerise coloured dye in a pad mangle.
The dye is dissolved in a strong solution of urea.
After dyeing, the wool is steamed for about 5 minutes to 'fix' the dye.
The plant can handle up to 1,000 pounds of wool an hour.





than the coarse knit. The effect is very pronounced; a small reduction in loop size can cause a reduction in shrinkage relatively twenty times as great.

Light fastness of dyes

The world of fashion demands fabrics in all colours, including white. Natural wool is off-white, having a creamy tinge to it. It can be made whiter by the use of fluorescent whitening agents. These agents are now commonly used in the textile trade. They are not only used for making wool white, but as a pre-treatment when wool is dyed in light pastel colours.

The trouble with these brightening agents is that their effect is temporary. Wool fabrics treated with them are more than usually prone to subsequent yellowing in sunlight. Research in the DIVISION OF PROTEIN CHEMISTRY has now established that a mixture of the chemicals thiourea and formaldehyde is particularly effective at preventing the yellowing of brightened wool by sunlight. This discovery is still in the laboratory stages. So far no industrial anti-yellowing process has been developed.

Dyeing and shrinkproofing

The introduction by the International Wool Secretariat (I.W.S.) of 'Woolmark' has had a number of repercussions for CSIRO scientists. The fashion houses of Europe are now asking the I.W.S. for better dyeing techniques and ways of dyeing wool in clear, bright, pastel colours. At present many shades can't be obtained.

The problem is that wool dyes don't usually have the brightness, fluorescence, or luminosity of other dyes. If they do have these qualities the dyes aren't fast enough. And the advent of the 'easy care' era for garments means that all woollens must be easily washable, and fast dyes are therefore essential.

Scientists in the DIVISION OF PROTEIN CHEMISTRY have been examining the effect of shrinkproofing processes on the dyeing quality of wool. It has been found that many of the processes, involving oxidative chemical treatments (such as chlorination), cause the wool to become dulled or discoloured during dyeing. This makes it impossible to get clear shades. Additive treatments, which typically deposit resins on the wool surface, don't promote dulling and discolouration. Wool treated in this way can be dyed much more successfully.

Burrs in wool

The Australian wool clip, instead of being assessed largely on the 'know-how' of wool buyers, is being subjected to an increasing amount of testing for moisture content and fibre yield. The DIVISION OF TEXTILE PHYSICS has a long established interest in the improvement of sampling and testing methods.

The Division has lately turned its attention to rapid methods for measuring vegetable matter (burrs and grass seeds) in wool. About three-quarters of the national clip has less than 3 per cent of burr, the rest ranging up to 15 per cent.

It is important for buyers and processers to know how much burr there is in a wool consignment. The buyer needs to know because it enters into calculations of the clean wool content. And burr content is one of the criteria used in deciding whether wool is to be processed through the woollen or worsted system. A low burr content is necessary in worsted processing.

The Division has begun with a study of sampling. A sample is taken from a wool bale by inserting into it, and then withdrawing, a long sharp-ended steel tube. The sample is then pulled out of the tube. If clumps of burrs occurred which were of the same order of size as the sampling tube, loss of sampling accuracy would result. This effect was found not to occur until the tube diameter was reduced to half an inch. Seven-eighths inch tubes are used in practice. In collaboration with the DIVISION OF MATHEMATICAL STATISTICS the Division is now working out how many samples must be taken from a consignment to give accurate and dependable measures of burr content.

New scouring plant

The first operation in wool processing is cleaning, or scouring. In traditional methods the greasy, dirty wool is scoured in a bath of soap-soda solution, though nowadays synthetic detergents are often used instead. The trouble with this is that the wool becomes very tangled, and the fibres tend to get broken in the carding and combing processes which follow later.

Several years ago the DIVISION OF TEXTILE INDUSTRY developed a dry-cleaning process in which the wool was jetted with white spirit, an industrial solvent. A 'solvent degreasing' plant, as it is called, is now in daily industrial use in a top-making firm in Adelaide. It works very well but the capital costs of the process have been too high to encourage its wider use.

More recently, the Division has developed a jetting process which uses commercial synthetic detergents and requires less capital outlay. Greasy wool is conveyed under the jets by perforated rotating drums. The British firm of Petrie and McNaught Ltd. have built a plant of this kind under licence from CSIRO. It is being installed by Wool Combers Ltd., the largest top-making firm in Bradford.

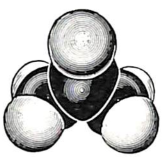
Melting wool

Fibres like terylene can be permanently set into desired shapes by heat treatment, but heat-setting of wool produces only a temporary effect. It could in the future be useful for wool if permanent setting could be carried out in the same plant and by the same processes used for synthetics.

Scientists in the DIVISION OF TEXTILE PHYSICS have been subjecting wool to a process akin to melting. The wool is heated to temperatures above 100 degrees Centigrade either under vacuum or in water under high pressure.

The wool fibres soften, and undergo internal structural changes. Their swelling behaviour in water changes. Normal wool fibres swell in diameter in water, while 'melted' fibres swell lengthways. This research has revealed some possible short-cuts in work on the chemical treatment of wool. Clues about the likely usefulness of chemicals can be obtained by measuring their effect on the melting point of wool.

Chemical strengthening of wool



Wool, like leather, rubber and plastics belongs to the group of chemical substances called polymers. These polymer molecules are very much longer than they are thick, and are really long repetitive chains of smaller agglomerations of atoms. They can be mentally pictured as long strings of sausages. When these molecules are aligned in parallel fashion, as they are in the centre of the wool fibre, there exists a possibility of building chemical links or bridges between them. If this can be achieved, as it is for example in the vulcanization of rubber, the properties of the material will be changed.

In the DIVISION OF PROTEIN CHEMISTRY scientists have been trying to build chemical bridges, or 'crosslinks' between molecules of wool protein. They have achieved such crosslinkages with a range of chemical reagents ('active esters and active amides') which they have produced themselves.

The effect of introducing these crosslinkages is best seen if the naturally existing but weaker crosslinkages in wool are first removed. It is then found that the chemically crosslinked fibres are stronger, less elastic, swell very little in water, and are more resistant to some forms of chemical attack. Crosslinked wool is more difficult to impart a 'set' to, but if crosslinking is introduced after setting the 'set' is much more permanent.

Over $1,000,000,000 worth of perishable food is produced in Australia every year. All of it is transported, most of it is processed, and a good deal of it is exported.

The consumer wants his food to be fresh in appearance, attractive in flavour, nutritious, inexpensive and of good keeping quality. One of CSIRO's jobs is to help the food industry to meet these requirements.

Research on meat, fish, eggs, fruit and vegetables is centred in the DIVISION OF FOOD PRESERVATION. The DIVISION OF DAIRY RESEARCH concentrates on butter, cheese, fresh and processed milk. The Bread Research Institute, a trade research association, studies the problems of the baking industry, and its work is supported by basic research in CSIRO's WHEAT RESEARCH UNIT.

Machine made cheese

In February, 1967, representatives of the Australian cheese industry attended a demonstration at the DIVISION OF DAIRY RESEARCH. They witnessed the first public demonstration of commercial plant for making Cheddar cheese by an entirely mechanical process.

Cheddar accounts for 90 per cent of Australia's cheese production and about 60 per cent of world production. It has been made for centuries, according to the following recipe. A vat of warm milk is soured by bacteria, then coagulated with rennet. The curd is cut into small cubes, which break free of the whey. The curds and whey are warmed a little more, and the mixture is stirred. The whey is drained off, and the curd particles settle as a bed on the bottom of the vat. They begin to cohere. Then the bed of curd is cut into slabs, which are turned over every few minutes. The slabs are finally sliced into finger-sized pieces, salted, placed in moulds, and squeezed in a press. What comes out of the moulds the next morning is Cheddar cheese ready for maturing.

This was the method used until a decade ago at all levels from farmhouse to factory. In the factory, the only power driven machines were the stirrers and the curd slicer.

In 1954 the DIVISION OF DAIRY RESEARCH set out to find a way of mechanizing and improving the hygiene of this laborious process. By 1958 the ground work had been completed, and industrial collaboration was sought. Teams from the Division and from the engineering firm of Bell Bryant Ltd. developed an industrial scale machine for slicing and salting curd and weighing it into moulds. This machine is now being widely used in Australia and other cheese producing countries. Details supplied by Australian cheesemakers suggest that it is now reducing their labour costs by $400,000 a year.

The most difficult part of the process to mechanize was the 'cheddaring' phase in which the curd particles were converted, by regular turning, into a smooth-textured mass.

This has at last been achieved, again in cooperation with Bell Bryant. The new machine has a capacity of 6,000 pounds an hour and can be operated by one man. Five men would be needed to do the same job manually.

By using both machines and completely mechanizing the process, it should be possible to reduce labour costs in factories by 60 per cent.

Bananas

Bananas, once picked, ripen very quickly. The growers' objective is to get their fruit to market while it is still green and hard. Often bananas are transported in very hot weather. They become overripe in the market and either go bad or have to be sold at a discount.

The DIVISION OF FOOD PRESERVATION has found a simple and easy way of keeping the fruit green. By merely sealing bunches of bananas in polythene bags and excluding air, respiration and ripening can be slowed down. The onset of yellowing can be delayed for 10 days, even when the temperature is in the eighties.

A disadvantage of the polythene packing technique is that it aggravates the problem of black-end rot, a fungus disease of bananas which is familiar to Australian housewives (see illustration). In collaborative work with the New South Wales Department of Agriculture, the Division has found a way of controlling this disease. Bananas are normally dipped in a fungicide solution, but the dip doesn't protect them from this particular disease. The invesigators have now found that a chemical called thiabendazole is dramatically effective, even when used in a very weak solution.

Freeze drying

Not many foods can be dried simply by leaving them in the sun or applying heat to them. Taste, texture, or appearance is usually affected. To overcome these disadvantages a method called freeze-drying was invented about thirty years ago. The food is first snap-frozen, then placed in a vacuum chamber. Under the vacuum, water is removed by vaporizing the ice-crystals.

The condition of foods dried in this way is excellent, but the process is not cheap. The average cost is about five cents a pound. This is satisfactory for expensive foods like strawberries or mushrooms, and the method is in fact used on them.

A scientist in the DIVISION OF FOOD PRESERVATION has invented a way of substantially reducing freeze-drying times. He has achieved this by admitting pulses of gas so as to vary the vacuum pressure in the chamber during drying. Each time a surge of gas enters the chamber it helps some heat to penetrate to the inside of the food being dried. As the gas is drawn off by the vacuum, it flushes water vapour out of the tiny pores in the outer layers.

This new method has been tried on 60 pound samples of food, including beef, sliced apple, and egg pulp. It worked with all of them, and reductions in drying time of up to 50 per cent were achieved. This suggests that the method could, in commercial use, lead to significant cost reductions.

Arrangements have been made with a Sydney engineering firm, James Budge Pty. Ltd., for commercial development of the process.

Drying ginger

In the Buderim region of Queensland, about 70 miles north of Brisbane, there is a small but rapidly growing ginger industry. In 1963 less than 400 tons of green ginger were produced; but already annual production has passed 2,000 tons.

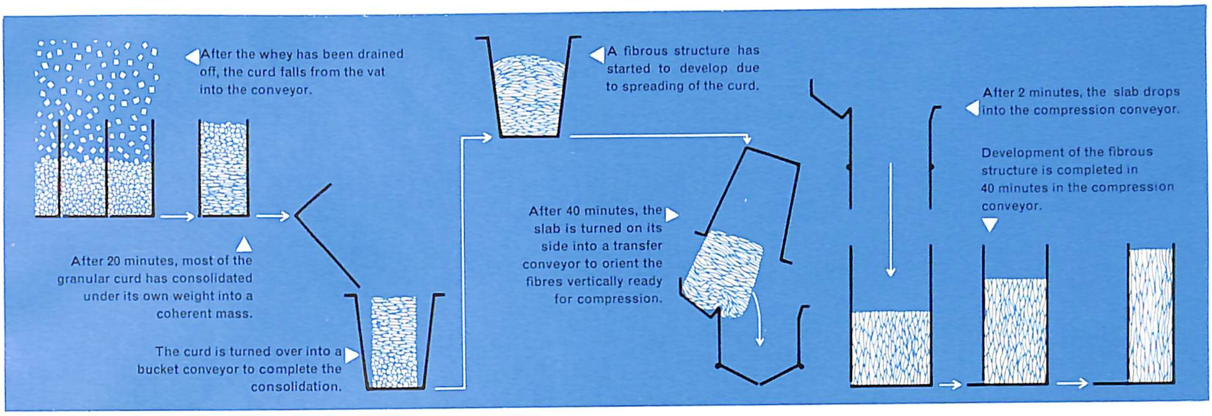
The green ginger roots, with a moisture content of about 90 per cent, were until recently dried and processed by the local growers cooperative in a batch dryer. By 1964 production was overtaking the capacity of the plant, and help was sought from the DIVISION OF FOOD PRESERVATION.

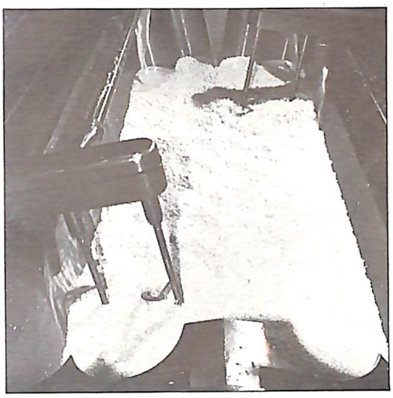
The Division's staff is well equipped to tackle drying problems of this kind. They have successfully dealt in the past with difficulties in drying peanuts and rice. They first made a laboratory study of the drying characteristics of ginger. Calculations based on these tests showed that 2,000 tons of ginger a year could be dried on a machine no bigger than the cooperative's existing dryer, if a continuous process could be used.

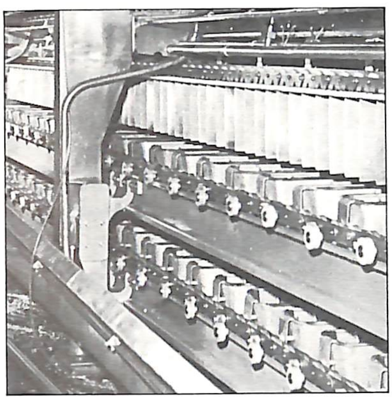
A design was developed in the Division for a dryer comprising a rotatable drum with sloping vanes to move ginger through it. This was then built, using most of the parts of the old dryer. The rebuilt machine reduces moisture content from 90 per cent to 10 per cent. Its capacity since re-designing and rebuilding has been increased six-fold. The investigations were supported financially by the growers.

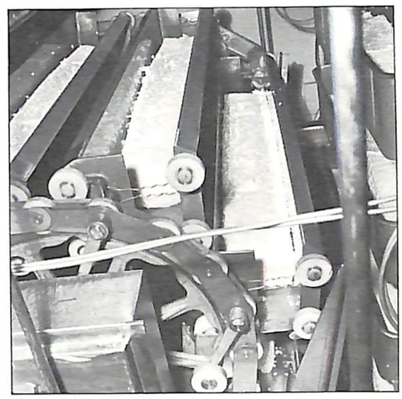
Cheesemaking
CSIRO's new 'cheddaring' machine converts pea-sized granules of curd into a smooth-textured mass. The conversion is effected by a gentle squeezing process, during which the curd first becomes fibrous, then homogeneous.

Bananas
The lower bananas are afflicted with the fungus disease called 'black-end rot'.
The others have been dipped in thiabendazole solution, which protects them from the disease.









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Drying prunes

About 3,000–5,000 tons of Australian plums are turned into prunes every year by drying. Trucks holding trays of fruit are passed slowly through a long tunnel, while hot air is blown through in the opposite direction. This method, known as a counter-flow system, will dry prunes in 24–30 hours, depending on the size of the fruit.

Forty years ago, scientists in California tried blowing the hot air through the tunnel in the same direction as the prunes. They reported unfavourably on this 'parallel-flow' method. Following up some 1965 work in California, the parallel-flow method has recently been reappraised by the DIVISION OF FOOD PRESERVATION.

The experimental evidence confirmed that the parallel-flow method is, in fact, superior. It allows prunes to be dried much more quickly without loss of quality. The detailed results have been passed on to the industry.

Powdered butter

Five years ago the DIVISION OF DAIRY RESEARCH announced the discovery of a new dairy product, powdered butter. Successfully produced in pilot-scale equipment, it contained as much butterfat as butter (80 per cent) plus milk proteins and mineral salts. Among its advantages over butter were stability in hot weather and easier mixing with other ingredients.

Since 1962 there have been numerous enquiries about powdered butter from all over the world. Now a commercial demand for it is evident in Australia, from manufacturers of cake mix. At the Warragul (Victoria) factory of Holdensen and Neilson Pty. Ltd., a member of the Petersville group, manufacturing trials have been conducted. Some troubles have appeared, mainly because it is difficult to handle hot butter powder without damaging it. Special modifications have been made to the spray dryer (designed for milk powder) to enable the butter powder to be extracted without harm or loss. One modification is the incorporation of a fluidized-bed cooler (see page 54) to cool and harden the particles of powder.

About 60 batches of butter powder have now been made under a wide variety of drying conditions. It is clear that manufacturing conditions need not be too stringent, and that a good product can be made with any one of several variations of the process.

Fresh milk from the shelf

A new process called U.H.T. or ultra-high-temperature sterilization has been introduced into Australia. It has been in use in Britain and elsewhere for the past few years. Milk or cream is heated to 270 degrees Fahrenheit for one or two seconds and then flash cooled in a vacuum chamber. The resulting product is almost indistinguishable in taste from the fresh product, but the milk will keep for six months on the shelf, and the cream for six weeks.

The first Australian plant has been installed by the Launceston firm of Bakers Milk Pty. Ltd. The firm is exporting U.H.T. sterilized milk to Singapore, and packing cream for local sale. The DIVISION OF DAIRY RESEARCH is making a study of the whipping quality of U.H.T. sterilized cream, and is working out just how the cream should be processed to ensure that it will whip well. Because the process will eventually be used in Australia generally the Division has drafted standards for the product. These are being transmitted to the States through the National Health and Medical Research Council.

Engineering and construction

THE DIVISION OF MECHANICAL ENGINEERING's main interests are in engineering fields of special interest to Australia, such as refrigeration, air-conditioning, the use of solar energy, and agricultural engineering. The DIVISION OF BUILDING RESEARCH is concerned with building materials, acoustics, construction methods, building operations and economics, and building in the tropics. The properties of soils as foundations, whether for roads, buildings, airfields, bridges or railway tracks, are studied by the SOIL MECHANICS SECTION. The DIVISION OF FOREST PRODUCTS is included under the 'Construction' heading as most Australian timber is used for constructing something, be it a fence, a house or an article of furniture.

Water for Coober Pedy

The DIVISION OF MECHANICAL ENGINEERING has pioneered the design of solar stills, in which heat from the sun is used to distil salty or brackish water. At the opal-mining desert township of Coober Pedy the South Australian Engineering and Water Supply Department has constructed the world's largest solar still, built to CSIRO's design.

The still, which is 38,000 square feet in area, has been operational for several months, producing up to 3,500 gallons of fresh water per day. There have been some difficulties with willy-willies and windstorms, and one corner of the still was damaged by a 100 m.p.h. gust. Minor design modifications have been made to stop this happening again.

Smaller stills have been built to CSIRO specifications in other isolated desert communities with brackish water supplies. Users include a motel on the Nullabor east-west road, and another on the Geraldton–Carnarvon road. Enquiries from all over the world are now being received. Some enquirers are considering building stills up to 100,000 square feet in size.

Comfort cooling

One of the world's most pressing problems is how to raise productivity in the tropics. Two-thirds of the world's population lives in the hot regions of the Earth, within 30 degrees of latitude from the Equator. The running costs of refrigerated air conditioning put it beyond the means of most people in the developing countries.

The DIVISION OF MECHANICAL ENGINEERING is investigating the performance of a new type of cooling system called Rock Bed Regenerative (RBR) cooling. The system involves the cooling of a bed of crushed rock with air from an evaporative cooler, then drawing drier fresh air into a building through the cooled rock bed. Prototype coolers are now in operation at Townsville, Brisbane, Griffith (New South Wales), Northam (Western Australia) and Melbourne. Power consumption for each of these plants is about 600 watts, less than that of a small radiator. The power consumption of an equivalent refrigerated air conditioner would be up to five times as much. At the peak of Melbourne's heat wave in February, 1967, the temperature in the RBR-cooled test house was 80 degrees, while the outside shade temperature was 105. The advent of natural gas may mean that RBR systems can be operated economically in winter for heating. This idea is being tested during the 1967 winter.

Scientists in the DIVISION OF BUILDING RESEARCH have been trying to find out what 'comfort' means to non-indigenous people living in New Guinea. Two surveys, each of three months duration, were recently conducted at Port Moresby.

Thirty-two men and women living in sixteen houses of four different types of construction took part. At specified intervals they filled in cards, noting their reaction to the temperature. They also recorded air movement, their previous activity, and whether they were sweating or not. Temperatures were taken from

1 The solar still at Coober Pedy covers nearly an acre. The sun shining through the glass heats water flowing slowly along a black shallow runnel. Some of the water evaporates, condenses on the glass, and pure distilled water runs off into gutters at the side.

2 A decorative mosaic panel made from enamelled glass.

3 Blue metal is one of the several kinds of aggregate which can be coloured with ceramic glazes.

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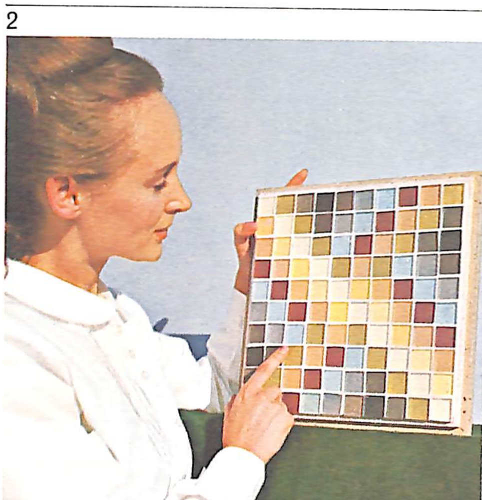

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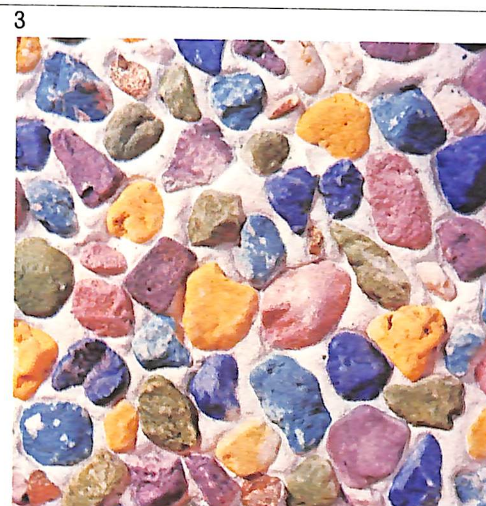

recording thermometers fixed to the walls of the houses.

The information from 3,600 cards was analysed in a computer. Some of the results were a little surprising. When there was only slight air movement in the house, the preferred temperature was 78.5 degrees, whereas in Sydney people are most comfortable at 73. Most of the difference is probably due to clothing.

New building materials

A number of new building materials have been invented by scientists in the DIVISION OF BUILDING RESEARCH. They are all ceramics, made by baking earthen materials at high temperatures. Several of them have been patented, and eight Australian companies have taken licences to manufacture.

Lightweight ceramics One new material is made by taking bloated clay or shale and bonding it with low melting natural or synthetic glass. Bloated aggregate has been fully available for some years, since the Division pioneered its use in lightweight concrete. The lightweight ceramic material can be cast in sheets or in any other desired shape or form after which it is fired at 1,000 degrees Centigrade. The final products are especially suitable for the external cladding of buildings. They are attractive looking, forty per cent lighter than bricks, and have the advantage that nails can be driven into them.

Basalt based ceramics A ceramic material can be made from 'basalt fines', particles of bluestone or road metal smaller than $\frac{1}{8}$ of an inch. The particles are a normal by-product of quarrying operations. They are bonded together with suspensions of clay in water, cast into moulds, and fired in a furnace. When the mix is fired at about 1000°C the resulting product can be used as a surface sheeting material or as a substitute for bricks or floor tiles. If the furnace temperature is higher the material is much more resistant to thermal and mechanical shock, abrasion and chemical attack. This greatly widens the potential field for the material, not only for building but for industrial uses.

Coloured aggregate The Victorian Housing Commission asked the DIVISION OF BUILDING RESEARCH to develop an attractive finish for exposed aggregate in concrete panels. The Division produced a series of low melting glazes with metal oxide pigments. These have been used to colour various forms of natural aggregate, including sand, river gravel, quartz, sandstone and blue metal.

Glass mosaics A new decorative material has been made by applying an alkali-resistant low melting enamel to ordinary window glass. Any sort of glass is suitable, including cheap materials like defective window glass, in any size down to half an inch square. The material can be used for making mosaics on concrete or for other decorative purposes.

Zircon ceramics Zircon, or zirconium silicate, is a product of the beach sands industry. Australia produces 85 per cent of the world's supply. The DIVISION OF BUILDING RESEARCH has found that zircon concentrates, with certain additives, can be moulded and made into ceramics. Zircon ceramics are highly heat-resistant and seem likely to have many industrial uses. Zircon can also be used as a raw material for making pigments for coloured ceramic glazes. It has also been added to the basalt-based ceramics to improve their resistance to heat and abrasion.

Economics in building with concrete

In conventional multi-storey buildings, concrete floors are supported on horizontal beams which are fixed to vertical columns. During the last ten years Australian builders have tended to adopt the 'flat plate' method of construction. A flat plate is a rigid slab of uniform thickness, attached to, or sitting on vertical columns.

The flat plate method reduces the overall height needed for each storey, and saves costs in elevators, stairs, air conditioning and construction materials.

The DIVISION OF BUILDING RESEARCH has been studying flat plates for several years. With the assistance of the building industry four experimental plates have been erected at the Division. The object of the research has been to make the slabs as rigid as possible.

Much has been achieved. The research team has discovered how to distribute the steel rods in reinforced concrete so as to maximize the rigidity of the slab. They have determined how thin slabs can safely be made in terms of the gaps which they must span. They have also studied the use of pre-stressed concrete and worked out the best distribution of pre-stressing 'tendons' or steel cables.

The Division has acted as a consultant to the contractors for several large flat-plate structures, including the R.A.C.V. and Princes Gate buildings in Melbourne, the Victorian State Offices, and the Carlton Centre in Sydney.

Resources for country roads

In half the rural areas of Australia there is a critical shortage of road-making materials. A road making contractor needs supplies of gravel and rock for crushing at no great distance from where he is working—in his terms 20 miles is a long haul. It is vitally important that he should have no difficulty in locating sources of raw material of suitable quality.

One of the aims of the SOIL MECHANICS SECTION has been to find a way of classifying country in terms of its resources of road-making material. In 1964 the Section ran a mobile field conference in northern Australia, to which engineers came from all over the world.

The information gained from the conference and from its own research results has enabled the Section to bring the project to a stage of finality. There is now a complete methodology for recognition, classification, description and mapping of road-metal deposits. The system can be used by any authority which has normal equipment for aerial photography and ground facilities for defining the engineering properties of the raw materials. The Section has itself drawn a number of 4-inch-to-the-mile maps of representative areas of northern Australia to demonstrate how the system is used.

How good is a soil sample?

If a sample of soil is taken from the earth for chemical testing, it doesn't matter if it gets shaken up a bit. The chemical composition won't change. But if the sample is destined for physical tests, such as tests of compressibility or load bearing capacity, then one must treat it as gently as possible. Exerting force on it can bring about irreversible changes.

Scientists in the SOIL MECHANICS SECTION have been studying the effects of the sampling process on the soil sample. They have found that even when 'good' sampling techniques have been used the samples have been subjected to forces half as great as those used to produce failure in the laboratory. In other words the sample is pre-stressed, and tests on it can give misleading results. It is clearly important to find ways of sampling which exert smaller forces. Meanwhile, it is necessary to recognize that samples are pre-stressed.

For example some of the piers for the Lower Yarra Bridge will be founded on compressible clay. The foundation designs are influenced by the clay's compressibility. Compressibility figures based on 'good' samples had indicated the need for an expensive type of deep foundation, but when the SOIL MECHANICS SECTION used improved sampling techniques it was shown that conditions were better than had been thought. A saving exceeding $500,000 can now be made.

Removing deposits from the pulp mill

For nearly 30 years various species of *Eucalyptus* have been used commercially for the manufacture of paper pulp. One of the problems in the industry is the accumulation of hard deposits on the equipment used for washing the pulp and at other places in the mill. These deposits are formed by interaction between salts in the washing water and materials derived from the wood itself.

Until recently each pulp washer had to be closed down for cleaning once a week. The cleaning process took about eight hours, and was somewhat hazardous, involving the use of concentrated nitric acid. Scientists from the DIVISION OF FOREST PRODUCTS and from Australian Newsprint Mills (Boyer, Tasmania) have now developed a new cleaning process. It does not use dangerous chemicals, and cleaning time is reduced to about ten minutes. Plant shut-down time is reduced accordingly. It is hoped to apply the process in other Australian pulp mills.

Pines from Portugal

The Western Australian Forests Department is planting forests on sites which are not suitable for other forms of cultivation. For these poor soils it has chosen the pine tree *Pinus pinaster*. Cuttings, seeds and wood specimens from above-average trees were recently imported from Portugal, where this type of pine was established four hundred years ago.

Using material brought to Australia, the Department is establishing a superior seed orchard. It will select the seedlings likely to grow best in the forest. The DIVISION OF FOREST PRODUCTS is taking part in the project by studying wood specimens from the parent trees. It is not only necessary to produce healthy, fast-growing trees; it is also important that the wood quality should be the best possible.

Pine trees and sirex wasps

When the Sirex wasp lays its eggs in pine trees, it infects the wood with a fungus. Some trees can confine the spread of this fungus. Others can't and subsequently die. The DIVISION OF FOREST PRODUCTS has been examining some aspects of the resistance of *Pinus radiata* to the fungus.

An examination was made of the trees that had recovered from attack by Sirex. Chemical compounds known as stilbenes were found in the sapwood surrounding the area attacked by the fungus. The stilbenes have fungistatic properties and are responsible for restricting the spread of the Sirex-borne fungus. Trees killed by the fungus showed no trace of stilbenes. Further work is being done to find out how the formation of stilbenes is 'triggered off' in the resistant trees. This might lead to a way of controlling the destruction of pines by Sirex.

Preserving New Guinea timbers

Many timbers used in buildings in Papua–New Guinea are not very durable, and have to be treated with preservatives. Ten years ago the DIVISION OF FOREST PRODUCTS developed and patented a low-cost dip-diffusion preservative treatment for building timbers. This is now widely used throughout the Territory.

In its original form, the various ingredients of the preservative had to be mixed together at the treating plant. Now the Division has modified the preservative so that it can be supplied in the form of a ready-mixed dry, free-flowing powder. This new development has also been patented and Australian manufacturers are supplying $250,000 worth of powder per year. This is enough to preserve most of the building timbers used in the Territory, estimated at about 20 million super feet per annum.

Chemistry and mineralogy

ALMOST EVERY laboratory in CSIRO has chemists on its staff. Certain Divisions, however, are built up around groups of scientists who share a common interest in one branch of chemistry. These are the Divisions of APPLIED CHEMISTRY, APPLIED MINERALOGY, CHEMICAL ENGINEERING, CHEMICAL PHYSICS and MINERAL CHEMISTRY, known collectively as the CSIRO CHEMICAL RESEARCH LABORATORIES. Many of the interests of the ORE DRESSING SECTION also centre around chemistry.

The problems of Australia's rapidly growing mineral industries absorb much of the interest of these laboratories. The problems are immediate, of great economic importance, and many of them are unlikely to attract the attention of research workers outside Australia. Some are of wide interest to the whole industry, while others are much more specific.

Drilling holes

One of the most basic and potentially widely applicable projects is a study of new ways of drilling holes in hard rock. Conventional drilling is expensive; a single 10,000 foot hole may cost as much as \$200,000. Many hundreds of thousands of feet of exploratory drilling are done in Australia each year and much more would be done if a cheaper method of drilling holes were available.

Scientists in the DIVISION OF APPLIED MINERALOGY, working at Perth, are cutting rock in the laboratory with high pressure water jets. In a typical experiment, water is compressed to 30,000 pounds per square inch, and then released through a fine jet. The water emerges with a velocity calculated to be about 2,000 feet per second and for a fraction of a second can penetrate granite at a rate of one foot per second. This is very much faster than conventional drilling rates but formidable mechanical problems have yet to be overcome in sustaining the jet velocity as the hole deepens. Nevertheless, the experiments suggest that these problems are worth tackling.

What is down the hole?

Conventional methods of drilling are of two kinds, rotary and percussion drilling. Rotary drilling allows the operator to withdraw cores, or cylindrical segments, from the hole, so that he can inspect and analyse samples from any given depth. Percussion drilling, which costs only one-fifth to one-tenth as much, does not yield cores from hard ground for inspection. Percussion drilling, being cheaper, would be more widely used if the operator could easily ascertain what was down the hole.

In the DIVISION OF MINERAL CHEMISTRY, scientists have conceived and are building a device which, when lowered down a hole, will identify metal bearing deposits. This instrument, which fits down a 3-inch diameter hole, fires neutrons at the walls of the hole. Most metals, when bombarded with neutrons, will respond by emitting gamma rays which are characteristic of the metal. The instrument has a gamma ray detector and will transmit to the surface information about what sort of metal, in what concentration, is located at a given depth.

Grinding ore

Grinding is an important part of mineral processing. Before lead, gold, zinc, tin, copper and other metals can be extracted from their ores, it is necessary in most cases to reduce the ore to powder.

Grinding can represent up to a third of the total cost of mineral processing, so it is important that it should be done efficiently. The key process, after preliminary crushing, takes place in a large machine called a ball mill, which breaks up lumps of ore by bombarding them with steel balls.

Research workers in the DIVISION OF

Bushfire research

Control burning in springtime in a eucalypt forest. The mild flames remove the litter and reduce the likelihood of bushfires in the summer.

(**a**) After a big bushfire weeds soon spring up again. The trees still living are badly damaged. The proliferation of new shoots makes the timber knotty and greatly reduces its value.

(**b**) After a control burn the trees are quite unharmed.

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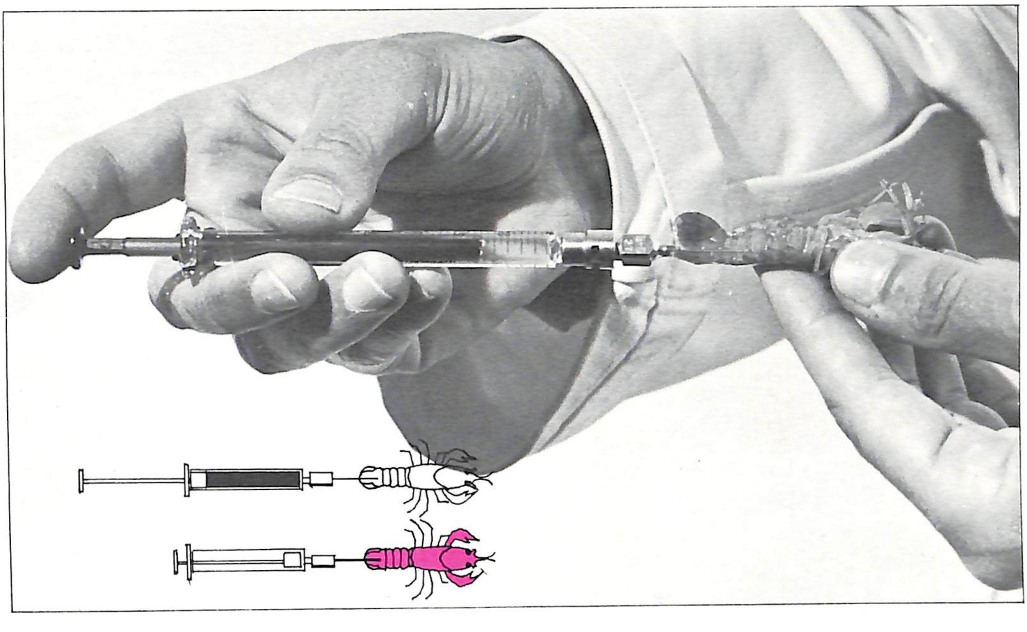
Insect hormones

One of the hormones obtained from crayfish waste can be detected by its ability to induce colour changes in yabbies.

This hormone and crustecdysone are usually found together.



CHEMICAL ENGINEERING have been making a study of just what happens in a ball mill. They are finding out how long particles remain in the mill, the rate of breakage of particles of different sizes, and the range of particle sizes after one breakage event.

By securing this information they have been able to simulate mathematically what is going on in the ball mill. This means that it is possible to predict exactly what will happen if there is any alteration in the hardness or grain size of the crushed ore entering the mill.

In the long run, it may lead to automatic control of the process, perhaps using a digital computer, so that ball mills can always be operated with maximum efficiency.

The ORE DRESSING SECTION is approaching the problem of ball milling efficiency from a different direction. A store of information about the grindability of different ores (in terms of power consumption per ton) is being built up. The ores are being subjected to laboratory tests which measure ease of grindability. Comparison between laboratory test figures and actual plant power consumption figures should show up any cases of inefficiency or errors of practice in industry. The study may also demonstrate a need to modify existing test methods.

Fluidization

The fluidized bed is widely used in industry. It consists of a chamber filled with solid particles such as iron pyrites, green peas, or a catalyst for cracking petroleum. A blast of air or gas is blown upwards through the bed with a force greater than the weight of the solid. The solid particles are violently agitated and the whole mass becomes fluid. The purpose may be to change the solid (pyrites is burnt and peas are frozen in fluidized beds) or to change the gas (petroleum vapour is 'cracked', or reduced to lighter fractions).

The DIVISION OF CHEMICAL ENGINEERING has been doing research on fluidization, using a large test bed with a 150 horsepower blower. Various sources of potential trouble have been discovered. For a start, experiments show that some regions of the bed may become defluidized. There is a certain critical gas flow rate (not predictable from small-scale experiments) where the whole bed is fluid, and this is influenced by the number and flow resistance of the openings in the air or gas distributor. Many existing plants tend to run at unnecessarily high flow rates with consequent waste of power.

Another problem is bubble formation, which can cause serious operating deficiencies, especially where chemical reactions are supposed to take place. A delicate sensor for detecting this fault has been built in the Division.

These experiments are providing the sort of information which will help engineers to design better plants, and to correct faults in existing ones.

Upgrading ores of titanium

Titanium oxide is the basic pigment material for paint. Australia is one of the world's main suppliers of raw materials from which it can be extracted. The main source is beach sand, which yields a small amount of rutile (95 per cent titanium dioxide, worth $90 per ton) but much greater amounts of ilmenite (50 per cent titanium dioxide, worth $10 per ton). The value of ilmenite exports is now of the order of $3,500,000 a year, but export earnings would be greatly increased if the ilmenite could be easily upgraded here.

Two mining companies have been supporting research to this end in CSIRO. Western Titanium N.L., a firm producing ilmenite in Western Australia, has joined forces with the DIVISION OF APPLIED MINERALOGY to explore the possibilities of upgrading ilmenite on lines originally suggested by members of the Western

Australian Government Chemical Laboratories. The result has been a new and potentially economic process which produces a titanium compound called anosovite. This material yields over 90 per cent of titanium dioxide and could be readily refined in existing pigment plants overseas.

At the same time the firm of Murphyores Pty. Ltd., which operates on the east coast of Australia, has sponsored work in the DIVISION OF MINERAL CHEMISTRY. After two years of basic research into the chemical reactions involved in removing iron from ilmenite, a solution process was developed. With this process it is possible to enrich ilmenite to a product containing 96 to 97 per cent titanium dioxide.

Patents to cover both these processes have been applied for, and both are now being studied at pilot plant level.

Carbon for aluminium production

Aluminium production at Bell Bay (Tasmania) and Point Henry (Victoria) is based on the electrolysis of alumina, obtained from bauxite. The process involves the use of carbon electrodes. The carbon must be of a special kind which is hard, pure and dense. At present this carbon is being manufactured abroad from petrol refinery residues. By 1970, our imports of electrode carbon will top 80,000 tons, worth more than $3,000,000. Obviously, it would be to Australia's advantage if it were made here.

In the Coal Research Laboratory of the DIVISION OF MINERAL CHEMISTRY tests have shown that suitable carbon can be made from natural gas. The process involves cracking the gas at high temperatures under controlled conditions to give very low-ash carbon together with large quantities of hydrogen gas.

If the process can be scaled up to industrial size, and if the hydrogen can be used in the manufacture of nitrogenous fertilizers (such as urea and ammonium nitrate) for which there is a growing demand, then carbon could be produced at a lower price than the imported product.

Bushfire prevention and control

If the debris on the floor of a forest is burnt under conditions where the forest trees are not damaged, the danger from summer bushfires can be considerably reduced. In the spring of 1966 the Western Australian Forests Department carried out trial burnings in collaboration with the DIVISION OF APPLIED CHEMISTRY's bushfire research team. The DIVISIONS OF RADIOPHYSICS and METEOROLOGICAL PHYSICS sent observers to make meteorological observations at the scene of the fires.

The method used involves dropping incendiary capsules from aircraft. A machine was built to make and drop an incendiary every two seconds, with complete safety and reliability. With a light aircraft and this machine 90,000 acres of forest floor were burnt off in 11 days, and a further 90,000 acres were burnt a few weeks later.

As a result, the fire hazard in Western Australia was greatly reduced, and for the first time there is a wide protective belt through the southern karri and jarrah forests. This was accomplished at a cost of only 10 cents an acre. Harm to wildlife seems to have been negligible.

After the disastrous Tasmanian fires of February, 1967, scientists from the DIVISIONS OF APPLIED CHEMISTRY and FOREST PRODUCTS and the Commonwealth Experimental Building Station (Department of Works) visited the scene. Questionnaires were given to 600 people whose houses had been destroyed, and a like number whose houses had just escaped. A tentative conclusion was that timber houses were no more prone to catch fire than brick. Despite contrary indications in press reports, no clear evidence could be established that houses exploded. At the worst time, when the temperature was over

102°F, relative humidity below 10 per cent, and wind gusts over 60 miles an hour it seems that large flaming masses of gas from the fire front leapt hundreds of feet into the air, descending to ignite the bush a quarter of a mile downwind.

Insect hormones

The control of insect pests by insecticides has enabled us to increase world agricultural production and control insect-borne diseases. But unrestricted use of insecticides may create hazards for wildlife and even for man.

One of the many alternative ways of controlling insects could involve the use of insect hormones to upset normal patterns of growth, development and reproduction. Most important, such hormones may be entirely specific to insects and harmless to wildlife and to man.

One of the difficulties in studying insect hormones is getting enough material. Scientists in the DIVISION OF APPLIED CHEMISTRY overcame this problem by trying a new attack. They obtained a few milligrams of hormone material from a ton of crayfish waste. Crayfish are biologically related to insects, and the hormone was found to be highly active in influencing blowfly development.

The new hormone, called 'crustecdysone' was analysed, and an effort was made to find other sources of it. The Australian brown pine *Podocarpus elatus* was found to be a rich source, so a more extensive study of crustecdysone will now be possible. It is already known that it can readily kill insects if doses are large enough.

Ice nucleators

Artificial rainmaking depends on distributing 'ice nucleators' among the water droplets in a supercooled cloud. Each particle of the 'ice nucleator' acts as a seed upon which an ice crystal will subsequently grow. The most commonly used material is silver iodide, which is not quite ideal for the purpose. It only works well in clouds which are colder than about minus 8 degrees Centigrade.

In the DIVISION OF APPLIED CHEMISTRY various alternatives to silver iodide have been tried. Some of these are better than silver iodide, but are too toxic for use in practice. In the course of some high-pressure experiments, an extraordinary and potentially useful 'memory effect' has been discovered.

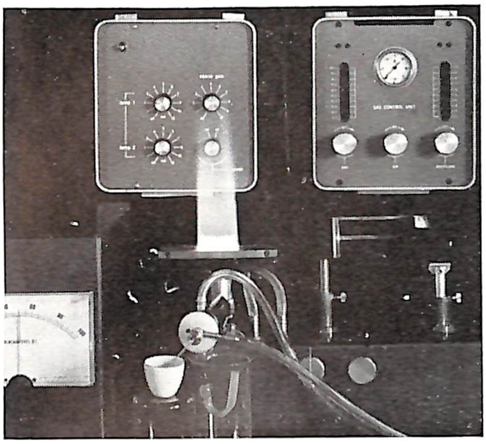
Various organic chemicals, including phenazine, vanillin and some amino-acids exhibit this effect. If they are used to nucleate ice once, and the ice is then melted, they will be far more effective nucleators on subsequent occasions. That is to say, they will seed water droplets which are not nearly as cold, or even not supercooled at all. So far this discovery is not applicable to rain-making.

In the DIVISION OF CHEMICAL PHYSICS, scientists apply some of the tools and methods of modern physics to chemical problems. This work is of the most fundamental kind, being concerned with the structure of atoms, molecules and crystals. The pursuit of basic knowledge is the Division's main objective, but practically useful inventions frequently arise from its research. Three novel or improved scientific instruments have come from the Division this year.

Analysis by light absorption

In 1953 a group of scientists in the Division invented an entirely new instrument for chemical analysis. It depended on the principle that when a light beam is passed through a flame, chemical elements introduced into the flame will absorb some of the light. The wavelength of the light absorbed is characteristic of the element; the amount of light absorption is a measure of how much of the element is present.

The instrument has hundreds of uses—for measuring trace elements in soils, cal-



cium and potassium in blood, corrosion in food cans, the proportion of metals in alloys, copper and lead in wine, and in prospecting for minerals. Exports of equipment made in Australia under licence to CSIRO now exceed $1,000,000 a year.

A number of refinements have been made over the years. The latest refinement, which further enhances the value of the instrument, was shown at the 1967 meeting of A.N.Z.A.A.S. in Melbourne and at meetings in the United States. It involves the use of a new method of detecting the characteristics of the light that has passed through the flame, and is called a 'resonance detector'. It has two advantages. Firstly, it enables several elements to be analysed simultaneously, which is useful in soil analysis, for example. Secondly, it is difficult to put the machine out of adjustment.

Leak detectors

Various kinds of industrial plant have to be completely leak-proof. Even the smallest leaks in air conditioning or refrigeration plant, pipelines or welded vessels, can cause serious problems. There is therefore a need for sensitive leak detectors, and in fact more than $US10,000,000 worth of these instruments are sold in America every year.

As a by-product of basic research in the subject of mass spectrometry, a very sensitive and versatile leak detector has been designed in the DIVISION OF CHEMICAL PHYSICS.

The device detects the presence of very tiny traces of helium gas. A system can be tested for leaks by pumping out most of the air, running helium gas over the outside, and testing for helium with the detector from inside. Alternatively, helium can be fed into the system and leaks detected by examining the surface with a probe. The new instrument is sensitive enough to detect a leak so small that it would allow less than one cubic foot of gas to pass in ten million years.

The leak detectors are to be manufactured under licence in Australia by Perkin–Elmer Pty. Ltd., a subsidiary of the Perkin–Elmer Corporation.

Micro-manipulation

The electron microscope was invented about thirty years ago. It is a powerful and versatile instrument with which one can 'see' objects far beyond the range of ordinary microscopes. Features as small as 4 or 5 hundred-millionths of a centimetre can be observed.

In the last few years scientists have been increasingly conscious of a need to move the specimen in the electron microscope while it is being examined. This enables the microscopist to learn much more about the shape and form of the object he is looking at.

A new kind of micro-manipulator has been designed and built in the DIVISION OF CHEMICAL PHYSICS. It enables specimens to be tilted to an angle of up to forty degrees in any direction. It is smooth in operation and does not permit contamination of the specimen. The device has been patented, and a licence for its manufacture is being negotiated with an electron microscope manufacturer.

THERE ARE FOUR CSIRO Divisions with broad interests in physics. They are the DIVISIONS OF PHYSICS, APPLIED PHYSICS, RADIOPHYSICS and TRIBOPHYSICS. The UPPER ATMOSPHERE SECTION is concerned with the physics of the ionosphere, which is important in long distance radio communications.

The DIVISIONS OF PHYSICS and APPLIED PHYSICS together comprise the NATIONAL STANDARDS LABORATORY. Under the Weights and Measures (National Standards) Act 1960–64 the Laboratory is custodian of Australia's standards of measurement. The two Divisions devote a great deal of research effort to improving standards, and they undertake precision calibrations for other laboratories and for industry. Not all their work is oriented to standards. The DIVISION OF PHYSICS, for instance, has interests in solar astronomy and APPLIED PHYSICS does research in production engineering and solid state physics.

The DIVISION OF RADIOPHYSICS has two main interests, radio astronomy and cloud physics, with its attendant technology of artificial rain-making. The DIVISION OF TRIBOPHYSICS is interested in the physics of the solid state, especially those properties of crystals which are determined by imperfections within the crystal or on its surface.

The PHYSICAL METALLURGY SECTION conducts research on the properties of metals and alloys. Special attention is paid to the mechanisms of deformation and fracture.

Watch on the sun

The surface of the Sun is in a state of continuous violent activity. Astronomers record huge flares, sunspots, surges and prominences. From time to time the Sun emits or ejects bursts of radio waves, blast waves, X-rays, cosmic rays, and high energy protons.

All the events which occur on the Sun are due to interactions between the solar gases (or 'plasma') and the Sun's magnetic field. Just how they interact is unknown. The study of this subject requires the use of instruments called magnetographs, which measure and record the magnetic fields in the Sun. The best conventional magnetographs will only make one observation each half hour. This is unsatisfactory, because some changes have short time scales of a few minutes, or even seconds. In the DIVISION OF PHYSICS, scientists are building a much faster device called a cine-magnetograph, which will make an observation about once a minute. This project has been supported by a $US97,000 grant from the U.S. National Aeronautics and Space Administration.

The far edge of the cosmos

A new chapter in the exploration of the cosmos was opened up in 1962 with the discovery of a new class of radio sources. These sources are not associated with galaxies but appear optically as faint star-like objects.

The starting point in this discovery was the pinpointing of the radio source catalogued as 3C273. This was done with high precision by a team of scientists from the DIVISION OF RADIOPHYSICS and Sydney University using the Division's 210-ft. telescope at Parkes, New South Wales. When plates taken with the world's largest optical telescope at Mt. Palomar, California, were examined this radio source was found to coincide with a relatively bright but unusual optical object which consisted of a star-like nucleus having a 'jet' associated with it. This identification provided a vital clue to the nature of these quasi-stellar objects, called 'quasars' for short. Analysis of the light from 3C273 indicated that it is receding with a velocity of 28 thousand miles per second. If this is due to cosmological effects then it must be 100 times brighter than the brightest known galaxy, and a class of objects has apparently been found which can be traced out to much greater distances in the Universe.

Precise determinations of position made with the Parkes telescope during the past few years have made possible the tentative identification of about 150 quasars. Identification has been based on examination of photographic plates taken at the Lick and Mt. Wilson and Palomar Observatories in California; it turns out that an object with a pronounced excess of blue or ultra-violet light seen in a position accurately pinpointed at Parkes is likely to be a quasar. They can also be recognized by their radio spectral characteristics. The three currently most distant objects are all Parkes-discovered quasars.

The quasars are exciting objects. They can be as brilliant as a hundred average-sized galaxies, but several thousand times smaller. The output of so much energy from so small a volume poses problems for physicists. In spite of their vast distances and energy outputs, changes in output can be seen, both at light and radio wavelengths, in only a few weeks.

The rotation of Jupiter

Jupiter, like the Earth, is surrounded by a Van Allen Belt, the spiralling electrons of which emit radio waves. By studying both we can get views from inside and outside a Van Allen Belt.

The DIVISION OF RADIOPHYSICS first showed that Io, the innermost moon of Jupiter, modulates the intensity of shortwave radio emission from Jupiter's Van Allen Belt. It is thought that Io distorts Jupiter's magnetic field as it orbits. The UPPER ATMOSPHERE SECTION has confirmed this effect of Io, and shown that the modulation is more complex than previously suspected.

Over ten years ago the DIVISION OF RADIOPHYSICS found that Jupiter's shortwave emission was also affected by the planet's rotation. This fact had been used to measure Jupiter's rotation rate, but the results were variable, suggesting that the rotation rate was also variable. Now the UPPER ATMOSPHERE SECTION has found that rotation should be measured by the beginning, and not mid-time, of the radio emission 'storms'.

This discovery has enabled the rotation speed of Jupiter to be measured with ten times greater accuracy. It now appears that the rotation speed is not variable after all.

Very low temperatures

At present there is no demand from Australian industry for ways of measuring temperatures approaching absolute zero (minus 273 degrees Centigrade). Such a low temperature calibration service is already needed in the United States, especially by suppliers to the aerospace industry. In Australia, the only demand at present is from Universities and research laboratories, though Australian industry is expected to need such a service within the next five years.

The thermometers used at these temperatures are quite unlike conventional thermometers. They are thin wafers of crystalline silicon or germanium, the same material from which transistors are made. Until recently they couldn't be calibrated in Australia.

Recent research in the DIVISION OF PHYSICS has enabled them to be calibrated down to a third of a degree above absolute zero. These very low temperatures are obtained with liquid helium, and the very lowest require the use of a rare isotope of helium, obtained from the U.S. Atomic Energy Commission.

Industry's need for measuring low temperatures, as distinct from very low temperatures, is rising at a rapid rate. The use of liquefied gases is becoming commonplace. The steel industry uses hundreds of tons of liquid oxygen daily, and liquid nitrogen is being widely used as a coolant in food transport vehicles.

Liquid helium and liquid air are used as refrigerants for thermometry and materials research at the National Standards Laboratory. The central unit here is a helium liquefier given to the Division of Physics by the Bell Telephone Laboratories of New Jersey. This replaces an earlier model which was made at the Laboratory and operated from 1950 to 1966.

Industry needs to test the behaviour of materials used for containers and handling equipment at temperatures in the range of minus 100 to minus 200 degrees Centigrade. The DIVISION OF PHYSICS is now providing a low temperature calibration service, based in part on the standards of the U.S. National Bureau of Standards. The Division is at present developing its own low temperature scale, which will be internationally accepted.

Length standards

For many years the world's official standard of length was a metre-long bar of platinum-iridium alloy, kept in a vault in Paris. In 1960 the metre was re-defined in terms of the wavelength of light from a lamp filled with krypton gas. This was much better than a metal bar—it could be used to calibrate rules or 'line standards' anywhere in the world, with a degree of accuracy of 1 part in 100,000,000.

Immediately there arose a need for effective ways of transferring a measurement from the primary (wavelength) standard to a working tool, such as a steel rule. A group of scientists in the DIVISION OF APPLIED PHYSICS has spent the last few years developing an instrument to do this. Their aim has been achieved, and it is now possible to measure line standards in Australia to an accuracy of one part in 10,000,000. Up to four measurements can be done in a day. From now on our line standards won't have to be sent back to Paris for comparing with other standards.

The standard of voltage

An absolutely accurate voltage standard doesn't exist in Australia. Determining the value of the volt is a very difficult business, and only about 6 laboratories in the world have sufficiently sophisticated facilities and equipment to do it. The rest of the world has to use standard cells or batteries calibrated from the primary standards.

Unfortunately standard cells don't remain standard for long. Gradually their voltage drifts. Form time to time they go back to Paris for checking, but they don't travel very well.

Even the absolute determinations are not very accurate, since different determinations vary by up to 10 parts per million. A more accurate, simple and reliable method is needed.

The DIVISION OF APPLIED PHYSICS has conceived an entirely new approach to voltage measurement. The experimental apparatus consists of an aluminized glass plate placed a few millimetres above the surface of a pool of very pure mercury. When an electrostatic voltage is applied to the plate, the mercury surface will be attracted towards it, in the same way that a charged comb will attract a piece of paper. The rise of the mercury surface can be measured very accurately. In theory, the method will permit the volt to be measured with an accuracy of 1 part in 1,000,000. Before this can be done, it will be necessary to overcome a number of practical difficulties, like vibration in the pool of mercury.

Solid lubricants

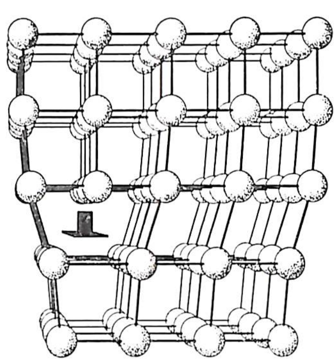
Graphite has long been used as a lubricant. Nowadays it is being replaced, in many of the places where solid lubricants are needed, by molybdenum disulphide. This chemical is used in two ways. A layer of it 1/1000 of an inch thick can be bonded onto a bearing surface with a resin. Alternatively, it is used as an additive in oil.

Scientists from the DIVISION OF TRIBOPHYSICS and from Molybond Laboratories Pty. Ltd. have been studying its lubricating action. The CSIRO CHEMICAL RESEARCH LABORATORIES have collaborated in some of the work. The experiments show that molybdenum disulphide, even when applied in a layer only 1 millionth of an inch thick, effectively reduced friction and wear. In laboratory experiments oil containing 0.2 per cent of the chemical was 1.6 times as effective as straight oil at reducing wear in engine components. This result has not yet been confirmed in road tests.

Crystal defects

Metals and other crystalline materials are not as strong as they ought to be. A crystal is a three dimensional regular array of atoms or molecules. For the last 40 years scientists have been able to measure the inter-atomic forces, and to calculate how strong materials should be. But ordinary metals have only about 1/1000 of their calculated strength.

The explanation of this lies in the fact that crystals always have imperfections, which are the sources of weakness. An imperfection may be due to an impurity atom, a vacant site in the crystal, an extra atom jammed into the crystal, or a dislocation (*see illustration below*).



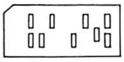
For years, defects have been studied by measuring their effects on such properties of the crystal as strength or electrical conductivity. With improvements in thin film techniques, it has become possible during the past five years to observe defects directly with an electron microscope. It has been noted that dislocations, which move through a crystal, often avoid taking direct pathways. This is most marked with substances in which the elasticity varies strongly with the direction of the stress or strain. Brasses in a special range of composition are typical examples of this and have been studied in the DIVISION OF TRIBOPHYSICS using the thin film technique.

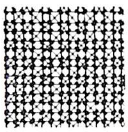
In the same Division, calculations have quantitatively explained the observed zig-zag movement of the dislocations and shown that this phenomenon is similar to the tacking of a yacht against the wind.

The behaviour of impurities in crystals is being investigated at the NATIONAL STANDARDS LABORATORY. The crystals are of common salt and the impurities are electrically charged atoms which wander through the array of charged sodium and chlorine atoms. When the impurity atoms are manganese each impurity acts as a tiny magnet. In the DIVISION OF PHYSICS, the motion of the impurity atoms is being followed by magnetic methods. These measurements have confirmed the discovery, made earlier by other methods of investigation in the DIVISION OF APPLIED PHYSICS, that when three of the impurity atoms meet in one place they combine to form a 'trimer' which then ceases to move. These 'trimers' are not the final product of the clustering of impurity atoms, however, and larger aggregates form later. It is in this later stage that the magnetic method has provided details of the clustering in a way which other methods could not do.

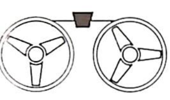
The ease with which impurity atoms may wander through a crystal and the nature of any clustering of impurities are basic to many properties of solids. Although these experiments are not aimed at any particular application, they help the solid state physicist to improve his understanding of how defects influence the strength of materials. They also have long-range implications as they are the basis on which the ultra-high-strength materials of the future are being developed.

Statistics and computation


Input


Storage


Processing


Output

NEARLY ALL EXPERIMENTS yield quantitative results. Above all else the scientist measures things; the effect of fertilizers, fluctuation in animal populations, the intensity of radio waves from distant galaxies. Mathematical help is often needed, so the services of the staff of the DIVISION OF MATHEMATICAL STATISTICS and the COMPUTING RESEARCH SECTION are in keen demand.

Statisticians can help the scientist to design his experiments properly and to make proper inferences from the results. The computing staff helps scientists to use the computer system to extract meaningful information from large quantities of experimental figures.

Both the statisticians and the computing staff are doing research in their own subjects, trying to find new ways of extending the usefulness of statistical and computing methods.

Picture interpretation

Much scientific information is obtained in the form of photographs. Cameras can be attached to microscopes or telescopes and sent aloft in aircraft or satellites. Aerial photographs of grazing kangaroo herds, microscopic pictures of blood smears, photographs of distant galaxies all have to be interpreted. Interpretation may involve counting things, or distinguishing one shape from another, or both.

The COMPUTING RESEARCH SECTION is trying to find ways of getting computers to interpret pictures. The problem is to find a language in which one can tell the computer what it has to look for. The Section is beginning by trying to program the computer to recognize differences of size or shape in simple objects.

Numerical weather forecasting

A scientist in the COMPUTING RESEARCH SECTION has written a program for the computer which makes it produce forecasts in weather-map form. One can feed in all the available meteorological data and then ask the computer for a map showing the weather situation two or four hours later. The map will then show up on the computer's visual display device. It's not possible to get reliable maps for a long time interval ahead, since neither the data nor the mathematical models are perfect. But steady improvement is being made. Each time the prediction differs from the real-life occurrence a correction can be made to the model. The future of this type of forecasting depends on the availability of better data, and satellites are providing this to an increasing extent.

Classifying things

Classification is one of the oldest and most widely spread of human activities. Usually we need to consider only a few attributes; the casual observer can classify his fellow humans into sexes by considering only hair style, clothing and figure. But to classify people on a basis of, say, life expectancy is very much more difficult. The advent of computers enables us to classify things on a scale never attempted before, since we can now consider hundreds of attributes and large populations.

The COMPUTING RESEARCH SECTION is seeking to find, through classification, some of the intrinsic patterns which lie concealed in complex situations. Many of the problems lie in the fields of land and marine survey. The Section has, for instance, made a study of the plants growing in 18 half-acre sites in the Queensland rain forests. Some 800 different plant species were found on these sites. The Section's methods of analysis enable it to answer all sorts of questions. 'Which plants are the most meaningful indicators for land classification?' Answer, the big trees. 'Are there definite plant associations, groups of plants which habitually grow together?' Answer, yes. 'How do you select representative samples from a forest?' Answer, select trees at random, and take also the five or six nearest neighbours of each. The Section is now grappling with more difficult problems, like predicting the characteristics of each class of land if it were to be used for agriculture.

The programs may also be applied to the solution of medical problems. Patterns have been sought in the neurosis symptoms of telegraphists in the P.M.G.'s department, a group notoriously susceptible to neurotic disorders. At the Brisbane General Hospital efforts have been made to classify respiratory diseases of children to find out whether doctors are treating one disease or several.

The expertise in classification built up in the Section is in world demand.

Uniform packing legislation

Commonwealth and State authorities are at present preparing uniform legislation to govern packaging. Draft laws will provide that in a sample of packages the average weight will be not less than the marked weight. No individual package may contain less than 95 per cent of the marked weight.

The DIVISION OF MATHEMATICAL STATISTICS has been examining the consequences of this draft legislation for manufacturers. Manufacturers have the problem that packaging processes are not absolutely controllable. This means that the actual weights delivered by a machine into packages is spread over a range. By adjusting the machine to deliver generous weights the manufacturer minimizes the risk of giving short weight, but loses profit in doing so. As he improves his profit position his risks increase. In practice he compromises with settings that ensure that, perhaps no more than one package in 100 is underweight. The DIVISION OF MATHEMATICAL STATISTICS has worked out tables and figures to help him make the right choice. Knowing the degree of variability of his machine, he can work out where to set the average weight to achieve any desired level of risk.

Saving computer programming time

Suppose that a scientist is conducting an experiment to compare several different varieties of wheat. He will grow his varieties on scores, even hundreds of trial plots in different districts. When the wheat is harvested he will analyse his yields to find out which varieties will have yielded well because they are superior. But the picture will be confused by other factors such as differences in soil fertility and soil type. If the experiment has been properly designed, the scientist can distinguish increases due to the variety from those due to differences in the environment. In practice, real experiments are more complex than this, as the scientist may wish to compare not only wheat varieties, but also such things as different cultivation and fertilizer treatments at the same time.

The result of experiments like this are nowadays analysed in computers. The computer is capable of answering quickly any question put to it concerning possible statistical relationships. But every question (and there may be hundreds of them) requires a new programmed instruction to the computer.

An officer of the DIVISION OF MATHEMATICAL STATISTICS has collaborated with a visiting British mathematician in the development of what is called a general statistical program, or 'Genstat' for short. 'Genstat' is so flexible, so general a system, that it could be used to explore nearly all the possible relationships in the wheat-yield experiment on the basis of only a few simple instructions. In wide use it could save hundreds of man-years of computer programming time. A prototype version of the system is now in use in Adelaide. A final version, containing improvements and refinements is to be published later in 1967.

Staff

Dr. M. C. Franklin

Obituary

Dr. M. C. Franklin, one of Australia's best known livestock scientists died in Sydney on 27th January, 1967. He graduated M.Sc. from Auckland University in 1927 and later obtained his Ph.D. at Cambridge. He joined CSIRO in 1939 and was appointed the first McIlrath Fellow in Animal Husbandry in 1953.

He was later appointed Director of the Meat Research Laboratory at the Camden Animal Husbandry Farm of the University of Sydney; in 1961 this was named the M. C. Franklin Laboratory by the Senate of the University.

In 1961 he moved to Brisbane to lead a new section of the DIVISION OF ANIMAL PHYSIOLOGY which had been created to work on problems of beef production in northern Australia.

Dr. Franklin was seconded to the Australian Meat Board in 1964 as Executive Officer of the Australian Cattle and Beef Research Committee.

Executive appointment

Professor E. J. Underwood, C.B.E., B.Sc., Ph.D., F.A.A., has been appointed to the Executive. He graduated with first-class honours in agricultural science from the University of Western Australia in 1928, and subsequently obtained a Ph.D. at Cambridge. He joined the Western Australian Department of Agriculture in 1932 and soon earned world-wide recognition for his contributions to animal nutrition and husbandry problems. He was a pioneer of trace element research and one of the original discoverers of the role of cobalt in the nutrition of livestock. He has been both President and Medallist of the Australian Institute of Agricultural Science.

Professor Underwood is now Dean of the Faculty of Agriculture and Director of the Institute of Agriculture at the University of Western Australia. He will serve on the Executive in a part-time capacity.

Retirement

Dr. J. Melville has retired from the Executive after being a part-time member for eight years.

After a distinguished career in agricultural research in New Zealand Dr. Melville came to Australia in 1956 as Director of the Waite Agricultural Research Institute in Adelaide.

He was appointed to the Executive in 1958. During his period with CSIRO he has contributed his considerable wisdom and his experience in the management of agricultural research to the deliberations of the Executive.

Dr. Melville has also played a leading part in the activities of the Wool Research Production Advisory Committee. He has been instrumental in bringing together CSIRO and University view points and in bringing to grower representatives a fuller understanding of the significance of scientific research.

Secretariat

Mr. Guy B. Gresford, B.Sc., A.R.M.T.C., the Secretary of CSIRO, has been granted leave to take up an appointment with the United Nations in New York. In July, 1966, he became Director of Science and Technology in the U.N.'s Department of Economic and Social Affairs. In his new post Mr. Gresford will be concerned with the application of science and technology in the developing countries.

Following his departure, the Executive named three men to head the central administration of CSIRO.

Mr. A. F. Gurnett-Smith, B.Agr.Sc., has been appointed Secretary (Agricultural and Biological Sciences).

Mr. J. P. Shelton, M.Sc., A.B.S.M., has been appointed Secretary (Industrial and Physical Sciences).

Mr. L. G. Wilson, M.Sc., has been appointed Secretary (Administration).

Professors

The following members of the staff have resigned during the year to accept appointment to University Chairs.

Dr. D. W. Goodall, MATHEMATICAL STATISTICS, has been appointed Professor of Population Ecology at the University of California.

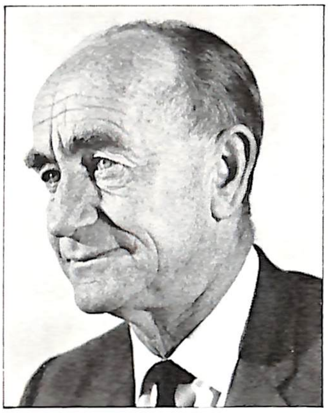
Dr. D. R. Miller, PHYSICAL METALLURGY, has been appointed Professor of Materials Science at the University of Adelaide.

Dr. J. D. Morrison, CHEMICAL PHYSICS, has been appointed Professor of Physical Chemistry at La Trobe University.

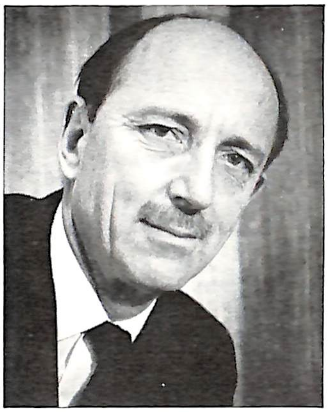
Dr. W. R. Stern, LAND RESEARCH, has been appointed Professor of Agronomy at the University of Western Australia.

Dr. S. S. Y. Young, ANIMAL GENETICS, has been appointed Professor of Genetics at the University of Ohio.

Professor E. J. Underwood
Appointed to the Executive



Dr. J. Melville
Retired from the Executive



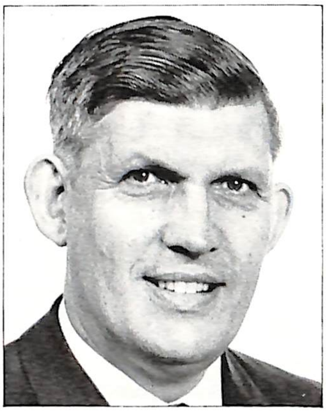
Mr. G. B. Gresford
Senior Post at United Nations

Dr. D. F. Waterhouse
Fellow of the Royal Society

Dr. C. H. B. Priestley
Fellow of the Royal Society and Symons Memorial Gold Medal

Dr. G. K. White
David Syme Research Prize

Dr. A. Walsh
Britannica Australia Award and President, Australian Institute of Physics



Dr. D. E. Weiss
H. G. Smith Memorial Medal

Dr. E. M. Hutton
Farrer Memorial Medal

Honours and awards

Dr. J. A. Barker, APPLIED CHEMISTRY; Fellow of the Australian Academy of Science.

Dr. D. E. Bland, FOREST PRODUCTS; Doctor of Science, University of Melbourne.

Dr. L. B. Bull, ANIMAL HEALTH; A.N.Z.A.A.S. Medal.

Dr. L. R. Clark, ENTOMOLOGY; Doctor of Science, University of Sydney.

Mr. D. J. Close, MECHANICAL ENGINEERING; Edward Noyes Prize of the Institution of Engineers, Australia.

Dr. C. G. Greenham, PLANT INDUSTRY; Doctor of Science, University of Queensland.

Dr. E. G. Hallsworth, SOILS; President, International Society of Soil Science.

Dr. H. G. Higgins, FOREST PRODUCTS; President of APPITA, the Australian and New Zealand Pulp and Paper Industry Technical Association.

Dr. E. M. Hutton, TROPICAL PASTURES; Farrer Memorial Medal.

Mr. H. Kobler, PHYSICS; Oswald Mingay Award of the Institution of Radio and Electronic Engineers of Australia.

Dr. T. J. Marshall, SOILS; President, Australian Society of Soil Science.

Dr. D. Martin, PLANT INDUSTRY; Medal of the Australian Institute of Agricultural Science.

Dr. A. McL. Mathieson, CHEMICAL PHYSICS; Fellow of the Australian Academy of Science.

Dr. J. Melville, MEMBER OF THE EXECUTIVE; Fellow, Australian Institute of Agricultural Science.

Dr. M. J. T. Norman, LAND RESEARCH; F. A. Brodie Memorial Prize of the Australian Overseas Transport Association.

Mr. T. Pearcey, COMPUTING RESEARCH; President of the Australian Computer Society.

Dr. J. R. Philip, PLANT INDUSTRY; Fellow of the Australian Academy of Science.

Dr. H. R. C. Pratt, CHEMICAL ENGINEERING; Chairman of the Australian National Committee of the Institution of Chemical Engineers.

Dr. C. H. B. Priestley, METEOROLOGICAL PHYSICS; Fellow of the Royal Society and Symons Memorial Gold Medal of the Royal Meteorological Society.

Dr. R. O. Slatyer, LAND RESEARCH; Fellow of the Australian Academy of Science.

Dr. M. Shibaoka, MINERAL CHEMISTRY; 1966 Medal of the Fuel Society of Japan.

Dr. C. G. Stephens, SOILS; Fellow, Australian Institute of Agricultural Science.

Dr. J. R. Vickery, FOOD PRESERVATION; Officer of the Order of the British Empire and President, Australian Institute of Food Science and Technology.

Dr. A. Walsh, CHEMICAL PHYSICS; Britannica Australia Award and President, Australian Institute of Physics.

Dr. D. F. Waterhouse, ENTOMOLOGY; Fellow of the Royal Society.

Dr. D. E. Weiss, APPLIED CHEMISTRY; H. G. Smith Memorial Medal, Royal Australian Chemical Institute.

Dr. R. H. Wharton, ENTOMOLOGY; Chalmers Medal, Royal Society of Tropical Medicine and Hygiene.

Dr. G. K. White, PHYSICS; David Syme Research Prize, University of Melbourne (shared).

Dr. H. B. Wisely, FISHERIES AND OCEANOGRAPHY; Doctor of Science, University of Canterbury (N.Z.).

Dr. S. S. Y. Young, ANIMAL GENETICS; Doctor of Science, University of New South Wales.

Advisory Council

Executive

Sir Frederick White, K.B.E., M.Sc., Ph.D., F.A.A., F.R.S. (*Chairman*)
C. S. Christian, B.Agr.Sc., M.S.
W. Ives, M.Ec.
J. R. Price, D.Sc., D.Phil., F.A.A.
M. F. C. Day, B.Sc., Ph.D., F.A.A.
E. P. S. Roberts
Sir Henry Somerset, Kt., C.B.E., M.Sc.
K. L. Sutherland, Ph.D., D.Sc., F.A.A.
Professor E. J. Underwood, C.B.E., B.Sc.(Agric.), Ph.D., F.A.A.

Chairmen of State Committees

NEW SOUTH WALES—W. Sloan
QUEENSLAND—W. J. D. Shaw, O.B.E.
SOUTH AUSTRALIA—Professor E. A. Rudd, A.M., B.Sc.
TASMANIA—V. G. Burley, B.E.
VICTORIA—L. W. Weickhardt, M.Sc.
WESTERN AUSTRALIA—E. H. Lee-Steere, C.B.E.

Coopted Members

K. E. Beazley, B.A., M.H.R.
Sir Arthur Coles, Kt.
Professor C. W. Emmens, D.Sc., Ph.D., F.A.A.
R. A. Irish, O.B.E., F.C.A.
C. R. Kelly, B.Agr.Sc.
P. J. Lawler, O.B.E.
C. G. McGrath, O.B.E.
J. A. L. Matheson, M.B.E., M.Sc., Ph.D.
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M. Wootton, B.Sc.
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Division of Wildlife Research

Headquarters:
Barton Highway, Canberra, A.C.T.

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Division of Protein Chemistry

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I. W. Stapleton, B.Sc., Ph.D.
E. Suzuki, B.Eng.
J. R. Yates, M.A., Ph.D.

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Division of Textile Industry

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D. E. Henshaw, B.Sc.
V. A. Williams, B.Sc., Ph.D.

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J. Lappage, M.Sc., Ph.D.

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J. R. Cook, A.G.Inst.Tech.
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B. C. Ellis, A.M.C.T.
H. D. Feldtman, A.G.Inst.Tech.
G. N. Freeland, A.G.Inst.Tech.
R. J. Hine, A.G.Inst.Tech.
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B. O. Lavery, Nat.Cert. in Mech.Eng.
J. D. Leeder, A.G.Inst.Tech. (*at Australian National University*)
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D. E. A. Plate, B.Sc.
C. P. Pritchard, A.G.Inst.Tech.

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G. C. West, A.G.Inst.Tech.

Division of Textile Physics

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LIBRARIAN
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H. W. Holdaway, B.Sc., M.E.
J. F. P. James, M.Sc.
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A. E. Stearn, B.Sc.
G. L. Stott, A.S.T.C.

Unattached Officers

INTERNATIONAL SCIENTIFIC EXPERTS
G. B. Gresford, B.Sc., A.R.M.T.C. (*seconded to United Nations as Director for Science and Technology, Department of Economic and Social Affairs.*)
F. G. Nicholls, M.Sc. (*seconded to United Nations Program of Technical Assistance, Thailand.*)

SENIOR PRINCIPAL RES. SCIENTISTS
W. L. Greenhill, M.E.
A. J. Vasey, M.B.E., B.Agr.Sc.
D. B. Williams, B.Sc.Agr., B.Com., Ph.D. (*Seconded to University of Melbourne*)

PRINCIPAL RESEARCH SCIENTIST
J. C. M. Fornachon, B.Agr.Sc., M.Sc. (*seconded to Australian Wine Research Institute*)

Chapter 4

Finance

THE SUM TOTAL OF FUNDS available for CSIRO's purposes in 1966/67 was $42 million, an increase of $4 million over the previous year. When we compare this sum with the estimates of a few years ago it seems very large. All the money voted to the Organization's predecessors during the decade 1916–26 would keep the present day CSIRO going for about two or three days. Today the budget for national scientific research has to be large because the economy is geared more and more to technological advance. Australia's continued development will demand even larger expenditure on research in the future.

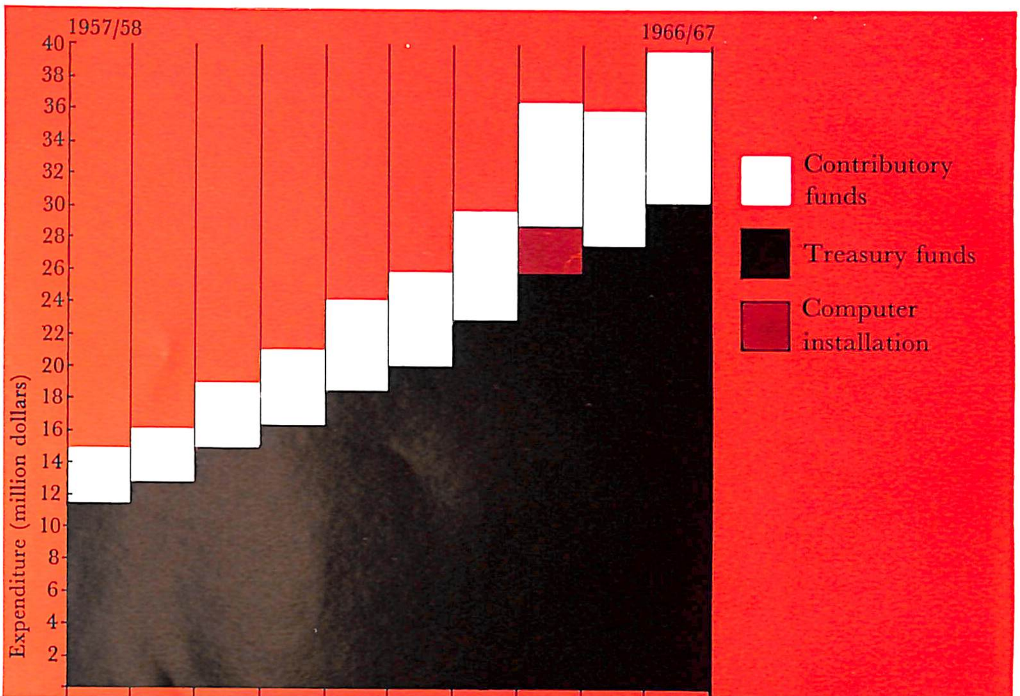
The histogram shown on the next page shows how expenditure by the Organization has increased in recent years. Much of the increase has been due to inescapable factors, notably rises in salary. Part of it is due to the increasing cost of equipping scientists with modern instruments. Electron microscopes, mass spectrometers and other complex instruments costing up to $40,000 apiece are nowadays regarded as essential items of equipment. CSIRO purchases a public tender item (costing over $1,000) about once a day.

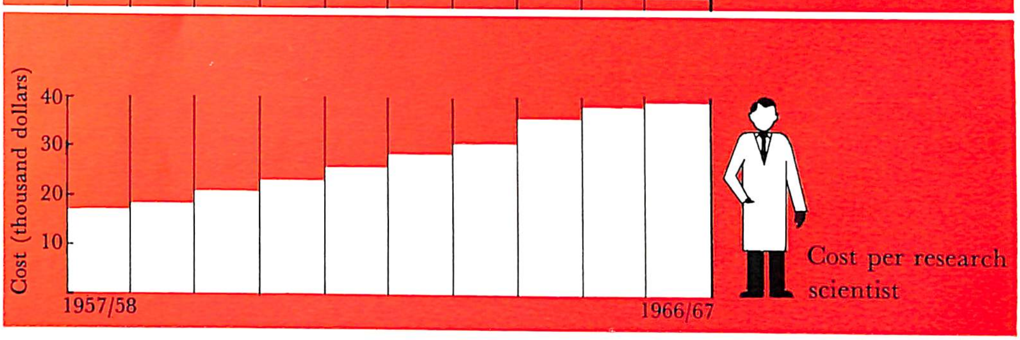
Some of the increase does, however, represent real expansion. In 1966/67 it was possible to employ 200 more people, thereby raising the number of staff to 5,900. Some new projects were started, including a study of water loss by plants ($18,000), a study of tropical air-conditioning ($60,000) and a scheme for short-term support for development (see page 9).

All in all, the financial backing which CSIRO receives has allowed a modest rate of expansion.

Expenditure by CSIRO (1957/58 – 1966/67)

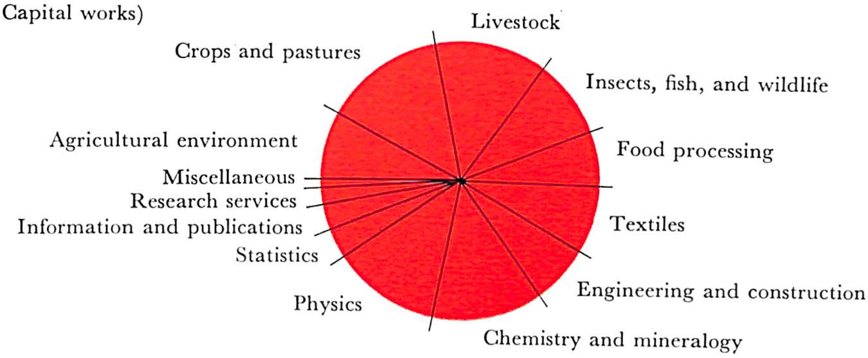
The values in the top histogram include annual running costs and capital works under CSIRO control. They do not include costs of land or buildings provided under the votes of the Departments of Works and Interior. The values for cost per research scientist are based on annual running costs only.



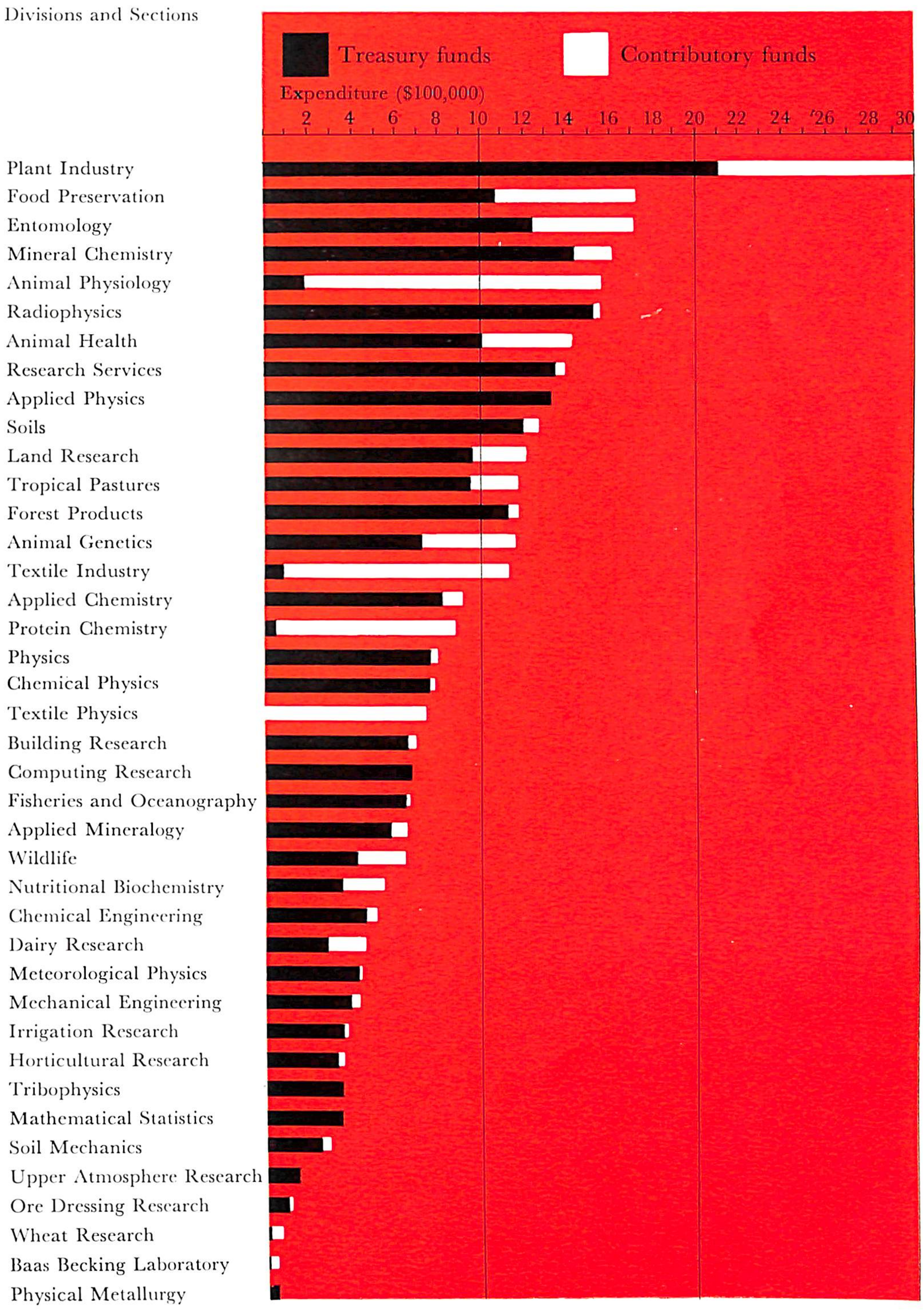


Expenditure on investigations 1966/67

(Excluding Capital works)



Expenditure on investigations by Divisions and Sections in 1966/67



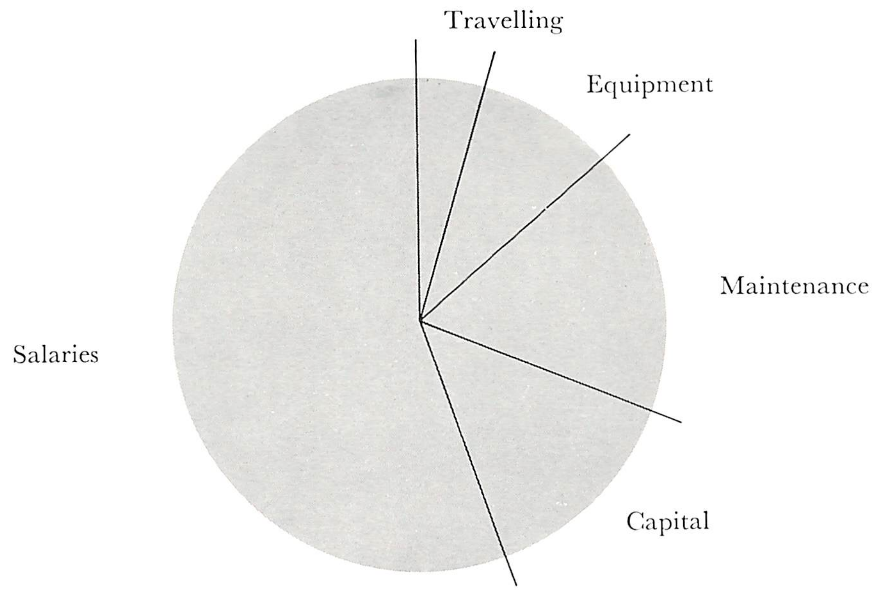
How CSIRO spent its dollar in 1966/67

Sources of contributory funds (1966/67)

More than 80% of contributory funds are provided from five Trust Funds established jointly by the Commonwealth and primary industry.

Wool Research Trust Fund	5,749,186
Meat Research Trust Account	1,388,527
Wheat Research Trust Account	193,033
Dairy Produce Research Trust Account	250,209
Tobacco Industry Trust Account	174,553
Other contributors	1,611,541
	$9,367,049

Uses of contributory funds



Land and buildings

During 1966–67 the Department of Works and the Department of the Interior spent $2,647,000 on the construction of buildings, other works, and acquisition of properties for CSIRO.

Expenditure

The following summary gives details of expenditure by CSIRO Divisions and Sections on other than capital items from 1st July, 1966 to 30th June, 1967.

DIVISION OR SECTION	Treasury Funds ($)	Contributory Funds ($)	Total ($)
Expenditure on Administration	1,999,639	—	1,999,639
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, staff and upkeep of State Committees, and general office expenditure.			
Expenditure on Investigations			
Animal Research Laboratories			
Animal Genetics	717,271	397,666	1,114,937
Animal Health	1,001,914	334,329	1,336,243
Animal Physiology	194,147	1,312,170	1,506,317
Nutritional Biochemistry	350,817	185,816	536,633
Plant Industry	2,120,448	1,084,120	3,204,568
Entomology and Wildlife			
Entomology	1,263,681	381,254	1,644,935
Wildlife	413,668	229,118	642,786
Soils	1,199,989	91,845	1,291,834
Horticulture and Irrigation			
Horticultural Research	330,204	33,731	363,935
Irrigation Research	364,255	19,813	384,068
Tropical Pastures	950,347	228,133	1,178,480
Land Research	966,397	225,888	1,192,285
Processing of agricultural products			
Food Preservation	1,081,044	155,271	1,236,315
Dairy Research	287,780	165,802	453,582
Wheat Research	15,650	60,466	76,116
Wool Research	9,704	1,593,648	1,603,352
Chemical research of industrial interest			
Chemical Research Laboratories	2,081,084	147,062	2,228,146
Protein Chemistry	44,337	791,050	835,387
Fisheries and Oceanography	660,466	10,427	670,893
Processing and use of mineral products			
Coal Research	834,714	122,345	957,059
Chemical Research Laboratories	1,189,247	138,590	1,327,837
Mining and Metallurgy	156,683	57,335	214,018
Physical research of industrial interest			
National Standards Laboratory	2,125,780	22,082	2,147,862

DIVISION OR SECTION	Treasury Funds ($)	Contributory Funds ($)	Total ($)
General physical research			
Radiophysics	1,386,286	46,855	1,433,141
Meteorological Physics	438,449	1,251	439,700
Upper Atmosphere	140,206	—	140,206
Radio Research Board	40,000	44,855	84,855
General industrial research			
Building Research	657,052	34,851	691,903
Tribophysics	348,581	1,045	349,626
Soil Mechanics	249,963	40,300	290,263
Mechanical Engineering	394,741	45,055	439,796
Processing of forest products	1,128,077	62,871	1,190,948
Research services			
Computing Research	678,768	—	678,768
Mathematical Statistics	344,792	—	344,792
Extramural Investigations	113,157	—	113,157
Other Services	1,231,587	49,082	1,280,669
Miscellaneous	265,383	32,532	297,915
Expenditure on other services			
Research Associations—Grants	161,371	—	161,371
Research Studentships	318,067	—	318,067
Other Grants	641,290	—	641,290
London Transactions—June	14,167	10,856	25,023
Total expenditure	28,911,203	8,157,514	37,068,717

Capital expenditure under CSIRO control

The table which follows shows expenditure of a capital nature from funds made available directly to CSIRO. It includes expenditure on capital and developmental works and on major items of equipment.

DIVISION OR SECTION	Treasury Funds ($)	Contributory Funds ($)	Total ($)
Administration	33,325	—	33,325
Animal Research Laboratories			
Animal Genetics	37,050	55,752	92,802
Animal Health	47,957	104,252	152,209
Animal Physiology	37,195	59,123	96,318
Nutritional Biochemistry	2,688	8,422	11,110
Plant Industry	71,485	39,209	110,694
Entomology and Wildlife			
Entomology	8,199	86,356	94,555
Wildlife	7,843	—	7,843

DIVISION OR SECTION	**Treasury Funds** ($)	**Contributory Funds** ($)	**Total** ($)
Soils	50,961	—	50,961
Horticulture and Irrigation			
Horticultural Research	23,990	—	23,990
Irrigation Research	3,000	—	3,000
Tropical Pastures	260,357	13,424	273,781
Land Research	—	21,772	21,772
Processing of agricultural products			
Food Preservation	14,143	497,172	511,315
Dairy Research	2,600	—	2,600
Wool Research	11,984	269,974	281,958
Chemical research of industrial interest			
Chemical Research Laboratories	256,140	—	256,140
Protein Chemistry	—	47,517	47,517
Fisheries and Oceanography	11,023	—	11,023
Processing and use of mineral products			
Coal Research	45,400	—	45,400
Chemical Research Laboratories	72,101	—	72,101
Physical research of industrial interest			
National Standards Laboratory	116,393	—	116,393
General physical research			
Radiophysics	19,950	—	19,950
Meteorological Physics	1,835	—	1,835
Upper Atmosphere	18,437	—	18,437
General industrial research			
Building Research	33,196	—	33,196
Mechanical Engineering	28,105	—	28,105
Processing of forest products	27,611	—	27,611
Research services			
Computing Research	25,377	—	25,377
Western Australian laboratories	4,929	—	4,929
Miscellaneous	21,873	6,562	28,435
Total Capital expenditure	1,295,147	1,209,535	2,504,682

Contributions

This table summarizes receipts and disbursements during 1966/67 of funds provided by contributors and recorded in a special account entitled 'Specific Research Trust Fund'. The largest amounts contributed for specific research projects are provided from joint Commonwealth–Industry Funds such as the Wool Research Trust Fund, Meat Research Trust Account, etc. However sums which are quite substantial in total are contributed by other bodies and industrial organizations, including several United States Government agencies.

DIVISION OR SECTION	**Receipts 1966/67 and balances brought forward 1965/66** ($)	**Expenditure 1966/67** ($)
Animal Genetics		
Wool Research Trust Fund	356,937	352,156
Meat Research Trust Account	64,762	57,013
Other Contributors	83,295	44,249
Animal Health		
Wool Research Trust Fund	255,504	248,423
Meat Research Trust Account	167,678	148,687
Dairy Produce Research Trust Account	19,992	15,036
Other Contributors	38,931	26,435
Animal Physiology		
Wool Research Trust Fund	1,295,069	1,267,820
Meat Research Trust Account	109,634	103,310
Other Contributors	3,254	163
Nutritional Biochemistry		
Wool Research Trust Fund	194,551	194,238
Plant Industry		
Wool Research Trust Fund	791,120	723,159
Meat Research Trust Account	44,046	42,158
Wheat Research Trust Account	43,945	24,249
Dairy Produce Research Trust Account	14,232	14,119
Tobacco Industry Trust Account	190,896	174,590
Other Contributors	203,240	145,054
Entomology		
Wool Research Trust Fund	65,215	64,402
Meat Research Trust Account	255,417	227,279
Wheat Research Trust Account	6,641	25,190*
Other Contributors	191,808	150,739
Wildlife		
Wool Research Trust Fund	197,700	185,132
Meat Research Trust Account	21,994	21,774
Other Contributors	22,383	22,212

DIVISION OR SECTION	**Receipts 1966/67 and balances brought forward 1965/66** ($)	**Expenditure 1966/67** ($)
Soils		
Wheat Research Trust Account	40,945	36,049
Other Contributors	87,721	55,796
Horticultural Research		
Other Contributors	40,827	33,731
Irrigation Research		
Other Contributors	27,076	19,813
Tropical Pastures		
Meat Research Trust Account	168,136	164,291
Dairy Produce Research Trust Account	55,507	55,252
Other Contributors	44,197	22,014
Land Research		
Meat Research Trust Account	34,913	28,734
Other Contributors	229,370	218,926
Food Preservation		
Meat Research Trust Account	596,638	580,254
Other Contributors	106,345	72,189
Dairy Research		
Dairy Produce Research Trust Account	179,239	165,802
Other Contributors	100	—
Wheat Research Unit		
Wheat Research Trust Account	63,225	60,466
Wool Research Laboratories		
Wool Research Trust Fund	1,982,325	1,833,238
Other Contributors	49,792	30,384
Chemical Research Laboratories		
Wool Research Trust Fund	32,258	30,652
Meat Research Trust Account	13,333	10,644
Other Contributors	135,844	105,766
Protein Chemistry		
Wool Research Trust Fund	865,558	796,418
Other Contributors	21,868	42,149*
Fisheries and Oceanography		
Other Contributors	1,204 Dr.	10,427*

* Expenditure in excess of receipts will be recovered in 1967–68.

Coal Research		
Other Contributors	178,615	122,345
Chemical Research Laboratories		
Other Contributors	208,378	138,590
Mining and Metallurgy		
Other Contributors	113,229	57,335
National Standards Laboratory		
Other Contributors	1,701	22,082*
Radiophysics		
Other Contributors	64,822	46,855
Meteorological Physics		
Tobacco Industry Trust Account	1,510	1,251
Radio Research Board		
Other Contributors	46,822	44,855
Building Research		
Other Contributors	73,670	34,851
Tribophysics		
Other Contributors	25,415	1,045
Soil Mechanics		
Other Contributors	68,275	40,300
Mechanical Engineering		
Wheat Research Trust Account	51,767	45,055
Other Contributors	6,500	—
Forest Products		
Other Contributors	85,514	62,871
Mathematical Statistics		
Other Contributors	10	—
Agricultural Liaison Unit		
Wool Research Trust Fund	53,460	45,558
Other Contributors	1,850	1,850
Film Unit		
Other Contributors	6,760	1,674
Miscellaneous		
Meat Research Trust Account	3,500	2,841
Other Contributors	394,993	36,253
London Transactions—June	—	10,856
Total contributions	10,799,048	9,367,049

Miscellaneous receipts

During 1966/67, miscellaneous receipts amounting to $701,709 were paid into Consolidated Revenue. Details of the receipts are as follows:

Sale of publications	28,437
Sale of equipment purchased in former years, and other receipts	106,302
Sale of produce	109,144
Royalties from patents	146,179
Testing fees	63,115
Computing charges	233,737
Miscellaneous	14,795
Total	$701,709