Commonwealth Scientific and Industrial Research Organization, Australia

CSIRO Twenty-eighth Annual Report 1975/76

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This report of the work of CSIRO for the year ending 30 June 1976 has been prepared as required by Section 30 of the Science and Industry Research Act 1949.

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

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

J. R. Price (*Chairman*)
V. D. Burgmann
M. E. Holman
V. E. Jennings
A. E. Pierce
W. J. Vines
F. M. Wiltshire
H. W. Worner

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

The powers and functions of CSIRO are:

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

the training of scientific research workers and the awarding of studentships

the making of grants in aid of scientific research

the recognition and support of research associations

the maintenance of the national standards of measurement

the dissemination of scientific and technical information

the publication of scientific and technical reports

liaison with other countries in matters of scientific research.

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Cover
A low intensity fire in a eucalypt forest as recorded by infra-red photography. Because infra-red photography makes it possible to 'see' through smoke and obtain a clear view of the flames it is being used by the DIVISION OF FOREST RESEARCH to study forest fires.

Photograph: Alan Edward

Research

Introduction

This year marks the fiftieth anniversary of the establishment of CSIR, the forerunner of CSIRO, and one could be forgiven for taking the opportunity to record some of the achievements of those past fifty years. But, while it may be both interesting and useful to look back at the past, I believe that it is much more important, in this jubilee year, to look forward to the future.

The Organization today—indeed science and technology in general—is facing situations quite different from those of yesterday; it has to adapt itself to deal with problems of a quite different nature and has to do so under changing economic and social circumstances. The problems to be solved by science and technology are unlimited, but the available financial resources are not. However, the changing situation with respect to governmental funded science and technology is not simply a matter of availability of funds, staff and facilities; there are also significant changes in the needs of the community and, more importantly, changes in national approach to world resource utilization, be they related to energy, food, water or population.

A criticism of CSIRO, which one encounters from time to time, is that it is too large. Those who offer this criticism rarely state what they mean by 'too large'—whether the Organization is too large for effective management or whether it receives what is thought to be too large a slice of the financial cake provided for science and technology by government. Yet in the size of CSIRO lies one of its great strengths. The sense in which I use the word 'size' relates not just to numbers of people employed or to budgets, but to the wide diversity of scientific and technological activities embraced by the Organization's programs.

This aggregation of scientific skills and facilities is not only exceedingly valuable now but will become even more so in the future, for two reasons.

Firstly, because collaborative multi-disciplinary research, which is becoming increasingly important, is most easily achieved within one Organization. Collaboration with other bodies, both nationally and internationally, is of course very important and will be even more so in the future. However, such collaboration tends to operate on a more formal basis and cannot always be entered into quite so readily or operated so efficiently.

Secondly, because of the broad base of CSIRO's activities there is almost always a nucleus in one or more Divisions which can be developed and built on to initiate research on new problems arising from changing community needs or changing economic conditions.

These two reasons, in my opinion, constitute a forceful argument for the existence of a broadly based governmental research organization such as CSIRO. However, it is unlikely that CSIRO will, in the foreseeable future, experience growth rates comparable with those of the fifties and sixties. Consequently, the Organization will need to develop the ability to redeploy resources in response to changing priorities to a much greater degree than has been necessary in the past.

Moreover, CSIRO is only one component in the total structure of scientific research in the Australian community and it must maintain and improve its relationships with other components. Indeed, the changes which have taken place in the seventies have made the Organization even more aware of the need for more effective external relations with many official bodies and community groups, particularly industry, Departments of State, universities and other bodies either involved in or having research needs, including, of course, the Australian Science and Technology Council.

I believe that the situation, which I have briefly outlined, points to the need for a management style and goal-setting arrangements for CSIRO that differ from those which sufficed in the past. Most organizations continually undergo self-modification in response to perceived needs, and this has certainly been true of CSIR/CSIRO over the past fifty years. But over and above the evolutionary changes that have been made, the Executive has in recent years conducted a series of reviews aimed at developing arrangements to optimize the performance of the Organization and enable it to discharge its responsibilities more effectively in the years ahead.

It is worthy of note that, in this jubilee year, the Commonwealth Government has decided to conduct an independent external inquiry into CSIRO. This decision doubtless testifies to the Government's recognition that requirements have changed during the twenty-seven years since the last external review of the Organization. I am confident that the combination of the Executive's own endeavours together with the advice resulting from the external inquiry will encourage further development of CSIRO as a national research institution, and ensure continuation of the quality of research and record of achievement that characterized CSIR/CSIRO in the past.

J. R. PRICE

Chairman

CSIR—CSIRO 1926–1976

CSIRO, or CSIR as it was then called, was set up by Act of Parliament in 1926, but its origins go back 10 years earlier. In 1916 the Prime Minister, Mr W. M. Hughes, called together a number of prominent scientists and industrialists to discuss the formation of a scientific research institution to work on problems affecting primary and secondary industry. A temporary body, the Advisory Council of Science and Industry, was formed to prepare the way for a permanent Institute of Science and Industry. Its aim, said Hughes, 'was to apply to the pastoral, agricultural, mining and manufacturing industries the resources of science in such a way as to more effectively develop our great heritage'.

By 1917 a scheme had been drafted, but at the critical moment political support failed. The Advisory Council struggled on. It had neither laboratories nor research staff of its own; its financial resources were extremely limited. Nevertheless, it appointed a number of expert committees which did much valuable work in coordinating and stimulating research in existing laboratories.

It was not until 1920 that the Government passed an Act establishing a permanent Institute. But finance continued to be restricted. Some progress was made, however, particularly in forest products research.

In 1925 the Government convened a conference of scientific and industrial leaders to advise how the Institute might best be organized and its activities extended. At about the same time, the then Prime Minister, Mr S. M. Bruce, invited an eminent British science administrator, Sir Frank Heath, to advise on the organization of national scientific research in Australia. As a result of the conference recommendations and Heath's report, Parliament passed the Science and Industry Research Act in 1926 establishing CSIR, the Council for Scientific and Industrial Research.

The Act vested control of the new organization in a relatively large Council which was composed almost entirely of part-time members representing a wide range of scientific, agricultural and industrial interests in each State. The Act also provided for an Executive Committee of three to carry out the Council's functions between Council meetings. The first Chairman of the Council and the Executive Committee was Mr G. A. Julius (later Sir George), a leading consulting engineer. The Chief Executive Officer was Professor A. C. D. Rivett (later Sir David) who resigned the Chair of Chemistry at the University of Melbourne to accept the appointment. The third member of the Executive Committee was Professor A. E. V. Richardson, a distinguished agricultural scientist. Julius resigned at the end of 1945 and was succeeded as Chairman by Rivett.

The illustration opposite showing the Chairmen of CSIR and CSIRO is taken from the book 'Surprise and Enterprise—Fifty years of science for Australia' which was produced to celebrate the 50th anniversary of CSIRO. 'Surprise and Enterprise' was written by Andrew Mackay, illustrated and designed by Robert Ingpen and edited by Sir Frederick White and David Kimpton.

Sir George Julius 1926–45

Sir Frederick White 1959–70

Sir Ian Clunies Ross 1949–59

Sir David Rivett 1946–49

Sir Robert Price 1970–

A number of the scientists who had advised the Government on the establishment of CSIR had argued strongly that creative scientific research required a type of environment not usually found in government departments. Because of this, CSIR was set up as a statutory authority and the Council was given considerable freedom in the appointment and management of its staff. The Council, particularly Julius, Richardson and Rivett, and its first Secretary, Mr G. A. Lightfoot, were thus able to develop an organizational structure and style of management which contributed significantly to the success of CSIR and later CSIRO.

Although CSIR was established to undertake research for the benefit of Australia's primary and secondary industries, the Council decided to devote most of its limited resources initially to problems of agriculture and the utilization of forest products. Gradually CSIR built up divisions dealing with animal health and nutrition, soils, plant industry, fisheries, food preservation and transport, entomology and forest products. Only a few of the Council's officers were engaged in activities such as radio research and mineragraphy.

A succession of useful discoveries helped the new organization gain acceptance by the industries it served and by the community generally.

In 1936 the Government decided to extend the activities of CSIR to provide scientific assistance to secondary industry. This proved to be a fortunate decision, for the National Standards Laboratory, the Aeronautical Laboratory and the Division of Industrial Chemistry, created in the years 1937–40, played an important part in the rapid war-time development of Australian industry. In 1940 three other laboratories were established to deal with problems raised by the war. They were the Division of Radiophysics, the Dairy Research Section and the Lubricants and Bearings Section (later the Division of Tribophysics).

After the war the Council was able to concentrate once more on problems of primary and secondary industry. New groups were formed as the Council expanded its research on building materials, wool textiles and coal, and entered new fields such as atmospheric physics, physical metallurgy and assessment of land resources.

Then in the late 1940s a political controversy developed over the compatibility between the needs of scientific freedom and national security. This led to the passing of the Science and Industry Research Act of 1949. Under this Act, CSIR relinquished all secret or 'classified' work of a military nature.

The Council was reconstituted as CSIRO, the Commonwealth Scientific and Industrial Research Organization. The management of CSIRO was placed in the hands of a small Executive instead of the previous Council. Sir David Rivett retired in the same year and Dr I. Clunies Ross (later Sir Ian) became the first Chairman of the Executive.

Since then successive governments have supported the gradual expansion of CSIRO's activities so that, in one way or another, the work of its 37 Divisions and seven Units now carries over into almost every field of primary and secondary industry, as well as into many other areas affecting the community at large—the environment, human nutrition, conservation, and urban planning.

General

Administrative arrangements

On 2 July 1975, an Administrative Arrangements Order published in the Australian Government Gazette made the administration of the Science and Industry Research Act 1949 the joint responsibility of the Minister for Science and Consumer Affairs and the Minister for Minerals and Energy. The responsibility of the latter Minister was defined as administration of the Act 'in so far as that Act relates to mineral and solar energy research'.

Following the change of Government in December 1976, revised Administrative Arrangements Orders restored full responsibility for the administration of the Science and Industry Research Act to the Minister for Science.

Executive appointments

Professor H. W. Worner was appointed a full-time member of the Executive in January 1976. Professor Worner joined the CSIR Lubricants and Bearings Section, later the Division of Tribophysics, in 1940. He was appointed Officer-in-Charge of the former Physical Metallurgy Section in 1956 and in the same year became Professor of Metallurgy at the University of Melbourne. He was Dean of the Faculty of Engineering at the University of Melbourne during 1958 and 1959, and President of the Australian Institute of Nuclear Science and Engineering from 1963 to 1964. In 1964 he relinquished his position with CSIRO in order to devote his full time to university activities.

Professor Worner succeeds Mr Lewis Lewis who retired from the Organization in January 1976. Mr Lewis, who joined CSIR in 1940 as Secretary of the Division of Industrial Chemistry, was asked by the Executive in 1955 to establish and lead an Industrial Research Liaison Section to promote and facilitate the application of CSIRO's research results by secondary industry. He became Executive Officer of CSIRO in 1964, an Associate Member of the Executive in 1966, and a Member of the Executive in 1969. Throughout his career with CSIRO, he made a major contribution to the development of the Organization's industrial research programs and to the utilization of the results of that research by secondary industry.

Professor Mollie E. Holman, Professor of Physiology at Monash University, was appointed a part-time member of the Executive in November 1975. She is the first woman to be appointed to the Executive. Professor Holman, an authority on the transmission of nerve impulses to muscle, is a Fellow of the Australian Academy of Science and a recipient of the Edgeworth David Medal of the Royal Society of New South Wales.

Professor Holman takes the place of Professor E. J. Underwood who was Chairman of the Western Australian State Committee and a Member of the Advisory Council before joining the Executive in 1966. One of Australia's most distinguished agricultural scientists, Professor Underwood has taken part in a number of major reviews of CSIRO's agricultural research programs and contributed to recent discussions on restructuring the Organization.

Senior appointments

Dr M. F. C. Day resigned his position as a member of the Executive in May 1975 to take up his appointment as Chief of the DIVISION OF FOREST RESEARCH. Dr Day, who has been acting Chief of the Division since its establishment last year, was appointed to the Executive in 1966.

Dr D. S. Taylor succeeded Dr M. Lipson as Chief of the DIVISION OF TEXTILE INDUSTRY and Chairman of the Wool Research Laboratories Committee following Dr Lipson's retirement from those positions in February 1976. Dr Taylor was previously a Chief Research Scientist with the Division.

Process Technology

Professor A. V. Bradshaw, formerly Professor of Applied Metallurgy at the Royal School of Mines, London, was appointed Chief of the newly established DIVISION OF PROCESS TECHNOLOGY in October 1975. The Division, which is part of CSIRO's MINERALS RESEARCH LABORATORIES, was formed from the Sydney-based sections of the DIVISION OF MINERAL CHEMISTRY which has its headquarters in Melbourne.

The DIVISION OF PROCESS TECHNOLOGY will carry out research into methods of deriving alternative fuels from Australian coal resources. It will also continue established research programs on pelletization of iron ore, direct reduction of iron ore to metal, and environmental protection.

Animal Research Laboratories

In November 1975, a major part of the DIVISION OF ANIMAL GENETICS was amalgamated with the DIVISION OF ANIMAL PHYSIOLOGY to form the DIVISION OF ANIMAL PRODUCTION. Dr T. W. Scott, who was formerly Chief of the DIVISION OF ANIMAL PHYSIOLOGY, was appointed Chief of the new Division and Dr J. M. Rendel, formerly Chief of the DIVISION OF ANIMAL GENETICS, became a Senior Research Fellow.

The remainder of the DIVISION OF ANIMAL GENETICS was made an independent Unit, the MOLECULAR AND CELLULAR BIOLOGY UNIT, with Dr G. W. Grigg as acting Officer-in-Charge.

Establishment of the DIVISION OF ANIMAL PRODUCTION was undertaken to achieve greater integration of livestock breeding and physiology research programs and to make more effective use of the existing research facilities.

In June 1976, Mr A. F. Gurnett-Smith, formerly Secretary (Research), accepted a two-year appointment as Officer-in-Charge of the CENTRE FOR ANIMAL RESEARCH AND DEVELOPMENT near Bogor, West Java. He succeeds Dr L. J. Lambourne.

CSIRO's ANIMAL RESEARCH LABORATORIES now comprise the DIVISIONS OF ANIMAL HEALTH and ANIMAL PRODUCTION, the MOLECULAR AND CELLULAR BIOLOGY UNIT, and the CENTRE FOR ANIMAL RESEARCH AND DEVELOPMENT.

Overseas liaison

Dr C. A. Anderson, formerly of the DIVISION OF TEXTILE INDUSTRY, has succeeded Mr E. E. Adderley as Counsellor (Scientific) in the Australian Embassy in Tokyo. He took up his appointment in October 1975.

In January 1976, Mr J. G. Downes, formerly Chief of the DIVISION OF TEXTILE PHYSICS, took up his appointment to the newly created post of Counsellor (Scientific) in the Australian Embassy in Moscow.

As a result of a Government directive to limit staff numbers in overseas posts, the number of senior staff in the Organization's overseas liaison offices in London and Washington will be reduced to one each as from July 1976.

Research

In a report of this size it is not possible to give a full account of all of CSIRO's current investigations. The items in this section have been chosen, therefore, to show something of the wide range of CSIRO's activities and their relevance to the needs of the Australian community. The items also illustrate that many research programs involve the collaboration of scientists from different disciplines and different Divisions. More comprehensive information on the Organization's current research activities can be obtained from the separate annual reports published by each Division. A brief description of the fields of research engaged in by each Division is given on pages 65–71 of this report.

Nitrogen losses from tropical soils

The mechanisms and extent of nitrogen losses from a number of Queensland soils are being studied.

In northern Australia, as indeed in many other parts of Australia, most soils provide insufficient nitrogen for sustained good growth of pasture grasses. Continued high yields require regular additions of nitrogen. Synthetic nitrogen fertilizers are a convenient source of nitrogen but are too expensive for general use. Accordingly, a major and successful effort has been made over the years by the DIVISION OF TROPICAL CROPS AND PASTURES to find tropical grazing legumes that will grow well in Australia and increase the nitrogen supply by fixing it from the air.

While most of the research effort has gone into increasing the nitrogen supply economically, CSIRO scientists have also been studying the fate of this valuable nutrient under normal grazing conditions, and have been recording large losses. It is easiest to measure losses when nitrogen is added in the form of synthetic fertilizer because the input can be recorded exactly. Work by the DIVISION OF TROPICAL CROPS AND PASTURES has shown that 40 to 80% of the fertilizer nitrogen added to tropical grasses grazed by beef cattle in southern Queensland is lost over a period of years. Most of the residual 20 to 60% accumulates in the soil's organic matter; only a small percentage goes off with the beef cattle when they are slaughtered.

It is more difficult to detect losses of nitrogen fixed by legumes because there is no simple way of recording the amount added, but there is growing evidence of serious wastage of this nitrogen also.

Several CSIRO Divisions are studying the mechanisms of these losses in the hope that it might be possible to reduce them or at least recognize when they have occurred. One line of work is concentrating on the loss of ammonia from the soil surface. Scientists from the DIVISIONS OF ENVIRONMENTAL MECHANICS and PLANT INDUSTRY have, for the first time, developed a realistic technique for measuring loss of ammonia from land surfaces. Collaborative research by the DIVISIONS OF ENVIRONMENTAL MECHANICS and TROPICAL CROPS AND PASTURES has shown that up to 10% of a dressing of urea fertilizer may be lost as ammonia within a week of application.

Another approach is concerned with

the microbial conversion of soil nitrate to gases other than ammonia. In the early 1960s, CSIRO scientists developed gas lysimeters in which plants could be grown in soil in an enclosed atmosphere and the atmosphere analysed for nitrogenous gases. Subsequent use of these gas lysimeters by the DIVISIONS OF TROPICAL CROPS AND PASTURES and SOILS, and by the Queensland Wheat Research Institute, has shown that significant gaseous losses from nitrate occur only when the soil is actually submerged.

It is not uncommon for soils in Queensland to be submerged during heavy cyclonic rains, and such rains are also likely to be responsible for a third type of loss—leaching of nitrate from the soil. Leaching losses are being studied by the DIVISIONS OF SOILS and TROPICAL CROPS AND PASTURES.

Although most of the research in progress concerns the fate of added nitrogen, there is also considerable interest in how nitrogen behaves in naturally fertile, arable soils. An important area of soils with high nitrogen fertility is the land that formerly carried brigalow forest in Queensland and northern New South Wales. An increasing proportion of this land is being used for grain cropping, but it is not known how long the yields will remain high without additions of legume or fertilizer nitrogen.

In 1968, therefore, the DIVISION OF TROPICAL CROPS AND PASTURES initiated a long-term study of fertility trends under continuous grain crops, crop–pasture rotations and continuous pasture on brigalow land at its Narayen Research Station near Mundubbera, Qld. Recently, this program has been expanded to measure rates of gains and losses of nitrogen under five contrasting forms of agriculture—sorghum for grain, mung beans (an annual legume crop) for grain, oats for hay, lucerne for hay, and green panic (a perennial tropical grass) for hay.

Knowledge of the nature of nitrogen losses in these different situations could help in the development of improved cultural practices to reduce the extent of such losses.

Nodules on the roots of a soybean plant. Rhizobia, bacteria which live in the nodules, obtain sugars from the plant and use these as a source of energy to help convert nitrogen gas from the soil air into chemical compounds that can be used by the plant. Plants such as beans, peas, and clovers, which are able to fix nitrogen in this way, are known as legumes.

Until recently it was thought that rhizobia could only fix nitrogen in association with legumes. However, the DIVISION OF PLANT INDUSTRY has found that some bacteria can fix nitrogen in a laboratory culture independent of legumes. Similar findings have been reported by research teams at Murdoch University, Perth, and at the Canadian Research Council in Saskatoon. Since then the DIVISION OF PLANT INDUSTRY has been able to define the physical and chemical conditions that will induce rhizobia to fix nitrogen in the complete absence of either whole plants or plant cells.

Photograph: Colin Totterdell

Breeding better livestock

Identification of inherited characteristics which are economically important in livestock production and the development of methods of selecting for them are leading to real and lasting improvements in the productivity of livestock.

For the first two decades of this century geneticists throughout the world concentrated their research on the way genes are distributed from parent to offspring. To do this they studied characters controlled by single genes. Having explained the mechanics of gene transmission underlying Mendel's laws, geneticists then focused their attention on characters whose variation is controlled by more than one gene.

Fleece weight, body weight, milk yield and number of eggs laid in a year are characters of this type. Where these characters vary between individuals in flocks and herds, the variation is not caused by single genes. But variation cannot be attributed solely to the influence of multiple genes either. In every case, variation is the product of an intricate interplay between multiple genes and differences in the environment. By the 1940s, geneticists had developed methods which unravelled this complex interaction and had worked out the extent to which such characters are genetically determined.

Because many genes may influence a single character, the techniques are necessarily statistical, selecting not the superior individual but the superior group of individuals whose mean performance is higher than that of the herd or flock from whence they came. Such superior groups are then used for breeding.

Key statistical concepts emerged at this time: the heritability of a character is the genetic fraction of its variation; a genetic correlation is the extent to which two individuals or groups are alike for genetic reasons; the selection differential is the amount by which a group of selected breeders exceeds the performance of the group from which it was drawn.

With these simple concepts it is possible to design breeding programs to change a character effectively in a desired direction. Broadly, there are three choices open to the breeder—mass selection, family selection and progeny testing.

When heritability is high and the character is expressed in both sexes, e.g. in the weight of wool grown by a sheep in a year, mass selection is the most effective method. When only one sex expresses the character, as in milk yield or egg laying, progeny testing or family selection, where the merit of an animal can be estimated from the merit of its relatives and progeny, are the most effective methods. With milk yield in dairy cattle, progeny testing proves on analysis to be better than family selection; with egg laying in poultry, family selection is usually preferred because of the low generation interval.

The former DIVISION OF ANIMAL GENETICS has published the simple methods most likely to succeed in increasing egg production in poultry. These are adaptations to Australian conditions of methods that have raised egg production world wide from some 120 eggs per hen housed per year in the 1920s to 240 per year. Although progress beyond this point has not yet been achieved, the DIVISION OF ANIMAL PRODUCTION is attempting to break through this genetic barrier.

In recent years CSIRO has taken part in discussions with State Departments of Agriculture concerning the introduction of progeny testing of dairy bulls used in artificial breeding centres. Previous attempts to prove bulls in natural service came to nothing because people had to compare a bull whose daughters were all milked in one herd with another bull whose daughters were milked in a different herd. As differences between herds are due mostly to feeding and management, the differences between bulls in natural service are more a reflection of the skill of the farmers than the worth of their bulls. But with the advent of artificial insemination and the development of artificial breeding centres, the genetic legacy of a bull could be observed in many herds and, as a corollary, the genetic legacies of many bulls could be compared in a single herd. It became possible to compare bulls on the basis of the yield of daughters who had been reared and milked side-by-side.

'Contemporary comparison', as this procedure is now known, is the key to breeding dairy cattle. The DIVISION OF ANIMAL PRODUCTION is using the technique to create a breed of tropical dairy cattle which will combine milk production with heat tolerance and tick resistance.

The first step involved crossing Indian Sahiwals, which have the heat tolerance and tick resistance characteristic of Zebu breeds, with British Jerseys. The bulls resulting from such crosses were selected by direct test for their heat tolerance and tick resistance and the top six to ten bulls were mated to crossbred cows and progeny-tested for milk production in their daughters. Finally, the top bull was used to breed further teams of bulls for testing. So far two generations of selection have been completed, each generation occupying 7 years. Already a breed has emerged with high resistance to ticks and heat, and with milk-producing ability equivalent to that of a Guernsey. The breed, known as the Australian Milking Zebu, or AMZ, is still small in number, but surplus stock have been sold to Malaysia, the Philippines and Trinidad, and semen has been used in India, Fiji and Mauritius.

Mass selection is the method being used by the DIVISION OF ANIMAL PRODUCTION to breed beef cattle for the tropics. The characters for which breeding stock have to be chosen are quite highly heritable and can be measured directly on the individual animal. Most important are those associated with heat tolerance, fertility, and resistance to ticks, worms and disease. A combination of Africander, Hereford and Shorthorn cattle, after some three generations of selection, has produced the Belmont Red, already a highly useful animal though, like the AMZ, still capable of many generations of improvement.

CSIRO has also used mass selection in sheep to increase production of wool and meat and to improve wool quality. In the case of multiple births, however, a character expressed by the female, the selection program had to include some means of assessing the male, either directly on the basis of his progeny or, by inference, on the merit of his sisters and half sisters.

The choice of a selection and mating system is fairly simple once the character to be improved and its mode of expression are known and its heritability determined. The choice of character and the means of measurement depend on the type of animal wanted and the convenience, cheapness and suitability of the measurement. However, it often happens that a measurement chosen for cheapness and convenience results in the wrong animals being selected for breeding.

The crimp of a wool staple is a classic example. Crimp frequency, once used extensively as an estimate of wool fineness, has been shown by the former DIVISION OF ANIMAL GENETICS to be an unreliable guide to mean fibre diameter. It is mean fibre diameter which is now accepted as the most important measure of wool quality. Not only is crimp relatively unimportant in wool processing, but selection for crimp alone leads to reduced yield of clean wool and depressed quality. The Division has shown that fleece weight can be increased by selection for high, clean-fleece weight while controlling quality by maintaining fibre diameter.

At a time when many of Australia's livestock industries are experiencing considerable economic difficulties, the productivity of individual animals is of prime importance. It is desirable therefore that every effort should be made to concentrate genetic selection on those characters which contribute most to performance. In some cases, CSIRO's research has indicated the particular characters that the farmer and stud master can use in their breeding programs to develop genetically superior animals. In other cases, important genetic characters such as tick resistance and heat tolerance in cattle are difficult to recognize and select for without the kind of facilities that are available to CSIRO geneticists in their laboratories and field stations. In these instances, however, the results of the geneticists' selection procedures have resulted in the development of genetically superior animals which are made available progressively to the industry for use in commercial flocks and herds.

Controlling the rabbit

Information on rabbit physiology, behaviour and ecology is providing a base for the development of methods of control to supplement myxomatosis.

In 1951, the successful release of myxomatosis by CSIRO into the Australian rabbit population dramatically reduced the numbers of rabbits which at that time were in plague proportions. The Bureau of Agricultural Economics estimated that in 1952–53, Australia's wool and meat production jumped by $68 million as pastures recovered from the ravages of rabbits. Since then less lethal strains of myxoma virus have emerged and rabbit populations have developed a degree of genetic resistance to the disease.

To counter this, better strains of virus were selected and methods of inoculation and dissemination of the virus were improved. The European rabbit flea was introduced into Australia as an alternative vector for transmitting the disease. Although these improvements have helped maintain the effectiveness of myxomatosis, there is little prospect of finding further techniques for making the disease effective. Myxomatosis remains a significant factor in rabbit control, but in time its effectiveness is likely to diminish and other methods of control will become increasingly important.

Over the past 15 years the DIVISION OF WILDLIFE RESEARCH has made intensive studies of the biology and ecology of the rabbit in an attempt to understand the factors on which its reproduction and survival depend. An adequate understanding of these factors is necessary in order to form a sound basis for designing effective long-term control measures.

The Division has shown that the

rabbit's success varies with climate—a Mediterranean-type climate with hot, dry summers and cool, wet winters suits it best. Within each region, distribution and numbers depend on topography, soil, vegetation, predators, disease and the activities of man.

A series of studies in key areas has highlighted the importance of residual populations which survive to form the nucleus for a subsequent increase in numbers. These residual populations may be in areas where natural mortality factors are less effective than elsewhere or where it is difficult to carry out control operations.

Major survival areas were pinpointed in some regional surveys. In agricultural regions survival areas are often in rocky, timbered hills and other areas where machinery cannot be used for eradication procedures. In arid areas the surveys covered a total area of 650 square kilometres and revealed the special importance of survival areas during times of drought when surviving rabbits are to be found in small areas near swamps and drainage channels. Control efforts directed at such areas, particularly during droughts, can be highly effective and long lasting.

Warrens are important for survival since they afford the rabbits protection and provide a focal point for their gregarious behaviour. Destruction of warrens is therefore an important part of many control programs.

Observations on the behaviour of rabbits have shown that they are less nomadic than was thought. This finding has provided extra incentive for implementing projects aimed at eradicating rabbits completely from large groups of holdings.

Behavioural studies on rabbits in enclosures have shown that poisoning is most effective when the rabbits are not breeding. During the breeding season they live in small groups in territories which they defend against intruders. For poisoning to be effective, the furrows in which the poison bait is to be laid must cut through each separate territory. But even if this is done and the breeding females are poisoned, studies have shown that unweaned kittens, which are more than 17 days' old but still not old enough to eat the poison bait, may survive the loss of their mothers and form a nucleus for another build-up in the population. Outside the breeding season the survival of young kittens is not a complicating factor and the rabbits are less restricted by territorial boundaries. Poisoning at that time is therefore more effective.

The poison '1080' (sodium fluoroacetate) has been widely used since trials at the DIVISION OF WILDLIFE RESEARCH revealed that it has advantages over other poisons, although precautions must be taken to protect stock and other animals against accidental poisoning.

The Division has devised a method of administering the poison, known as the tarbaby technique, which minimizes the danger to other animals. Behavioural studies showed that rabbits groom their front paws by licking them. If 1080 is mixed with a tacky base and placed on the floor of each opening to a burrow, rabbits step on it and then ingest the poison when they lick their feet to clean them. But although the technique gave promising results in field trials there proved to be practical problems in adapting it for use by land-holders.

Another technique of poisoning has been developed for subalpine areas by exploiting the rabbit's appetite for sodium. In the spring and summer when soils and plants in these areas are particularly deficient in sodium, rabbits develop a considerable appetite for it. In experiments, sodium-deficient rabbits gnawed avidly at softwood pegs dipped in sodium chloride and 1080 poison.

The Division hopes that it may be able to improve poisoning by developing chemical attractants based on the rabbit's system of communicating by smell. Behavioural studies have shown that fluids exuded from chin, anal and inguinal scent glands are used for communication among rabbits, enabling them to recognize their home territory or group and alerting them to rabbits from outside their group.

Rabbits in all areas are infested with internal parasites. Many of the parasites found in rabbits in Europe are not found in Australia and the Division is giving high priority to testing these and other organisms for biological control. No parasite will be introduced, however, until it has been shown to have no harmful effects on stock or native animals.

The role of predators in rabbit control is also being evaluated. It is already clear that the most important predators are two important animals, the European fox and the feral cat. In the arid and Mediterranean-type areas predators may account annually for about 80% of the death rate in young rabbits.

The large amount of data gathered by the Division on rabbit physiology, behaviour and ecology is providing a base for further experimental studies on rabbit control. It has also demonstrated that there is little possibility of developing a single strategy for control that can be applied to all situations. Different ecological zones will require different approaches.

Grading wheat for marketing

Improved methods of segregating wheat varieties and of sampling and testing grain are facilitating quality control of Australia's export wheat.

In recent years wheat buyers have become increasingly quality conscious, setting specifications for protein content, moisture content, insect contamination and so on.

The WHEAT RESEARCH UNIT has been collaborating with the New South Wales Grain Elevators Board and other wheat industry authorities to improve methods of segregating wheat varieties and of sampling and testing the grain. Adoption of these methods will help ensure that Australia's wheat crop is marketed in homogeneous grades of known quality.

The different physical and chemical properties of the various wheat varieties determine the commercial use to which the grain is put. Hard wheat of high protein content commands the highest prices and is in demand in western countries for bread-making, and in Asia for making certain types of noodles. Wheat of lower protein content is used for foods such as biscuits, cakes and Japanese white noodles.

Australian wheat varies in protein content from 8 to 16%, hence the need to segregate at receival points on the basis of variety and protein content.

Quality control begins on the farm. Provided farmers follow the recommendations of their State Department of Agriculture with respect to varieties sown, planting schedules, fertilizer programs and harvesting procedures, the wheat from a particular area should be of uniform and predictable quality. Tests at receival points can then be restricted to rapid, mainly visual methods of grading according to market requirements.

The first place where sampling is practicable is at the receival points in the country. On delivery to the country silo the grain is checked to ensure that it is sound and clean. If premium quality wheat is to be segregated, checks on variety and protein content are also carried out. Individual truckloads from farmers tend to be fairly uniform in quality and a sample at this stage is usually adequate for segregation.

The WHEAT RESEARCH UNIT in collaboration with State Departments of Agriculture has produced a handbook describing the growth, head and grain characteristics of commercially grown Australian wheat varieties. The book provides a reference which assists the managers of country silos, and others, to check the identity of wheat as it is delivered. This facilitates segregation of premium quality grades.

The Unit has also developed laboratory methods of identification for confirming and extending the determinations made visually. The most specific of these uses the technique of electrophoresis to separate wheat proteins into marks or bands which stain blue when a dye is applied. The pattern of the bands is characteristic of a particular variety, regardless of the growing conditions.

The standard method of measuring protein in grain is the Kjeldahl method. While highly accurate in the hands of a trained operator, it is time consuming, and not suitable for use in areas where laboratory facilities are minimal. The Unit has therefore developed two rapid methods of protein determination which are suitable for use in these situations.

In the first method the protein is treated with alkali and the ammonia liberated is distilled off and estimated by titration with acid. A numerical factor is then used to convert the titration figure to percentage protein. Each analysis takes about 20 minutes and a minimum of training is required to operate the apparatus. The method has been used successfully for four harvests in southern New South Wales to separate Southern Hard from Australian Standard White wheat.

The second method depends on a reaction between protein and copper. The apparatus automatically reacts a pre-weighed sample of ground grain with a measured quantity of chemicals. It then filters the products and measures them colorimetrically. The reaction takes about 5 minutes and the results are presented directly as percentage protein. This equipment has been tested under harvest conditions and several units, manufactured commercially, have now been sold.

Although additional checks are made at several points during the passage of the grain from the country receival point to the shipping terminal, great reliance is placed on these initial tests.

The shipping terminal is another key sampling location since samples taken at the terminal enable the results from the country receival points to be checked. They also aid weighing-up operations before shipment. Collecting representative samples at this stage, however, has presented a significant problem because of the high speeds at which conveyor belts move and the huge quantities of grain involved.

Since quality control is limited by the accuracy of sampling techniques, the Unit has turned its attention to shortcomings in the methods by which samples are drawn from the bulk grain. It has examined the two types of grain sampling probes used in Australia and found that one drew a much more representative sample than the other. The Unit has also developed a simple device for continuous sampling of grain going either into or out of country silos, arriving at seaboard terminals or, more importantly, grain ready for shipment overseas. The device is presently being tested both at country silos and at seaboard terminals.

Several of the devices have been installed at the Newcastle shipping terminal in order to keep a close watch on the quality of overseas shipments. Samples are collected every 15 minutes so that the protein and moisture content of the shipment can be calculated accurately and so that wheat of higher protein content can be blended in if portions of the shipment are failing to meet the specifications.

Insect pests in stored grain

Alternatives to current methods of controlling insect pests in stored grain are being sought.

Commonwealth Government regulations require that grain for export must be free from living insects and that chemical residues from insecticides do not exceed certain specified levels. To meet these requirements, Australia has had to rely on a few internationally acceptable chemicals, especially malathion. However, malathion has never been very effective against moths and most other grain insects have become resistant to it. In addition, if grain treated with malathion is stored for more than 6 months, a second treatment is necessary.

The DIVISIONS OF ENTOMOLOGY and MECHANICAL ENGINEERING are seeking practical solutions to the problem of insects in stored grain. While more acceptable chemical methods of control are being investigated as a short-term measure, the long-term aim is to develop methods that will eliminate the use of chemicals.

The DIVISION OF ENTOMOLOGY is taking part in a working party organized by the Australian Wheat Board to evaluate alternative insecticides which are long lasting and leave chemical residues that are not harmful to man. So far the most promising alternatives are the synthetic pyrethroids, synthetic chemicals closely related to the natural substance found in pyrethrum plants. One of these chemicals successfully controlled the grain insects in five commercial silos during trials and several other pyrethroids are being evaluated.

Other studies at the Division have resulted in far smaller amounts of chemicals such as dichlorvos and phosphine being used to fumigate the grain immediately prior to shipment without loss of effectiveness. By using combinations of the most effective chemicals it may be possible to reduce even further the total quantity of chemicals used both during storage and for pre-shipment fumigation.

Scientists at the DIVISION OF ENTOMOLOGY have also tested methods of controlling grain pests by eliminating almost all the oxygen from the grain store. If grain is loaded into air-tight underground pits, the insects use up the available oxygen until there is not enough left to support life.

A scanning electron micrograph of the granary weevil, *Sitophilus granarius*, on a grain of wheat. The ability of the scanning electron microscope to resolve fine surface details at relatively low magnifications enables photographs to be used to illustrate the differences between species. Magnification: $\times 66$.

Initial trials of air-tight storage in pits showed that the method was cheap and effective, and protected the grain from insects and from a mouse plague which devastated grain stored above ground at the time of the trials.

Additional trials are now in progress. At Narrabri, N.S.W., polyethylene sheeting has been used to line a pit in a trial which is due to end this year. A long-term trial is also under way with another pit containing 100 tonnes of wheat. This will be opened in several years' time to test the wheat for insect damage, moisture content, and baking and milling quality.

The principle of excluding air can also be applied to silos, but experiments have shown that it is extremely difficult to build completely air-tight silos. Small holes are usually found around loading points near the base and where the roof joins the walls. Convection can cause substantial losses of gas through these holes even when the air is still. Steady winds of low velocity cause still greater losses. Simulation studies carried out in a wind tunnel by the DIVISION OF ENVIRONMENTAL MECHANICS showed that in moderate wind conditions the displacement of air in a silo containing two small (4 sq cm) holes—one at the top and one at the bottom—could be as great as 8% a day.

An alternative solution in which nitrogen is used to flush out oxygen from the silos is therefore being tested by the DIVISION OF ENTOMOLOGY. The nitrogen is introduced rapidly at first to displace the air and then slowly to compensate for leakage. The results from silos with steel bins are encouraging and long-term trials are under way. In the case of silos with concrete bins, however, leakage is considerable and a large amount of nitrogen is needed continuously to make up the loss.

In conjunction with the New South Wales Grain Elevators Board the Division is searching for a compound that can be applied to the insides of existing concrete silos to minimize leakage. The compound needs to be of reasonable cost, long lasting, impermeable, non-toxic to humans, and tough enough to resist grain abrasion yet pliable enough to stretch across cracks that open as the silo fills with grain. Three compounds are being tested at present.

The DIVISION OF MECHANICAL ENGINEERING is developing alternative methods of control which exploit the insects' sensitivity to both cold and heat—temperatures below about 15°C are too cold for insects to reproduce and above 60°C too hot for their survival. In Australia grain is often harvested in temperatures of 30°C or more and the warmth is retained remarkably well in bulk storage providing ideal conditions for insect attack.

In North America a system of forcing naturally cool air through the grain mass in a silo is used extensively to lower the temperature to a level where insect damage is prevented. Scientists from the Division found that the method could be utilized in the cooler areas of Australia where night temperatures are low enough to cool the grain sufficiently. A special control device was developed to aerate the grain only at periods of low temperature without creating moisture problems.

In the more northerly wheat-growing areas of Australia, however, the nights are too warm for aeration to be successful. Even in the cooler regions the temperatures are low enough only to control insect populations but not to eliminate them. To provide conditions too cold for insect reproduction, the Division has developed a system of refrigerated aeration. This reduces the temperature of the bulk grain to less than 10°C over a period of about 6 weeks. In trials over two seasons at Brookstead, Qld, no live insects were found despite extensive sampling 8 months after the silo had been insulated and cooled with refrigerated air. The method is safe, clean and does not impair the quality of the grain. Running costs can compare favourably with current chemical methods of control, but the capital outlay is greater.

The DIVISION OF MECHANICAL ENGINEERING is also testing a rapid method of heat sterilization which uses a fluidized bed. The individual grains are suspended for a short time in a jet of hot air, then quickly cooled. By controlling temperatures and exposure times, insects can be destroyed at all stages of their life cycles without affecting the quality of the grain. The times and temperatures required for this have been determined by the DIVISION OF ENTOMOLOGY. It is envisaged that the process could be used at export terminals where a method of destroying insects rapidly without leaving a residue is needed.

Storing fruit and vegetables

Basic research on the physiology and biochemistry of plant cells is helping to improve methods of storing and transporting fruit and vegetables without loss of quality.

Most fruits and vegetables begin to deteriorate from the moment they are harvested or shortly after they have ripened. This is because they are living material. Once detached from the parent plant or removed from their growth environment, they must produce the energy needed to stay alive by breaking down the sugars in their tissues to carbon dioxide and water—a process known as respiration.

Slowing down respiration by storing at low but not freezing temperatures prolongs the life of many fruits and vegetables. Moreover, the storage life and final quality can often be improved still further by increasing the amount of carbon dioxide and decreasing the amount of oxygen in the atmosphere around the fruit.

Since the 1930s the DIVISION OF FOOD RESEARCH has carried out a considerable amount of research, much of it in association with State Departments of Agriculture, to develop improved storage techniques based on the use of low temperatures and controlled atmospheres. Although these methods have brought about substantial improvements in storage, they have given rise in some instances to new and unexpected problems such as various low-temperature storage disorders of apples and pears.

By the 1950s it had become clear that a solution to these problems would require a better understanding of the basic physiology, biochemistry and biophysics of the myriad cells of which plant tissues are composed. Accordingly, the Division formed the Plant Physiology Unit in 1952 to examine the basic mechanisms underlying the post-harvest behaviour of fruits and vegetables.

In order to gain a better understanding of the processes involved in maturation and ripening, the Unit adopted a two-pronged attack. One line of approach was to investigate the physiology and biochemistry of ripening fruit to determine, both at the whole tissue and at the cellular level, the nature of the changes that take place during ripening and the factors that control these changes. The banana was chosen as the main fruit on which to carry out this research and particular emphasis was placed on the effects of ethylene gas and other plant hormones in initiating ripening. The other line of work involved studying the processes concerned with the regulation of maturation. Much of this work was directed at the chloroplast, one of the minute particles found in plant cells. In leaves exposed to light, chloroplasts are a major site of protein synthesis. The Unit is now studying the regulation of the synthesis of Fraction I protein, the main protein of the chloroplast and the world's most abundant protein. This work is expected to give clues about how very long-living cells such as those found in a cool-stored fruit maintain the protein synthesizing capacity needed for their well being.

It has been known for some time that the calcium concentration in fruit is important in minimizing post-harvest storage disorders. Recent work at the Unit has shown that the level of calcium in apples can be increased after harvest by infiltrating calcium salts into the fruits.

Although the function of calcium in plant membranes is largely unknown, studies suggest that calcium interacts with plant cell membranes to reduce the leakage of nutrients from the cell.

But while the Unit's research has helped overcome a number of problems associated with cool storage, there are still many fruits, particularly tropical ones such as bananas, that are injured by low temperatures.

About 10 years ago the DIVISION OF FOOD RESEARCH, in conjunction with the New South Wales Department of Agriculture, developed a system of transporting green bananas in plastic bags over thousands of kilometres. On reaching their destination, the bananas were given a dose of the natural ripening hormone, ethylene, under conditions of controlled temperature to ripen them quickly and evenly. In this way, cool storage during long-distance transport was avoided.

With tomatoes and many other fruits, however, this technique does not work owing to uneven ripening after harvest. The Plant Physiology Unit is trying to find out why some tomatoes in a crop ripen earlier than others. By comparing normal strains of tomatoes with mutant strains, which do not ripen or which ripen only partially, scientists at the Unit are hoping to discover missing factors which might regulate the ripening process. This could then give a lead to possible genetic or chemical means of regulating ripening in tomato crops so that all of the fruit ripens at the same time.

Research by the Unit has also revealed why tomatoes and many tropical fruits are injured quickly by low temperatures and soften, while other fruit and vegetables can survive low temperatures with little damage. The key to understanding the mechanism of the process that enables some plants to withstand chilling has been found in the physical properties of the cell membranes.

These membranes are composed of fatty substances, called lipids, and proteins. In most tropical plants growing at temperatures of about 15°C or above, the membrane lipids are in a 'melted' condition and the membranes are fluid. When the temperature is reduced below about 15°C (the critical temperature varies from species to species), physical changes in the membrane lipids cause them to 'freeze' and the membranes become more 'rigid'—like butter hardening in a refrigerator. This physical phase transition from fluid to rigid state has profound effects on the properties of the membranes and of the chemical processes in the cell. When the membranes turn rigid they become like an open mesh instead of a semi-porous skin—nutrients leak out of the cell, foreign substances leak in, energy production slows down, and the chemistry of the cell becomes disorganized. Plants and fruits which are resistant to chilling have membrane lipids which remain semi-fluid at low temperatures.

The Unit is now trying to discover why there is such a variation in sensitivity to chilling among different species of plants. It is also working on methods that could help plant breeders select chilling-resistant plants more easily and improve the keeping quality of their fruit.

Pine trees and termites

Shortage of timber in the Northern Territory has led to a search for suitable tree species that can be grown locally.

The inability of forests in the Northern Territory to meet local requirements was recognized many years ago. During World War II much of the suitable timber within 250 km of Darwin was harvested and so the problem became more acute. In 1955 the Forestry and Timber Bureau began a search for tree species that would endure the harsh northern climate and yield general purpose timber. This work continued after incorporation of research groups from the Bureau into the newly formed CSIRO DIVISION OF FOREST RESEARCH in 1975.

A wide range of tropical trees has been studied and the most promising species so far is *Pinus caribaea*, a native of Central America and the Caribbean islands which has been successfully planted in tropical Queensland, Fiji, and parts of Africa and Asia.

Most of the *Pinus caribaea* seed used in the early tests came from Belize, but the Commonwealth Forestry Institute at Oxford, U.K., arranged for officers from the Division and the Department of the Northern Territory to collect seed from the variety *hondurensis* in Belize, Guatemala, Honduras and Nicaragua for inclusion in subsequent trials. Seedlings from collections made on the coastal plains of northern Nicaragua and adjacent Honduras have shown the fastest growth in plantings near Darwin and on Melville Island.

The Division used seeds from seed orchards in Queensland and Fiji to test their potential under conditions in the Northern Territory. Results to date, however, indicate that selection from local plantations will be necessary to achieve optimum growth and form.

One major threat to the successful growth of *Pinus caribaea* around Darwin is the termite *Mastotermes darwiniensis* which may kill up to 30% of young trees in a year.

With the cooperation of the Australian Atomic Energy Commission, the DIVISION OF FOREST RESEARCH has developed a radioisotope method for tracing subterranean colonies of the termites. Because individual termites exchange nutrients with others in a colony, a small amount of a radioisotope eaten by a few termites spreads through a colony containing several million members. In this way the Division can estimate the extent and population of a colony before introducing an appropriate poison. The same process of transfer spreads the poison among the termites and eventually wipes out the colony.

The Division has demonstrated that in order to establish the new plantations clean clearing of the existing eucalypt forest is important. The population of *Mastotermes darwiniensis* increases in wood debris remaining on the site after normal clearing and its early removal by burning greatly reduces the persistence of the termites. When economic considerations preclude thorough clearing, the poison bait method of controlling termites, which may emerge from logs in windrows or in adjacent forests, is effective and easy to apply.

In addition to research on the best tree species for the Territory, the Division has extended earlier work by the former DIVISION OF LAND RESEARCH and the Department of the Northern Territory on the soils of the region.

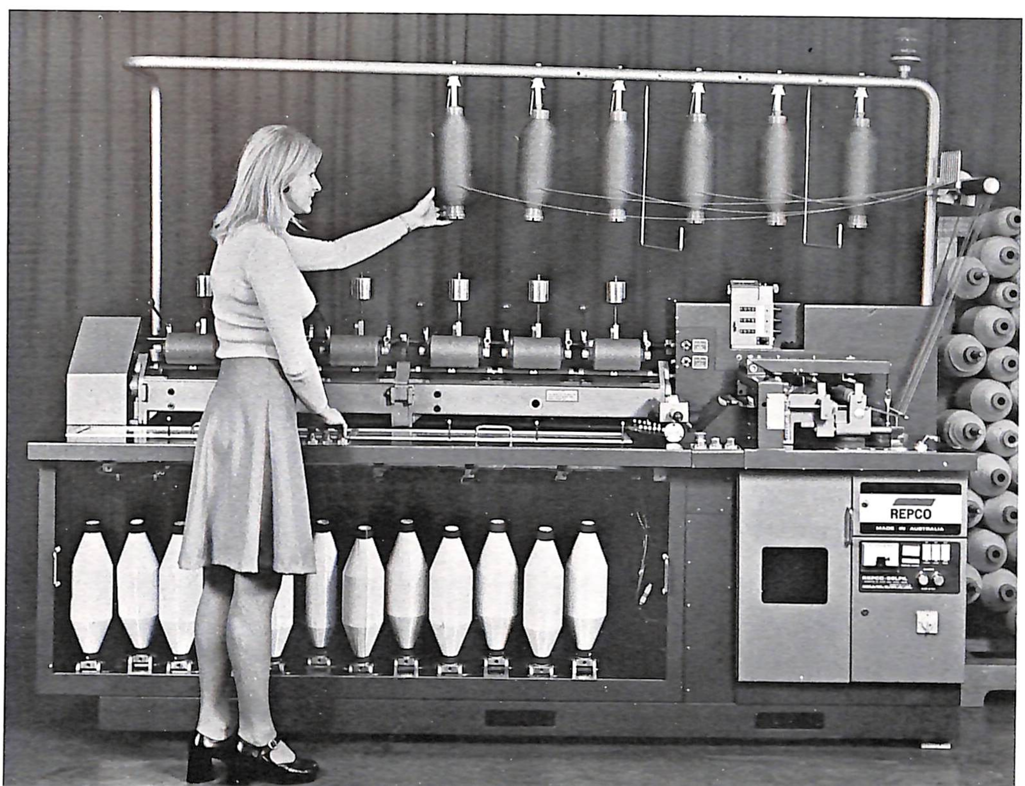
Most of the soils are shallow, gravelly and infertile, but a few, particularly the deeper red and yellow earths, are suitable for the establishment of plantations. Fertilization with phosphate, nitrogen and sulphur appears to enhance tree growth in most cases and the Division has found that relatively small amounts of mixed fertilizer—about 25 g a tree—establish the trees and promote early growth.

Spinning new yarns

Rapid spinning techniques are being used to combine wool with synthetic filaments to produce new yarns for knitting.

Wool has outstanding natural properties as a textile fibre—it is warm, soft, resilient and easy to dye, and it absorbs moisture. On the other hand, wool is expensive to harvest, sell and transport overseas, and turning fleece into yarn requires many processing operations. Because of the great importance that wool has always had in the Australian economy, much of the effort of CSIRO's WOOL RESEARCH LABORATORIES over the last 27 years has been directed towards overcoming wool's disadvantages and enhancing its virtues so that it can compete successfully with other textile fibres.

One of the most notable achievements of this work has been the self-twist spinning machine which was developed by the DIVISION OF TEXTILE INDUSTRY in collaboration with Repco Ltd. The Repco Spinner occupies only a fifth of



The SELFIL Spinner, developed jointly by Repco Ltd and the DIVISION OF TEXTILE INDUSTRY.

Photograph: John Card

the floor space of a conventional spinning machine of comparable output; it is faster, cleaner and quieter, and it uses less power. In 1970 the Repco Spinner won the Prince Philip Prize for industrial design and in the last 5 years more than 1600 machines worth $20 million have been sold.

A new but complementary spinning machine, again developed by the Division in collaboration with Repco, was unveiled at the International Textile Machine Exhibition in Milan in 1975. This machine—the SELFIL Spinner—produces a completely new type of knitting yarn from a mixture of wool and synthetics. Whereas the Repco Spinner produces a two-ply yarn suitable for weaving, the SELFIL Spinner wraps two continuous synthetic fibre filaments around a core of wool to produce what is essentially a single-ply yarn that is particularly suitable for knitting. The new machine combines all the advantages of the Repco Spinner with the additional advantages of outstanding yarn performance, both in knitting and garment manufacture and in the wear properties of the garments.

The SELFIL yarn, consisting of 80% or more wool, is very strong and long wearing and is ideal for use in products for which all-wool yarns have proved impracticable. For instance, fine SELFIL yarns are suitable for knitted wool suitings and shirtings. Although fine all-wool yarns can be used for these products, they are expensive to produce by conventional methods and break excessively during knitting.

Fabric knitted from SELFIL yarn has all the advantages of wool—it is soft, warm and does not snag. In addition, it is stronger and more resistant to abrasion and pilling, it possesses fewer knitting faults, and the stability and ease of cutting and making-up of fabric knitted from it are greatly improved.

In the Repco Self-Twist Spinner, two strands of wool are passed between a pair of rotating synthetic rubber rollers which are also moving rapidly from side to side in opposite directions to each other. This results in a short section of each strand being twisted in one direction, the next section in the opposite direction and so on. As the two twisted strands emerge from the rollers they are immediately brought together so that they twist about each other, forming a stable two-ply yarn.

In the new SELFIL Spinner, a single wool strand is passed through self-twist rollers and is then brought into contact with a synthetic filament. The alternating twist of the wool causes the filament to wrap around the strand. This filament-wrapped strand then moves forward to a second twisting stage. Here, alternating twist is again imparted, this time by bringing the strand intermittently between two rotating discs. A second filament is added at this point, resulting in the complete SELFIL structure. The two filaments are phased so that a section of high twist in the one filament coincides with a section of zero twist in the other filament, and vice versa.

A feature of the machine is automatic threading of the very fine filaments by blowing the thread through tubes with compressed air. Quietness and cleanliness are some of its other attractive features, leading to brighter, cleaner, quieter working conditions.

In 1975 the SELFIL Spinner, like the Repco Spinner, won the Prince Philip Prize for industrial design.

Bringing calibrations to industry

The NATIONAL MEASUREMENT LABORATORY *is devising new techniques to help it provide an on-site calibration service to industry.*

CSIRO's NATIONAL MEASUREMENT LABORATORY is responsible for maintaining standards of measurement in Australia. Its instruments and techniques measure electric resistance and potential with an uncertainty of less than one part in a million, reproduce the wavelength of a laser beam to one part in 10 million, and determine intervals of time with an uncertainty of less than one part in a million million.

One of the main activities of the NATIONAL MEASUREMENT LABORATORY is examination of instruments and standards to determine the nature and size of any errors in their nominal or indicated values. These examinations, or calibrations, are usually undertaken in the Laboratory. In the past few years, however, there has been an increasing need to calibrate equipment which cannot be taken to the Laboratory. In some instances, the Laboratory's usual calibration instruments have been taken to the site where the equipment is to be examined. In others, the NATIONAL MEASUREMENT LABORATORY has either developed special equipment or devised new techniques for the purpose.

A recent example of the development of special equipment is the construction of a mobile high-voltage test unit to calibrate items of high-voltage measuring equipment which cannot be brought to the Laboratory because of their bulk or fragility. It allows calibration to be carried out in the operating situation so that it is possible to take into account local environmental factors such as the nature and stability of the available power supply, the arrangement of the apparatus, and the proximity of walls and ceilings. The high-voltage test unit is unique in Australia, and its introduction heralds a major improvement in the accuracy of on-site calibrations in the electric power industry.

Some calibrations must be performed on-site because the items to be calibrated are integral parts of large built-in installations. For example, in the case of large quantities of liquids, such as petroleum products flowing through pipelines, there is an increasing need for precise measurement of liquid flow. Large meters monitor the flow and are calibrated by on-line devices called 'provers'. The Laboratory has devised a technique for calibrating provers which has operated under working conditions with high accuracy.

The NATIONAL MEASUREMENT LABORATORY also helps users calibrate their own equipment. Manufacturers can, for instance, use standard test blocks calibrated in the Laboratory to calibrate their hardness-testing machines. They can also measure the viscosity of fluids such as lubricating oils by using the Viscosity Standardization Service operated by the Laboratory. This Service supplies samples of liquids at certified viscosity so that the performance of working viscometers can be checked.

Besides providing for on-site calibrations, the NATIONAL MEASUREMENT LABORATORY undertakes on-site measurements which require the use of special techniques. In some industrial processes, for example, accurate control of temperature in furnaces is important. In these cases it is necessary not only to know the average temperature in the furnace, but also the variations in temperature from point to point. Scientists from the Laboratory can make on-site measurements of the temperature distribution within furnaces and advise on ways to improve this distribution.

The Laboratory also measures humidity in industrial situations where there are unusual difficulties in making measurements or special requirements for accuracy.

Measurements of a different kind are involved in checking the accuracy of alignment of large installations such as rolling mills. Optical techniques adapted to the special requirements of each installation are used by the Laboratory in making such measurements.

Machine tools, being fixed firmly to their foundations, are usually examined on-site. The Laboratory will undertake 'static' tests on machine tools, such as checks for flatness of surfaces, alignments, spindle run-outs, and accuracy of linear and angular displacements. It is now developing equipment and techniques for 'dynamic' testing, particularly in relation to the ability of a machine tool to remove material from the workpiece without 'chatter'.

Improving chemical analysis

Advances are being made in chemical analysis by atomic absorption, atomic fluorescence and atomic emission techniques.

The technique of atomic absorption spectroscopy, developed by the DIVISION OF CHEMICAL PHYSICS 20 years ago, has been described as the most significant advance in chemical analysis this century. Atomic absorption instruments can identify and quantify some 65 metallic elements. World production of these instruments now exceeds 5,000 a year.

The almost universal acceptance of atomic absorption has encouraged the Division to develop the equipment further and to devise methods which extend its usefulness. Thus work is proceeding on a method of determining heavy metals in solutions like sea water, human blood and other body fluids which contain large amounts of sodium chloride.

Atomic absorption spectroscopy is based on the fact that atoms of a given element absorb and emit light at wavelengths specific to that element. In the standard instrument, an atomic vapour is produced by vaporizing a solution of the sample in a flame. Light characteristic of the element to be determined is passed through the vapour and the amount of light absorbed measured by a detector. This can then be related to the concentration of the element in the sample.

One of the limitations inherent in using the flame as an atomizer is that some elements are only partially atomized. For many years, therefore, work in the DIVISION OF CHEMICAL PHYSICS has been directed towards developing alternative means of atomization. The result is a technique called cathodic sputtering in which charged atoms generated in a low-pressure electrical discharge bombard the sample, thereby liberating atoms from its surface. Cathodic sputtering allows solid samples to be analysed without having to dissolve them first.

The sputtering unit has proved particularly useful for the direct analysis of alloys for minor alloying constituents. It can also measure the variation in concentration of elements according to their depth in a surface layer by successively etching away the surface layer through sputtering, and recording the variation in absorbance of the atomic vapour produced.

In addition to atomic absorption, the Division is concerned with the two other branches of atomic spectroscopy—atomic fluorescence and atomic emission. In atomic fluorescence, the spectrophotometer arrangement closely follows that of the atomic absorption instrument, except that the detector is placed at right angles to the incident beam to measure the light absorbed by the atomic vapour and re-emitted as fluorescent radiation. In atomic emission, atoms in the sample are excited by the action of heat or an electrical discharge. The quantity of an element present is determined directly by measuring the amount of its characteristic light which is emitted.

At present, atomic absorption is mostly used for analysing solutions; atomic fluorescence is rarely used but it offers the possibility of a cheap though effective method of simultaneous multielement analysis; atomic emission is used for the direct analysis of solids or when multielement analysis is required. Multielement atomic emission instruments are, however, very expensive.

One of the most notable advances made by the Division in recent years is the discovery that a special type of flame—a separated flame—can act as an efficient isolator of the characteristic radiation of a wide range of elements, a function required in atomic absorption, emission and fluorescence spectroscopy. A monochromator normally fills this role, but monochromators are bulky, easily knocked out of adjustment, and expensive. In fact, of all the components of a conventional atomic absorption spectrophotometer, the monochromator is the most expensive.

In the separated flame technique, a pure solution of the element to be determined is sprayed into the separated flame. On illuminating the atomic vapour produced, the vapour gives rise to fluorescent radiation only at wavelengths characteristic of this element. All other radiation passes straight through the flame. The flame can be changed from acting as isolator of the characteristic radiation of one element to that of another simply by changing the pure solution sprayed into it.

This technique may provide a cheaper alternative to the monochromator in many applications, and it contains no parts which can become misaligned. More important, however, is the fact that the separated flame isolator opens up the possibility of a general purpose atomic spectrometer for analysing solutions and solids, which will be able to operate in the absorption, fluorescence and emission modes. An experimental spectrometer of this kind has recently been constructed and its performance is being evaluated.

Utilizing iron ore

A comprehensive program of research is being undertaken on the utilization of Australia's iron ore reserves.

In 1975 Australia's exports of iron ore and pellets were worth almost $750 million. Because of the importance of the iron ore industry, the five Divisions of the MINERALS RESEARCH LABORATORIES have set up a comprehensive interdisciplinary research program to investigate problems associated with exploration, mining, primary processing and subsequent upgrading.

The detailed exploration of an ore body and its exploitation by drilling and blasting involve sinking a large number of bore holes. Accurate analysis of the material encountered during drilling is essential for the subsequent development of the ore body and for quality control during production.

A logging system for determining the grade of iron ore in blast holes has been developed by the DIVISION OF MINERAL PHYSICS following earlier trials at the Tom Price mine of Hamersley Iron Pty Ltd. The system utilizes the interaction of γ-rays with the walls of the blast hole, and provides a more accurate measurement of mean ore grade for each blast hole than that obtained by current techniques. It also provides detailed stratigraphic data that assist mining practice.

The techniques developed for bore hole logging are being employed by the Division in a laboratory instrument that measures the average grade of 25-kg samples of iron ore. Extensive testing at Mt Tom Price has shown that the instrument gives results that are just as accurate as those obtained by established methods while involving few processing steps and requiring less labour.

More than 90% of Australia's iron ore reserves lie in the Pilbara region of Western Australia. The ores contain 1–6% alumina and this can cause problems during iron and steel making. The Division is therefore investigating the use of neutron activation techniques to measure alumina content for quality control during processing and to monitor alumina levels in ore on a conveyor belt.

Pilbara ores also contain traces of phosphorus and these, too, can cause problems during iron and steel making. The ores fall into two main groups, those containing about 0·05% phosphorus and a more abundant group containing about 0·12%.

The DIVISION OF MINERALOGY is seeking to account for the geographic and geological distribution of the low phosphorus ores with the objective of developing an improved rationale for future mineral exploration.

In anticipation of the future needs of the Australian mining industry for techniques to control ore grade and process subgrade materials, the DIVISIONS OF MINERAL CHEMISTRY and CHEMICAL ENGINEERING are studying fractionated haematite–goethite ores from the Pilbara. Their investigations have indicated that fairly simple processing techniques can be used to beneficiate subgrade iron ores.

The DIVISION OF CHEMICAL ENGINEERING is also working on the ore-dressing operations of crushing and screening, and the way in which these operations combine to produce varying amounts of lump and fine products from a given batch of ore. Lump ore—material with a diameter greater than 6 mm—is used as blast furnace feedstock, while fines—diameter less than 6 mm—are used in sinter and pellet plants.

At Dampier, W.A., lump ore is rescreened before shipment to reduce the quantity of fines to contractual limits. At present, the ore is sampled and sized automatically and the data recorded by a process control computer.

The DIVISION OF CHEMICAL ENGINEERING has developed a new operating system for the computer which maintains quality as close as possible to the contractual limits and yet allows ore to be loaded into ships at maximum rates.

Because the penalties for failure to meet the contracted levels are so severe, iron ore companies generally aim for an iron content in their shipments of 0·5% above the level required. This practice represents an annual loss of some $1 million and emphasizes the need for strict quality control of the ore.

While most Australian ore is shipped overseas as lump or fines, about 25% of the fine ore is converted to pellets for use as a premium blast furnace feed. This form of secondary processing involves grinding the fines and agglomerating the particles with water to produce balls with a nominal diameter of 12 mm. These balls are then dried and fired at a high temperature to produce pellets. Conditions in the pelleting plant need to be adjusted continuously to ensure that the pellets produced will be strong enough to withstand mechanical

This laboratory-scale ball mill is used by the DIVISION OF CHEMICAL ENGINEERING to grind iron ore used in the preparation of experimental batches of pellets.

Photograph: Wallace Hastie

handling, transport by sea, and the severe conditions encountered in the shaft of a blast furnace, yet will reduce readily in the blast furnace from iron oxide to iron.

At the Hamersley Iron Pty Ltd pellet plant at Dampier, iron ore fines are dry ground in open circuit ball mills to produce pellet plant feed. As part of a cooperative program, the DIVISION OF CHEMICAL ENGINEERING is examining the effects of the moisture content of the feed, rate of feed, and air-sweep speed on the size distribution of the product in the mills.

A more detailed laboratory study is also in progress using a small continuous air-swept dry mill with a length-to-diameter ratio similar to the Hamersley mills. The results will be used to develop a model of the grinding process that will allow more efficient control of the mills with possible reductions in the cost of producing pellets.

The drying and heat-hardening stages in pellet production have been extensively studied by the DIVISION OF PROCESS TECHNOLOGY. Much of this work has been done with a 25-cm pot-grate designed to simulate conditions in a full-scale travelling grate plant. Drying problems experienced in one particular plant due to pellets spalling or exploding were shown to be caused by an increase in the goethite content of the ore and the fact that this component dries too rapidly. A control scheme was devised which enabled production to be restored to normal.

Firing conditions have also been studied in considerable detail in the pot-grate simulator, and the effects on fired pellets of temperature, ore size, and the levels of silica, alumina and lime have been examined. The results have been analysed by computer to determine conditions for optimizing pellet quality and production rate in commercial plants. This should assist operators of pellet plants to cope more effectively with variations caused by changes in the composition and grindability of the feed ore. The work should also provide a foundation for introducing automatic control techniques to the industry.

Conditions needed to produce strong, readily reducible, high-grade pellets have been determined for ore samples from existing mining operations and from proposed new mining areas. Studies are continuing on the effects of fluxes such as dolomite and of preformed bonding agents on the strength, swelling properties and reducibility of pellets. Investigations aimed at producing low-phosphorus pellets, sinter, or metallized products from currently unsalable high-phosphorus iron ores are also in progress.

Recent research at the DIVISION OF MINERAL CHEMISTRY on thermal bonding processes in iron ore pellets of the Pilbara type is contributing to the development of improvements and innovations in existing production schemes.

Mineragraphic studies have elucidated the effects of changes in plant processing conditions on the properties of pellets and have helped explain the measured variations in cold compressive strength, abrasion index, reducibility and strength after reduction.

The work on the basic mechanisms that contribute to the strength of pellets is being supplemented by Hamersley Iron Pty Ltd which is using a pot-grate simulator built from a design supplied by CSIRO. The results from these investigations are helping the DIVISION OF CHEMICAL ENGINEERING develop a mathematical model of the hardening process. This is part of a long-term project to lower the cost of manufacturing the pellets.

In view of the possible introduction of direct reduction processes to Australia, the DIVISION OF PROCESS TECHNOLOGY is investigating the best processing conditions for producing metallized pellets with either solid or gaseous reducing agents. Considerable experience has been gained concerning the factors controlling reduction rates and product quality.

Experiments in a rotary kiln simulator, using a solid reducing agent, showed that lower temperatures not only required abnormally long processing times but gave weak pellets. Excessive temperatures produced a coherent, highly metallized, but relatively impervious shell on each pellet, and this shell impeded complete reaction.

Particular attention was given to the gaseous reduction of pellets under conditions simulating those prevailing in shaft kilns. Close control of the lime content was found to be necessary to minimize swelling and cracking.

Loss of pellet quality following corrosion of iron during storage and transport is being assessed by subjecting metallized pellets to a severe urban–marine atmosphere. Completely exposed individual pellets have lost up to one-third of their iron by rusting in 6 months. The loss was greatest where the original reduction was by hydrogen at temperatures over 800°C. Pellets shielded from direct exposure, either by storage or by being submerged in a stockpile, suffered only one-tenth of this rate of deterioration.

The DIVISION OF PROCESS TECHNOLOGY has undertaken a preliminary survey of the environmental problems associated with processing the Pilbara ore deposits, particularly dust emissions from processing plants, stockpiles and blending operations. The results will help indicate how such problems might be overcome.

High-strength industrial ceramics

Difficulties associated with using zirconia as an engineering ceramic may have been finally overcome.

About half of the copper and brass produced in Australia is extruded in the form of bars or rods of different shapes which can be machined or subjected to further processing. Extrusion involves forcing a billet of hot metal through a die of the correct contour. Because the dies used to extrude brass, copper and other metals are expected to maintain their dimensions and surface finish over long periods of time, technical and economic limitations restrict the range of metals that can be extruded if the die is also made of metal.

Engineers are turning increasingly to ceramic materials for use in engineering components which need to perform at high temperature and under severe conditions of abrasion or corrosion. Zirconium oxide (or zirconia) is one of the ceramics that has been studied for possible industrial use for many years.

Zirconia was evaluated by a large Australian company some 10 years ago as a material for tube extrusion dies for copper and brass. An initial batch of dies, made to order in the United States, gave excellent results, but that success has never been repeated. About 5 years ago the DIVISION OF TRIBOPHYSICS began looking into the reasons for the erratic behaviour of zirconia dies.

Zirconia is a chemically inert material, giving low friction during extrusion and a high quality surface finish on the product when used as a die. On the other hand, it is brittle, like all ceramics, and requires special design measures to avoid fracture under extrusion stresses. It also possesses three different crystal modifications according to its temperature, a characteristic that has become the basis of a new method of strengthening the material.

Zirconia undergoes a change in crystal structure when heated to about 1100°C. This change causes a 4% change in volume which destroys the mechanical integrity of the material and which needs to be countered if zirconia is to be employed in extrusion dies. Alloying zirconia with small amounts of other oxides such as magnesium oxide (magnesia) or calcium oxide (lime) stabilizes it by converting it to yet another form. Zirconia which has been only partially stabilized (PSZ) has proved to have superior properties to the fully stabilized material in terms of fracture toughness and resistance to thermal shock.

The DIVISION OF TRIBOPHYSICS has studied the effect of processing variables on the mechanical and thermal properties of PSZ (with lime or magnesia as added oxide) by means of X-ray and electron diffraction methods to interpret the crystal structure. The processes studied included the preparation and conditioning of the powders, pressing into rough shapes, firing to high temperatures to densify, and machining to final dimensions.

By close control of these processes, and the use of lime as the additive (magnesia was used in the American dies), the Division has produced a material with reproducibly high mechanical and thermal properties that are several times better than those obtained by conventional methods of production. The Division believes that this material is the toughest and one of the strongest ceramic oxides known.

Extrusion dies for 12–13-mm rod made in this way have been tested and then put into routine use in a production plant for about 2 years. Over 1000 extrusions have been obtained compared with only 100–150 really satisfactory rods through metallic dies. Dies producing 25-mm rod are currently being evaluated by industry and preparations are being made to produce dies to extrude copper tube 100 mm in diameter.

The process has a number of proprietary features for which patents have been lodged and licensing to an Australian company negotiated. Thread guides, made from PSZ, to suit the Repco–CSIRO SELFIL spinning machine are also being developed.

Purifying water

New processes based mainly on specialized polymers of unconventional physical form are being developed to purify water and treat waste water.

The need to purify poor quality water for domestic and industrial use will become increasingly urgent in the next decade. For example, desalination of brackish water from the saline catchment areas of Western Australia, Victoria and South Australia will be required on a large scale by the 1980s. Recycling of water from sewage and industrial effluent will also become more important for both industry and agriculture.

In an attempt to anticipate the future need to provide water supplies from poor quality sources and to control pollution of waterways, the DIVISION OF CHEMICAL TECHNOLOGY is concentrating much of its present research on improving the processes used for purifying water. In particular, the Division has been developing processes based mainly on specialized polymers of unconventional physical form.

The central theme of the Division's water purification work is the economical removal of small amounts of impurities by bringing large volumes of water into contact with small amounts of reagents. One of the first water treatment projects tackled by the Division, therefore, was that of desalination where the high cost of conventional techniques limited both the recycling of water and the use of brackish water. The work on desalination culminated in the invention of specially designed ion-exchange resins which remove salt rapidly and economically and which can be regenerated by flushing with hot water rather than expensive chemicals. Flushing with water instead of chemicals also reduces the pollution loading of the effluent to a minimum.

Desalination with heat-regenerable resins was found to be economical only if the polymer particles were extremely finely divided in order to allow a very rapid rate of reaction. However, micro-particles present severe handling difficulties. When used in packed beds they provide substantial resistance to the flow of water; if used in stirred vessels they settle out extremely slowly.

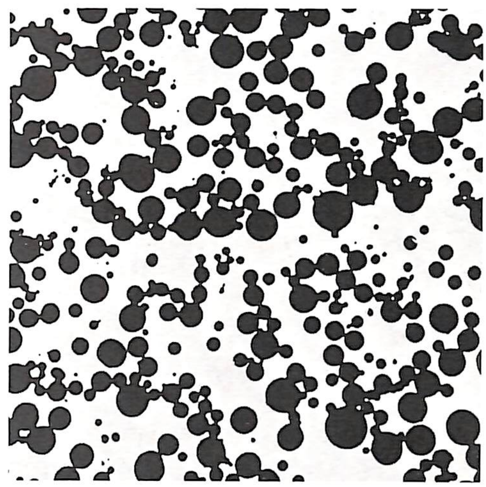
To overcome handling problems, techniques were developed for combining the acidic and basic micro-particles into conventional-sized, composite beads, either by using a binding agent which is permeable to both water and salt, or by grafting the two types of micro-particle together in the absence of a binder. The composite beads can be handled normally and rapidly absorb substantial quantities of salt.

Marketed as Sirotherm, the resins were developed in conjunction with ICI Australia Ltd. Water containing up to 3000 mg/l of salt has been treated successfully with these resins, resulting in salinities as low as 50–100 mg/l. The first commercial plant, located at an ICI factory at Adelaide, was completed in 1975. Removing 80% of the salinity, it produces 600 cubic metres of purified water a day. The resin is regenerated with hot feed-water at 85°C. A pilot plant has also operated successfully at a sewage works in Tokyo.

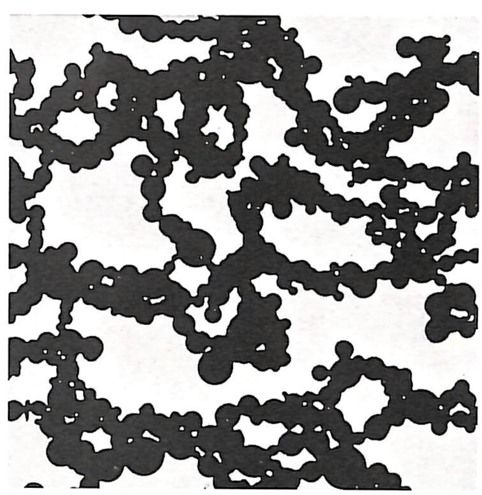
As a result of the Sirotherm project, a new approach has emerged for carrying out ion-exchange reactions. The resins are used in the form of individual micro-particles containing small amounts of iron oxide. The particles, having been made magnetic, flocculate strongly. When agitated, they disperse and react rapidly; when agitation stops they flocculate once more and quickly settle out.

Modifying the structure of the polymers enables them to be used for a wide range of ion-exchange processes. For example, they can be used to remove bicarbonate, calcium and magnesium ions (de-alkalization), and heavy metals, and to soften and decolorize water. De-alkalization is currently being investigated in pilot studies and could be of practical benefit in treating alkaline bore waters in areas such as the Great Australian Basin.

A novel feature of the resins is the very high volume of void or space included between clusters of magnetic polymer particles in the flocculated form. Because of the high voidage, there is a certain amount of flexibility in the structure which allows the resin to be pumped directly—an impossible operation with standard resins. Previously, purification operations have not been completely continuous as the flow of water has had to be stopped periodically to allow regeneration of the resin. With the new process, water and resin are pumped in opposite directions through a column. Fresh resin is added continuously at one end of the column, while spent resin is withdrawn at the other end for regeneration. The system is more efficient and economical than the intermittent system, and has the added advantage of being suitable for large-scale work since the equipment can be built of concrete. Trials have now reached the pilot plant phase and arrangements are being made for manufacturing the resins.



Individual polymer particles, averaging 50 micrometres in diameter, containing iron oxide. The particles are not yet magnetized. Magnification: ×40.



After passing between the poles of a magnet the particles are magnetized and flocculate together. Magnification: ×40.

Treated sewage contains high levels of nitrates and phosphates which, if discharged to waterways, cause excessive growth of weeds and algae. The Division is using algae to remove the nitrates and phosphates from sewage treatment lagoons and the algae, in turn, are removed with magnetic particles. This means that the phosphate and nitrate contents can be kept to acceptable levels, and the harvested algae used as a protein-rich animal feedstock.

Magnetic particles to aid chemical coagulation during the clarification of turbid water are also being developed. By increasing the rates of settling the cost of equipment is reduced. A method has been found for regenerating the magnetic particles so that they can be re-used and the cost of the chemicals reduced. At the same time a smaller volume of sludge is produced.

Magnetic polymers which rely on their physical structure rather than on active sites have been highly successful as filter aids. The particles have the irregular shapes and approximate size of diatomaceous earth, the commonly used filter aid on which they were modelled. Because of the very high volume of void in the magnetic polymers, a settled bed forms an open network which is a highly efficient filter. The polymers can be recovered by vigorously agitating the filter bed to release the accumulated impurities, which are then washed away, while the heavier polymer particles are collected for re-use. Laboratory-scale tests have proved the efficiency of the method; long-term testing is now needed to assess the costs of the process which depend on how many times the filter aid can be re-used. The process is currently being studied for an industrial application.

An analogous procedure has been devised for collecting oil spills. A magnetic polymer, which is wetted by oil rather than water and which floats because of entrapped air, is first spread on the spill with the aid of a specially designed craft. The oil is absorbed in the voids of the flocculated polymer in amounts up to 20 times the volume of the particles. The polymer is then recovered on magnetic discs as the craft moves through the contaminated area. The system is designed for use in harbours and the polymer can be recovered by centrifuging. The method is being evaluated by ICI Australia Ltd as part of a joint program to develop magnetic polymers for use in water treatment.

Apart from its polymer-oriented research, the Division is also investigating physical and chemical methods of water treatment. At its pilot plant at Lower Plenty, Victoria, the Division is using lime treatment, ammonia stripping with air, coagulation with iron salts, sand filtration, disinfection with chlorine, and activated carbon treatment to produce higher quality effluent than is possible with commonly used biological methods.

The sewage is treated before the ammonia it contains has become oxidized to nitrate, so that denitrification involves only removal of ammonia, an easier process than removing nitrate. A method of stripping the ammonia by blowing with air is also being investigated and should prove less costly than removal by biological means.

In the search for better and cheaper ways of controlling the organic content of effluent, scientists at the Division have adopted a novel approach. The waste water is treated with ozone and light emissions from the reaction between the organic matter and the ozone are monitored continuously. The work is now well advanced with trials in progress at a sewage works. It will be used to improve the effectiveness of a variety of water treatments.

Remote sensing of the earth's resources

Imagery obtained from American satellites is providing valuable information on Australian resources and is being used by a number of CSIRO Divisions.

Two earth-orbiting satellites, LANDSAT I and II, launched by the United States in 1972 and 1975, have provided pictures of more than 95% of the Australian continent. Each picture covers an area of 185 by 185 km and is ideally suited for studying short-lived conditions that extend over wide areas; the extent of floods, bushfire burns, the amount of land under cultivation, the depth of water on a reef, and so on, can be estimated from a single picture. Several CSIRO Divisions have been experimenting with these pictures as a means of obtaining information that can be used in the management of Australia's resources.

Thermal imagery data from a NOAA satellite, converted into chart form, is being used by the DIVISION OF FISHERIES AND OCEANOGRAPHY in its fisheries research program and by the DIVISION OF LAND RESOURCES MANAGEMENT for forest and rangeland studies. Although the NOAA satellite has poorer resolution than LANDSAT, data from its thermal channel and its twice daily coverage of the Australian continent make it a useful source of information.

The DIVISION OF FISHERIES AND OCEANOGRAPHY has also used visual and infrared data from the NIMBUS-6 satellite to study near-shore processes and to track free-drifting oceanographic buoys. It hopes to use the SEASAT-A satellite, after its launch in 1978, to monitor the ocean off the east coast of Australia continuously for the first time.

The DIVISIONS OF LAND USE RESEARCH and MINERAL PHYSICS in collaboration with the South Australian Department of the Environment have conducted a feasibility study for an ecological survey of South Australia. LANDSAT pictures provide the mapping base used to coordinate and extend the information obtained from conventional sources.

The LANDSAT satellite takes four pictures of any scene—green, red and two infrared images. These are combined to form a colour picture. Once land parties have linked certain types of vegetation or land formation with a particular image, the satellite picture provides an accurate survey of the whole area from a limited number of measurements on the ground. LANDSAT is markedly superior to ordinary aerial photography in that the whole area being surveyed is 'photographed' at the same time and under identical lighting conditions.

The uniform lighting conditions and the great height of the satellite make it possible to infer variations in depth of water over reefs and shoals from a single picture. For this, the 'green' picture is used, since green light has greater penetrating power in water. The DIVISION OF LAND RESOURCES MANAGEMENT is developing this technique for the mapping of shoals and reefs off the northern coast of Western Australia. Obvious applications also exist in the unmapped regions of the Barrier Reef and the Gulf of Carpentaria. This method permits mapping to a depth of 20 metres at a fraction of the cost of the conventional 'sea-going' method.

An early, accurate prediction of the wheat crop is of major economic importance to Australia. To this end, a resources satellite offers the promise of a more accurate measurement of the area sown with wheat. Consequently, the DIVISION OF MINERAL PHYSICS in conjunction with the New South Wales Department of Agriculture is investigating the accuracy of crop identification from LANDSAT. Feasibility studies have been conducted by means of instruments mounted on a tower on a truck. These experiments have now been extended to the use of LANDSAT pictures obtained during 1973–75. Application of the technique to other crops (barley, soybean) is also being investigated.

Preliminary results from measurements conducted in collaboration with the New South Wales Department of Agriculture suggest that land units of agricultural importance may be mapped from the data obtained from the satellite. An investigation is also being conducted with the University of Sydney to see whether the extent and severity of soybean rust (a serious plant disease in south-east Asia) can be mapped with the aid of LANDSAT. Experiments conducted in conjunction with the DIVISIONS OF ANIMAL HEALTH, ANIMAL PRODUCTION and ENTOMOLOGY have clearly shown that the browning-off of pastures may be predicted from satellite data up to 2 weeks before the effect is visible. Moreover, this work has revealed that there is a strong relationship between certain aspects of grazing practice and the information recorded by LANDSAT.

Although satellite imagery has the advantage of providing pictures of regional features of earth resources, many situations still remain where more detailed observations are needed. For these purposes present satellite pictures sometimes do not have adequate resolution and aerial photography, in one of its many forms, is more useful. For example, studies by the DIVISION OF SOILS in eastern and southern Australia have shown that soils cannot always be recognized or mapped from satellite photographs. This is because the satellite photograph has to be interpreted from its vegetative cover. In some cases the same sort of vegetation clothes several different types of soils.

Satellite pictures provide a broad overview of the geology of a region which is superior to that available from other sources. Accordingly, the DIVISIONS OF MINERAL PHYSICS and MINERALOGY, sometimes in collaboration with mining companies, have been investigating several applications of satellite photography in exploration for minerals.

Specifically, attention is being given to extracting the maximum amount of useful information from satellite pictures by both conventional photographic interpretation and computer-assisted identification of rock types. In the latter case LANDSAT is being used as an exploration guide for mineralization in the Fortescue region of Western Australia. Elsewhere, the mapping of faults in the earth's crust which might be associated with mineralization is being investigated, while a study of faulting in the Sydney Basin is concentrating on features of possible significance to coal mine development and to civil engineering in general.

Each LANDSAT picture is transmitted to earth as a stream of 30 million numbers. The picture, in its raw state, contains many imperfections which must be removed if the human eye or computer is to make the best use of the image. The DIVISIONS OF MINERAL PHYSICS and COMPUTING RESEARCH have developed two alternative procedures to do this. Very high quality pictures are now being produced, and these are key ingredients of several of the other investigations mentioned previously. Recognizing that the LANDSAT pictures will provide a definitive base-line for many different research investigations in Australia in the future, the DIVISION OF MINERAL PHYSICS is assembling a 'once-over' cover of the whole of Australia of the highest quality practicable.

If satellite imagery is to be used on a routine basis to measure, say, the total area of Australia's wheat crop, computers will have to be programmed to process the imagery, identify areas sown to wheat, and measure their extent. The DIVISIONS OF MINERAL PHYSICS and LAND RESOURCES MANAGEMENT are developing the expertise and means to program computers for this role. A specialized computer is being used to perform classifications on an experimental basis, and research is continuing to improve the speed and accuracy of the classification.

The earth-satellite may become an important source of information on Australia's resources. CSIRO is obtaining the experience needed to determine the effectiveness of such a data source. In the process, it is obtaining archival and other material that will be of permanent value to Australia.

Atmospheric pollution

Research by several CSIRO Divisions is helping to provide the chemical insight needed by industry and pollution control authorities to improve their assessment of particular problems and to develop more effective control strategies.

Increasing industrialization threatens the existing chemical composition of the atmosphere. The recent growth in the burning of fossil fuels is releasing chemical substances in quantities which may corrode building stones, stunt development of vegetation, endanger health or even affect climate by scattering and absorbing radiation entering and leaving the earth.

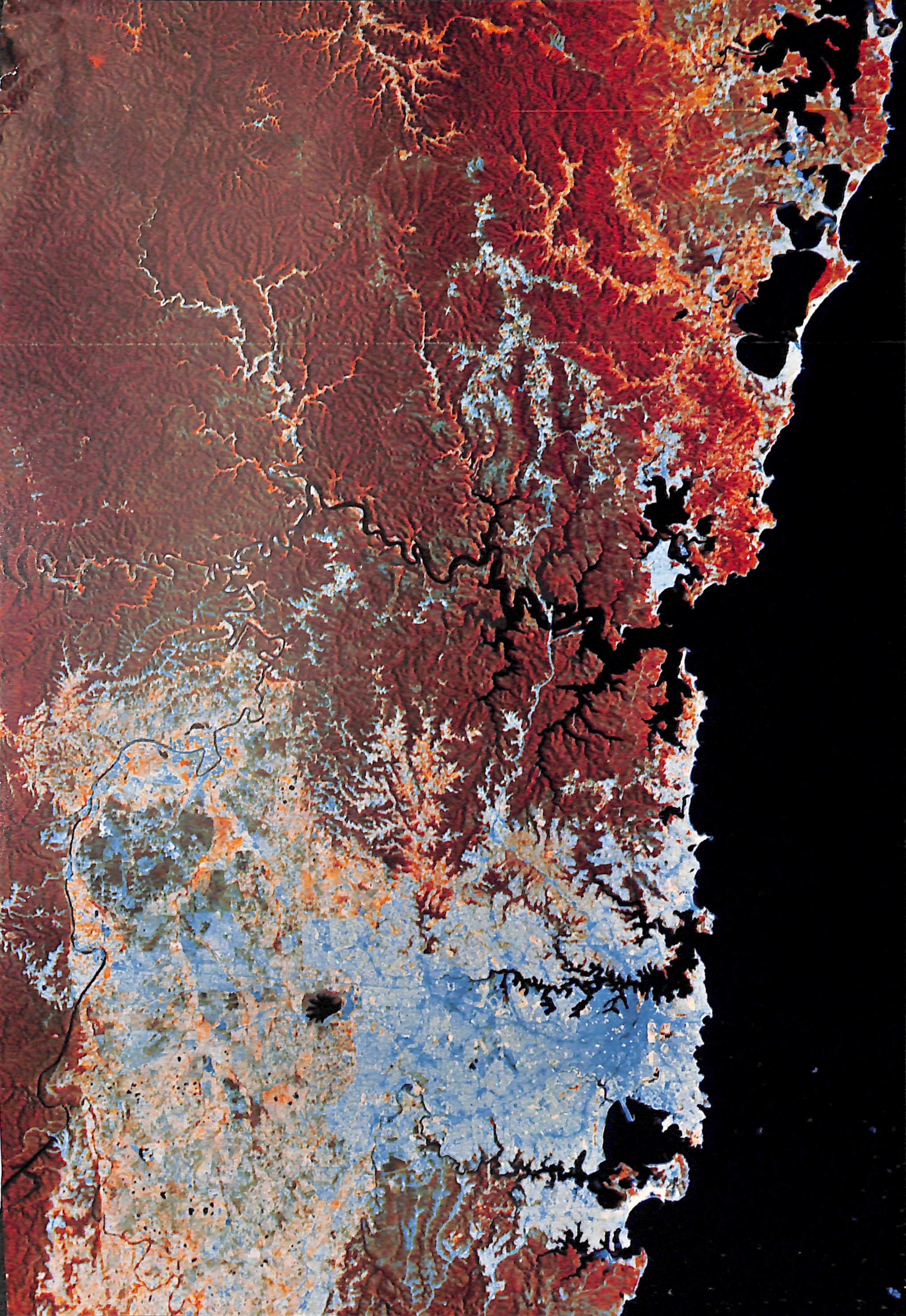
The most obvious manifestation of air pollution is smoke, but its effect on the atmospheric chemical balance is only now being seriously considered.

Experimental equipment and techniques for aerial sampling of smoke have been developed in CSIRO over the past 6 years. A highly sensitive nephelometer has been invented by the DIVISIONS OF CHEMICAL TECHNOLOGY and MINERAL CHEMISTRY and is being offered for manufacture under licence as a smoke detector in buildings. Quantitative measurements of smoke concentration and its optical properties made by the DIVISION OF MINERAL CHEMISTRY will enable State Forestry Departments and the Bureau of Meteorology to calculate and predict the effects of controlled burning of forest undergrowth on air quality.

In association with industry and various government agencies the DIVISION OF PROCESS TECHNOLOGY has undertaken investigations of photochemical smog, urban haze and pollution by sulphur dioxide.

Photochemical smog, well known in places like Los Angeles, is now

By means of a technique of computer enhancement, the DIVISION OF MINERAL PHYSICS has combined three separate photographs taken by the LANDSAT satellite from an altitude of 915 km to form a colour picture of a portion of the New South Wales coastline stretching from just south of Sydney to Lake Macquarie. CSIRO scientists are using this type of photograph in experimental ecological, oceanographic, agricultural, urban and geological studies.



being experienced by the larger cities of Australia. The obnoxious constituents of the smog are not emitted to the atmosphere directly, but under appropriate meteorological conditions they are generated by photochemical reactions in the atmosphere. The reactions are brought about by two kinds of precursor pollutants—hydrocarbons and nitrogen oxides—both of which are emitted principally from motor vehicles and industrial sources.

Work by the DIVISION OF PROCESS TECHNOLOGY in collaboration with the DIVISION OF FOOD RESEARCH and the New South Wales Pollution Control Commission is aimed at characterizing the smog-forming hydrocarbons present in the atmosphere of Sydney, Australia's most smog-bound city. The minute concentrations present in air samples are concentrated by a special technique originally developed to study the flavours of foodstuffs. They are then analysed by gas chromatography combined with mass spectrometry.

Results so far show the substantial presence in Sydney's atmosphere of aromatic hydrocarbons derived from unburnt petrol and perhaps other petrochemical sources. While this is similar to the experience of large cities overseas, there are local peculiarities.

The nitrogen oxide precursors of photochemical smog are products of combustion. The chemistry of their formation in flames is being studied in the laboratory to find better ways of reducing the amounts emitted. Work is also being carried out on the complex reactions by which photochemical smog forms in the atmosphere. The Division is collaborating with CSIRO's NATIONAL MEASUREMENT LABORATORY in constructing complex apparatus to study these reactions.

In large cities air pollution most commonly appears as a yellow or brown haze. This is known to be produced, at least partly, by aerosols, i.e. by microscopic particles suspended in the atmosphere which may or may not be associated with photochemical smog. In a joint program with the DIVISION OF MINERAL PHYSICS and the Department of Nuclear Physics at the Australian National University, the DIVISION OF PROCESS TECHNOLOGY is studying the chemical constitution of Sydney's smog aerosols to discover their origin.

Because the coals burnt in our power stations are relatively free from sulphur, Australia is spared many of the problems that arise from air pollution by sulphur dioxide in Europe and North America. On the other hand, Australia produces vast quantities of metals from sulphide ores and the sulphur dioxide emitted from smelters is causing concern in some areas.

To assess the environmental effects of the emissions it is necessary to find out how long the sulphur dioxide remains in the atmosphere and what happens to it. The chemical history of the sulphur dioxide emitted in the plume of a large smelter at Mt Isa, Qld, is being studied by remote sensing and local sampling techniques. The instruments are being carried in either an aircraft or a heavy-duty land vehicle. The smelter provides a point emission source in the midst of hundreds of square kilometres of sparsely inhabited country. So far the plume has been examined at distances up to 250 km from Mt Isa, and it appears that the sulphur dioxide is absorbed by the ground and by vegetation much more slowly than is the case in Europe and the United States.

Techniques developed by the DIVISION OF CLOUD PHYSICS for identifying small particles in the stratosphere have been applied to atmospheric pollution. For example, particles collected in the upper atmosphere from the Mt Isa smelters have been identified as sulphuric acid.

Because of its isolation from other industrial activity, the Mount Isa smelter provides an excellent opportunity for the DIVISIONS OF PROCESS TECHNOLOGY and CLOUD PHYSICS to study the fate of sulphur dioxide and particulates emitted into the atmosphere.

The existing balance between the earth's atmosphere and the life it supports is a delicate one. For example, a fall in global temperature of only a few degrees would bring Ice Age conditions to large areas of the earth's surface, while an even smaller rise in temperature would melt the Polar ice caps and cause flooding of most of the world's seaboard cities.

Particles in the atmosphere are potentially capable of producing climatic changes. Clouds control the balance of radiation reaching and leaving the earth and it is the net energy received by the surface, and its distribution, that drives the world's weather systems. The probability that clouds will rain is modified by the particles that take part in ice crystal and raindrop formation. The DIVISION OF CLOUD PHYSICS is contributing to an international program for monitoring these particles to establish their origins and how they affect climatic conditions.

The DIVISION OF ATMOSPHERIC PHYSICS is studying the effect of artificially created carbon dioxide on the climate. Carbon dioxide in the atmosphere regulates temperature on the earth by trapping some of the heat that would otherwise escape. During the past 100 years or so, man's burning of fossil fuels has added very large quantities of carbon dioxide to the atmosphere and scientists are now trying to correlate this build-up of the gas with changes in temperature.

Australian and international airlines have cooperated with the Division by carrying sampling equipment in their aircraft. In this way the Division is acquiring regular carbon dioxide samples at altitudes of up to 11 km over routes from Perth through Melbourne and Sydney to New Zealand. Analysis of the samples shows a rising trend in carbon dioxide concentrations—in common with findings in the northern hemisphere where a similar trend has been evident since 1958.

In the early stages of the work it became clear that significant discrepancies existed between carbon dioxide observations made by the various world authorities. The DIVISION OF ATMOSPHERIC PHYSICS eventually traced the problem to the reference gases with which the atmospheric samples are compared. A member of the Division subsequently visited the main monitoring stations of the world and with a sample of the reference gases used at the Division's headquarters in Melbourne, conducted comparison experiments with overseas workers. As a result, many of the former inconsistencies were cleared up and the intercomparison of world-wide carbon dioxide measurements placed on a sounder footing.

Compared with our northern hemisphere counterparts, Australia's records are few in number and short term in nature. Yet in order to properly evaluate what is happening now, it would be of great benefit to know what has happened in the past. A completely new phenomenon in increasing carbon dioxide concentration may be occurring or it might be part of a cycle of events. In an attempt to find the answer the Division is adopting two approaches.

The first involves measuring carbon isotopes in old trees whose age can be determined from their growth rings. Trees build up cellulose by taking carbon dioxide from the air, the lighter isotope, C^{12}, being taken up in preference to C^{13}. Because the ratio of C^{13} to C^{12} depends on the source of the carbon dioxide at the time, measurements of the ratio make it possible to determine whether the carbon dioxide came, for example, from the sea or from rotting vegetation.

The second approach for obtaining past information is via air bubbles trapped in the Antarctic ice sheet, and the Division has begun a joint program with the Antarctic Division of the Department of Science to analyse gas samples obtained at maximum depths of 200 m in ice 10–20,000 years old.

For many years the DIVISION OF ATMOSPHERIC PHYSICS has been making observations of ozone—a gas that occurs naturally some 25 km above the earth's surface. Produced in relatively small quantities by the action of solar radiation on oxygen, it plays a vital part in our lives by filtering out harmful ultraviolet radiation from the sun's rays.

The Division initiated its first daily program of ozone measurements in 1955. Since then it has set up an extensive network of monitoring stations around Australia. Measurements are made by a ground-based spectrometric technique. The observation program is now the biggest in the southern hemisphere, with the Division's laboratory in Melbourne acting as a national calibration centre and the focus for all ozone activities in the south-west Pacific.

Continued monitoring of ozone in the atmosphere is essential because so many products of our everyday life are capable of destroying it. The chlorinated hydrocarbons used as dry-cleaning solvents and the freons used as propellants in aerosol cans disperse throughout the atmosphere. By decomposing and liberating chlorine, they become potential catalysts for the destruction of ozone.

Nitrogen oxides emitted from man-made sources can affect the natural balance of ozone at high altitudes. An Australian Academy of Science Committee, which considered the effects of supersonic air travel on the atmosphere, concluded that there were unlikely to be any deleterious consequences. However, it recommended that a careful watch be kept on the concentration of stratospheric ozone.

Ozone near the surface of the earth exists in small quantities which are odourless and harmless. But the concentration of ozone can increase markedly in urban areas, and ozone is one of the main constituents of photochemical smog. At its laboratories at Aspendale, Melbourne, the DIVISION OF ATMOSPHERIC PHYSICS has been measuring low-level ozone since 1965. Between then and 1973 the average yearly concentration has doubled in the Melbourne area because of the increase in photochemical smog.

Focus on tropical meteorology

Research in tropical meteorology is providing a better understanding of the factors that influence the Australian climate.

Half of the earth's surface lies between 30° N. and 30° S. and it is in these tropical regions that most of the solar energy, which produces currents in the atmosphere and the oceans, is absorbed. For this reason the tropics are sometimes described as the 'boiler house of the atmospheric heat engine'. By means of winds and ocean currents the net gain in heat at the tropics is transferred upwards and outwards to the poles, compensating for heat lost elsewhere and maintaining the climatic balance.

Yet despite the key role of the tropical zone, tropical meteorology has lagged far behind the advances made in the meteorology of the temperate zones, mainly because the countries with sufficient resources to provide major weather services are situated in temperate latitudes and have concentrated on the weather problems which affect them directly. The second world war stimulated an interest in tropical meteorology which was heightened in subsequent years by the needs of international aviation and, more recently, by the development of resources in tropical regions.

For a country straddling the Tropic of Capricorn, Australia, too, has in the past devoted little research specifically to the problems associated with tropical weather. Yet some of these problems such as the role of the tropical arm of the general circulation in controlling climatic fluctuation, interhemispheric flow and the summer monsoon rains, and tropical cyclones, are particularly relevant to Australia.

In recent years, the DIVISION OF ATMOSPHERIC PHYSICS has attempted to redress the balance by placing greater emphasis on tropical meteorology. The Division is using theoretical and practical observations in conjunction with accumulated meteorological data, such as weather charts and records of wind, pressure and temperature, to deduce the effects that certain meteorological phenomena produce. If the cause and effect relationship can be better understood, weather predictions can be made more accurately from observed meteorological patterns.

In this way it has been found that the summer monsoon which brings rain to northern Australia is connected with the winds at upper levels. For example, above-average rainfall in Darwin is directly related to stronger easterly winds or lighter westerlies at an altitude of 12 kilometres between Alice Springs and Darwin. Also, if the pressure at 12 kilometres over Alice Springs is higher than usual, the summer rainfall in the area is likely to be greater.

Whether these effects are local or part of a large-scale phenomenon is not yet known. Certainly the increased upper easterlies, which accompanied the record rainfall over northern Australia in January 1974, extended from Fiji in the east to Singapore in the north, through Cocos Islands and as far as Mauritius in the west.

Statistical analysis of precipitation and pressure data has shown that rainfall in northern and eastern Australia is closely related to variations in surface pressure in areas as remote from Australia as the central and eastern Pacific. In other words, precipitation in the parts of Australia with a predominantly summer rainfall is greatly influenced by global-scale wind patterns. This relationship, which has been known to exist since the 1920s, is still poorly understood mainly because of a lack of meteorological observations over some areas of the ocean.

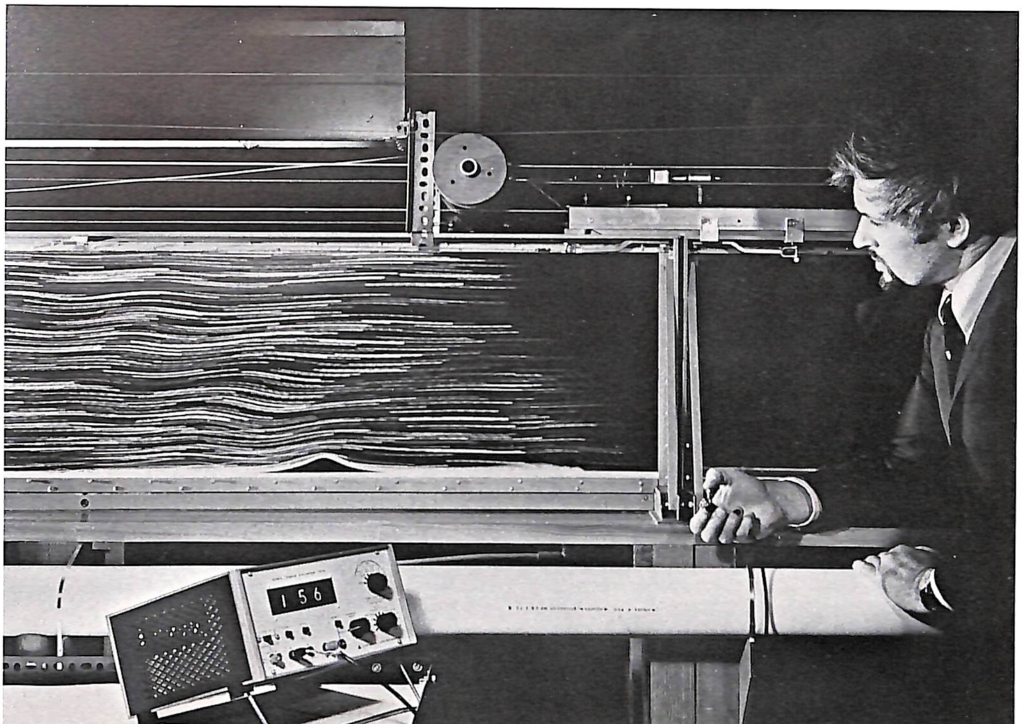
The Japanese geostationary satellite, due to take up a position almost directly over Australia in 1977, will greatly aid the Divisional scientists working in this field. The satellite will cover large areas of ocean that are not covered by any land-based observation stations and should help to detect high level winds from the movement of cirrus clouds. This information will increase understanding of the link between the dynamics of the atmosphere and precipitation.

In attempting to determine the part that sea surface temperatures play in modifying climate, it has been found that ocean influences originating in the central Pacific Ocean are probably partly responsible for rainfall in Australia many months later. Scientists at the DIVISION OF FISHERIES AND OCEANOGRAPHY are providing observations for this project—one of many overlapping areas of interest and cooperation between meteorologists and oceanographers. The Australian merchant fleet, too, has assisted in obtaining readings of sea surface temperatures over a large tract of the western Pacific extending from the east coast of Australia to the 180° meridian and from the Equator to 45° S. These direct observations of sea surface temperature can be used to check the observations made from satellites.

The approach of the AUSTRALIAN NUMERICAL METEOROLOGY RESEARCH CENTRE to the problems of tropical meteorology is through the use of numerical methods to simulate atmospheric processes, based on known or estimated physical relationships between various meteorological elements. These relationships make it possible to project a currently known state of the atmosphere forward in time. This procedure forms the basis of numerical weather prediction and climate modelling. The Centre,

The DIVISION OF ATMOSPHERIC PHYSICS makes considerable use of physical models in its experimental work. In the case of the earth's atmosphere, however, where there is complicated, three-dimensional motion on a revolving sphere, it is necessary to break down the problem into its component parts. For example, air flow over a mountain can be simulated by means of a tank of salt solution containing suspended beads. This composite photograph, which shows the waves generated by fluid flowing over the small hillock on the floor of the tank, has been obtained by time-lapse photography.

Photograph: David Whillas



which is sponsored jointly by CSIRO and the Department of Science, has successfully simulated the behaviour of the tropical atmosphere both on a global scale and on the scale of individual cumulus clouds. For example, on a global scale, the tropical doldrums and the east winds throughout the troposphere have been successfully simulated using only basic physical laws. Such numerical models have great potential, and are being used in both short-term (36 hour) weather prediction and for experiments aimed at understanding the factors controlling climate, both in the tropics and elsewhere.

The importance of convective clouds (both cumulus and cumulo-nimbus) in the tropics has been known for some time; indeed an adequate understanding of these processes is fundamental to the study of tropical meteorology. The effect that large groups of cumulus clouds exert on the broad-scale flow patterns is an important physical factor that has to be taken into account in modern studies of the dynamics of tropical weather patterns. To represent this adequately in numerical models, it is necessary to understand the structure and mechanism of formation of individual clouds. This work constitutes a major part of the research program of the DIVISION OF CLOUD PHYSICS.

In one study of the tropical environment, conducted off the coast of Queensland, the Division has used its specially instrumented aircraft to measure the transfer of heat and moisture from the surface of the tropical ocean to the air. The measurements have been made during both fair weather and disturbed conditions.

Laboratory models are also being used by the DIVISION OF ATMOSPHERIC PHYSICS to simulate atmospheric movements on a measurable scale, and have proved to be one of the few successful ways of understanding the effects that the virtual absence at low latitudes of a 'Coriolis force' has on the dynamics of the tropical atmosphere. In temperate climates the 'Coriolis force' plays an important part in the formation of rain-bearing depressions. For the laboratory models, water tanks are used, where layers of salt solution simulate the changes of density with height, and spinning simulates the earth's rotation.

Recently, an experiment with laboratory models to investigate the transfer of energy in a rotating fluid like the earth's atmosphere showed quite clearly that angular momentum—a form of energy associated with rotating bodies—can be conveyed through the atmosphere by the type of convection that gives rise to cumulus clouds. This finding has important implications in the formation of tropical cyclones as angular momentum, generated by the earth's rotation and concentrated by convection, could provide the energy needed to initiate the vortex of a cyclone.

This idea is now being investigated along two lines. Firstly, the process of energy transfer has been incorporated into numerical models and, secondly, the case histories and satellite photographs of individual tropical cyclones are being studied in order to determine whether convection could have played a part in their creation. Again, the geostationary satellite will provide very useful information since differences in temperature, observed by infrared imagery, should show up deep convective towers in contrast to overlying cirrus and shallow convection clouds with a clarity not previously possible.

CSIRO is actively participating in the Global Atmospheric Research Programme (GARP) sponsored by the International Council of Scientific Unions and the World Meteorological Organisation in which the first global observing experiment planned for 1978–79 will pay special attention to the tropical regions. The DIVISIONS OF ATMOSPHERIC PHYSICS and FISHERIES AND OCEANOGRAPHY are developing ocean-going buoys for monitoring variables such as sea and air temperatures and wind speeds. After transmission via satellite to the United States of America for processing, the data will be returned to Australia for analysis. Scientists at these Divisions hope to use this information to study such processes as the interchange of heat between the ocean and the atmosphere, and turbulence and evaporation over the ocean.

Aids for planners

Computer-based systems have been developed to help urban and regional planners evaluate alternative courses of action.

Planners—whether considering the location of new towns, the development of a region, or the design of multi-storey buildings—need access to the right kind of information if they are to evaluate alternative proposals properly.

To assist planners in their decision making, the DIVISION OF BUILDING RESEARCH has developed a general planning model that can be adapted to plan any system ranging from buildings to cities and even large regions. Known as TOPAZ—Technique for Optimal Placement of Activities in Zones—the model takes into account the significant factors that apply to a particular planning problem and uses a computer to study the interactions between them. For an urban system these factors could be secondary industry, transportation, and utilities, which interact through the movement of people, goods, water, power, sewage, and so on.

The planner programs the computer for specific goals based on assessments of community needs. The goals might include such factors as the distances people have to travel to and from work and the effects of industries on the living environment. When the needs are not clear, TOPAZ can show how one decision can affect the prospects of achieving other goals.

TOPAZ is being used by the Division in an urban study of alternative development corridors for the expansion of Melbourne to a population of 4·5 million by the year 2000. The study evaluates proposals by interested action groups and examines the effect of different population growth rates.

At the request of the State Planning Authority of New South Wales, the Division has used TOPAZ to investigate alternative development strategies to cater for a five-fold population increase within the Gosford–Wyong region by the end of the century. The system has also been applied to urban and regional planning studies of Blacksburg in the United States and Darwin, as well as to the location of hospital facilities in and around Sydney.

TOPAZ can also be used to solve general layout problems in multi-storey or industrial buildings. It has, for example, been used in planning redevelopment of the Royal Melbourne Institute of Technology and the State University at Blacksburg in order to minimize overall rebuilding and operating costs.

The DIVISION OF BUILDING RESEARCH has devised submodels of TOPAZ to deal with various social and environmental matters. One submodel covers the generation and diffusion of air pollution from industry and traffic. Another deals with the benefits and drawbacks from a variety of viewpoints including environmental impact, travel time and cost of different forms of public and private transport.

Factors which influence the siting of buildings, roadways, tunnels, and so on include the engineering properties of the underlying soil and rock, the slope of the land, and patterns of drainage. The DIVISION OF APPLIED GEOMECHANICS has therefore developed a system for classifying land on the basis of characteristics such as these. Known as PUCE—an acronym for Pattern Unit Component Evaluation—it is based on a combination of interpreting aerial photographs of an area and carrying out on-site tests. This enables the terrain features of the area to be mapped in varying degrees of detail.

PUCE was tested and used some 10 years ago to plan beef roads in Queensland and the Northern Territory. Later, at the request of the Town and Country Planning Board of Victoria, it was used to help with the planning of Melbourne and its environs. Areas in the Port Philip District were eventually chosen for urban development partly as a result of this work.

More recently the Division has applied this technique of terrain analysis to the Albury–Wodonga region. The whole designated development area was analysed and assessed for various land uses. Areas chosen for urban development were then analysed in more detail for various types of development such as large city buildings, a university, parks and gardens, communication and service paths, and housing locations. Large-scale maps were prepared to assist with the choice of types of development.

PUCE has also been used by the Division to advise the former Cities Commission and the Moreton Region Strategy Investigation on specified engineering aspects of development of the Moreton Region around Brisbane.

The Division has completed the development phase of PUCE and demonstrated its applicability to a wide range of situations. The system is now ready for commercial application.

Another approach to assisting planners is represented by the 'South Coast Project' undertaken by the DIVISION OF LAND USE RESEARCH. As a result of this survey, begun in 1972, the Division has investigated methods of collecting all the different sorts of information that might be of use to regional planners. The Division has also devised methods of storing this information, and of displaying it in a convenient and flexible form by means of computers.

An area of the South Coast of New South Wales was divided into nearly 4000 units. Air-photo interpretation and field surveys of each unit were then used to provide information of a biological and physical nature, while existing statistics and interviews supplied the necessary information on economic and social aspects of the unit. The units were also studied for various possible land uses.

All the information has been stored in a computer data bank and can be made available to planners in map form once they have indicated their requirements. Now that this planning aid has been established, the Division is seeking ways of modifying and improving the system.

Quasar pairs

Pairs of quasars have been discovered in which the members of each pair have different red shifts.

In 1962, shortly after the radio telescope at Parkes, N.S.W., had been commissioned, researchers from the DIVISION OF RADIOPHYSICS and the University of Sydney used the eclipse of the radio source 3C 273 by the Moon to establish the source's position so accurately that astronomers at Mount Palomar Observatory in the United States of America were able to identify it on their photographs.

Up to this time many of the stronger radio sources outside the Milky Way had been identified with galaxies, but the photographs showed that 3C 273 was not a galaxy; it was small and star-like and so was named a 'quasi-stellar object' (QSO) or 'quasar'.

When astronomers at Mount Palomar measured the optical spectrum of 3C 273 they were astonished by the size of the red shift of the spectral lines. The red shift is attributed to the speed at which an object moving away from the observer and, according to Hubble's Law, the greater the red shift the further away is the object. By Hubble's Law, 3C 273 was about two thousand million kilometres distant and moving away at 0·15 times the speed of light. At the time this was considered extraordinary, because for an object as distant as this to be seen at all, it would have to be emitting light of an intensity equivalent to ten million million stars like the Sun or a hundred normal galaxies, yet measurements showed that the object was a million times smaller than a single galaxy.

Since then scientists at the Division have led the world in the investigation of quasars, discovering some 550 to date, i.e. considerably more than half the total number catalogued. For all these the data are consistent with those for 3C 273 with red shifts as high as 0·9 times the speed of light and emissions of almost unbelievable energy for their size.

The magnitude of the energy emitted can be appreciated by considering that a hundred galaxies converting hydrogen to helium throughout their entire life span put out a comparable amount of energy, some 10^{65} ergs. With a quasar, this whole nuclear process is contained in an object with the tiny dimensions of a single star—a seemingly impossible situation. Some theorists have suggested that the source of energy in a quasar is gravitational, not nuclear, but the problem remains unsolved.

Recently, scientists at the Division, working with astronomers from the Anglo-Australian Observatory and the United Kingdom Science Research Council at Siding Spring Mountain, N.S.W., and from overseas, have discovered the existence of pairs of quasi-stellar objects in which one of the pair is a normal radio quasar emitting both light and radio waves and the other is non-radio, emitting only light. In a number of cases the non-radio component was confirmed as being a quasar in nature by spectroscopic observations.

The most intriguing feature of the pairs examined so far is that the two members of each pair have different red shifts. In the most extreme case the difference is so large that the two members are moving away at speeds differing by almost a third of the speed of light.

The pairing of quasars seems to be statistically significant, but a far larger sample will be needed to establish the significance beyond doubt. If indeed they are true pairs, they could cause a revolution in astrophysical thinking: the discordant red shifts would cause great doubts about the cosmological origin of the red shifts of quasars and perhaps the whole question of universal gravitation would have to be reexamined.

Finance and Buildings

General

The table below summarizes the sources of CSIRO funds for 1975/76 and the categories of expenditure. Some 82% of CSIRO's income for the year was provided directly by the Commonwealth Government. Of the remaining 18%, two-thirds was contributed from trust funds concerned with various primary industries. Most of these funds are derived from a statutory levy on produce with a supporting contribution from the Commonwealth Government.

During 1975/76 CSIRO spent \$98·8 million of Treasury funds on salaries and general running expenses, an increase of \$14·4 million over the previous year's expenditure.

About \$7·6 million, or slightly more

Source of funds	Salaries and general running expenses ($)	Grants for studentships and grants to outside bodies ($)	Capital works and services and major items of equipment ($)	Total ($)
Treasury appropriation, including revenue	98,814,973	3,552,574	2,306,100	104,673,647
Wool Research Trust Fund	11,484,663	—	313,947	11,798,610
Meat Research Trust Account	2,505,972	—	40,209	2,546,181
Tobacco Industry Trust Account	34,967	—	—	34,967
Dairy Produce Research Trust Account	252,576	—	—	252,576
Wheat Research Trust Account	238,995	—	4,197	243,192
Fishing Industry Research Trust Account	140,968	—	85,000	225,968
Dried Fruits Research Trust Account	41,688	—	—	41,688
Chicken Meat Research Trust Account	170	—	—	170
Pig Industry Research Trust Account	11,634	—	—	11,634
Poultry Research Trust Account	—	—	890	890
Other contributors	4,519,758	—	3,791,344	8,311,102
Total	118,046,364	3,552,574	6,541,687	128,140,625

than half of the increase, was absorbed by salary adjustments arising from arbitration determinations and by increments, reclassifications and other inescapable commitments in the nature of salary. A further \$3·9 million was absorbed in offsetting increased costs of goods and services resulting from price rises and the occupation of new accommodation, and \$2·9 million was spent on salaries and operating expenses by the DIVISION OF FOREST RESEARCH which was established on 1 July 1975.

In addition to the money that CSIRO received from the Government, from industry and other contributors, some \$19·2 million was spent by the Department of Construction and by the Department of Administrative Services on buildings and other works for CSIRO, and on the acquisition of land.

In essence, the 1975/76 Treasury appropriation enabled the Treasury-funded component of the Organization's research activities to continue at approximately the same level as in 1974/75. However, in the case of those research activities funded by primary industry trust funds, inescapable increases in salaries and operating

The 355-tonne research vessel *Courageous* was chartered by CSIRO in September 1975 for an initial period of 3 years. The vessel is being operated by the DIVISION OF FISHERIES AND OCEANOGRAPHY as a fisheries resources survey vessel. In addition to standard commercial bottom and midwater trawling gear, she is fitted with advanced equipment including echo-sounders whose signals are interpreted by an on-board computer to estimate the total weight, number and size of fish beneath the vessel. The *Courageous* is also collecting oceanographic data to assess the environmental requirements of different species of fish.

costs arising from inflation made it impossible to maintain these activities at their previous level.

During the year the Executive redeployed some 238 positions and \$1·5 m of operating funds. This program of redeployment was aimed in part at reducing CSIRO's dependence upon the Wool Research Trust Fund. It also enabled some expansion of activities in high priority areas such as human nutrition, fisheries and oceanography, forestry, and minerals and energy.

Buildings

Owing to the Government's policy of financial restraint during 1975/76, most building projects were deferred and no major contracts were let during the year.

The National Measurement Laboratory at Bradfield Park, Sydney, by far the largest single construction program undertaken by CSIRO, continued to progress and is expected to be completed during 1977. Some preliminary work on the Australian National Animal Health Laboratory, Geelong, has been undertaken, but major work on the site has not yet commenced.

Work is proceeding satisfactorily on the Centre for Animal Research and Development near Bogor, West Java. This project is being undertaken by CSIRO in conjunction with the Australian Development Aid Agency.

Major projects completed during the year include:

FISHERIES AND OCEANOGRAPHY—Fisheries laboratory at Cleveland, Brisbane—\$1,797,000.

COMPUTING RESEARCH—Alterations and extensions to Black Mountain Laboratory, Canberra. A contract in three stages was let in 1974/75 for \$1,507,000. The first two stages were completed during 1975/76. Stage 3 will be completed during 1976/77.

ANIMAL HEALTH—Insect-proof, large animal accommodation at Indooroopilly, Brisbane—\$819,000.

FOREST RESEARCH—Library at Yarralumla, Canberra—\$334,000.

FOOD RESEARCH—Environmental growth cabinet building at North Ryde, Sydney—\$140,000.

ANIMAL PRODUCTION—Carcass incinerator at Prospect, Sydney—\$88,000.

Annual Expenditure

The following summary gives details of expenditure by CSIRO Divisions and other Units on other than capital items from 1 July 1975 to 30 June 1976.

DIVISION OR UNIT	Treasury funds ($)	Contributory funds ($)	Total ($)
Head Office			
The main items of expenditure under this heading are salaries and travelling expenses of the administrative staff at Head Office and the Regional Administrative Offices, salaries and expenses of officers at the Liaison Offices in London, Washington, Moscow and Tokyo, and general office expenditure.	8,099,284	52,120	8,151,404
Research Programs			
Animal Health and Reproduction			
Animal Production; Molecular and Cellular Biology Unit *	3,617,715	3,566,971	7,184,686
Animal Health	3,748,369	1,023,693	4,772,062
Human Nutrition	999,699	195,480	1,195,179
Centre for Animal Research and Development—Indonesia	—	4,420,419	4,420,419
Plant Industry	5,783,298	655,323	6,438,621
Entomology and Wildlife			
Entomology	4,452,198	1,281,240	5,733,438
Wildlife Research	1,766,196	611,956	2,378,152
Horticulture and Irrigation			
Horticultural Research	1,279,400	60,730	1,340,130
Irrigation Research	1,072,997	73,537	1,146,534
Tropical Crops and Pastures	3,878,298	935,869	4,814,167
Land Resources			
Soils	3,340,197	76,172	3,416,369
Land Use Research	2,231,908	344,761	2,576,669
Agro-Industrial Research Unit	114,243	—	114,243
Land Resources Management	2,411,725	692,117	3,103,842
Forest Research	2,903,215	25,958	2,929,173
Processing of Agricultural Products			
Food Research	4,477,549	1,083,887	5,561,436
Wheat Research	119,946	121,488	241,434
Textile Industry	188,183	2,715,023	2,903,206
Textile Physics	130,700	1,824,174	1,954,874
Protein Chemistry	484,099	1,605,652	2,089,751
Fisheries and Oceanography			
Fisheries and Oceanography	4,504,626	332,985	4,837,611
Marine Biochemistry Unit	111,269	—	111,269
Chemical Research of Industrial Interest			
Applied Organic Chemistry (including Microanalytical Laboratory)	2,016,371	220,668	2,237,039
Chemical Physics	1,970,099	890	1,970,989
Chemical Technology	1,952,898	162,033	2,114,931
Minerals and Solar Energy Research			
Mineral Research Laboratory, Clayton	1,536,697	20,883	1,557,580
Mineral Research Laboratory, Port Melbourne	2,382,699	117,535	2,500,234
Mineral Research Laboratory, Floreat Park	857,698	12,676	870,374
Mineral Research Laboratory, North Ryde	3,632,526	183,351	3,815,877
Baas Becking Geobiological Group	13,400	52,310	65,710
Solar Energy Studies Unit	98,834		98,834

DIVISION OR UNIT	**Treasury funds ($)**	**Contributory funds ($)**	**Total ($)**
Physical Research of Industrial Interest			
National Measurement Laboratory	5,810,400	—	5,810,400
General Physical Research			
Radiophysics	3,367,092	193,915	3,561,007
Atmospheric Physics	1,633,400	16,623	1,650,023
Cloud Physics	903,193	515	903,708
Environmental Mechanics	517,899	8,140	526,039
Australian Numerical Meteorological Research Centre	239,443	—	239,443
General Industrial Research			
Building Research	4,387,899	78,051	4,465,950
Tribophysics	1,918,900	30,159	1,949,059
Applied Geomechanics	1,382,907	207,790	1,590,697
Mechanical Engineering	1,441,599	157,933	1,599,532
Research Services			
Computing Research	666,876	234	667,110
Mathematics and Statistics	1,856,098	53	1,856,151
Western Australian Administration	300,799	—	300,799
Extra-mural Grants	198,520	—	198,520
Australian Mineral Development Laboratories	80,000	—	80,000
Developmental projects	169,000	—	169,000
Information and Publications			
Central Information, Library and Editorial Services	2,577,765	—	2,577,765
Film and Video Centre	180,592	—	180,592
Miscellaneous	1,006,255	303,663	1,309,918
Grants			
Research Associations	771,526	—	771,526
Research Studentships	428,048	—	428,048
Other grants and contributions	2,353,000	—	2,353,000
Total expenditure	**102,367,547**	**23,466,977**	**125,834,524**

* Following a reorganization of the Animal Research Divisions in November 1975, the above Division and Unit were formed from the previous Divisions of Animal Physiology and Animal Genetics. This also refers to the statement of 'Capital Expenditure under CSIRO Control' on page 58.

General Revenue

During 1975/76 general revenue amounting to $797,593 was received by the Organization. Details of receipts are as follows:

	$
Sale of publications	133,583
Receipts in respect of expenditure of former years	194,124
Sale of produce, including livestock	141,710
Royalties from patents	139,024†
Testing fees	67,699
Miscellaneous receipts	121,453
Total	**797,593**

Of the above sum $647,792 was spent during 1975/76. This expenditure was approved by the Minister for Science and the Treasurer as part of the general estimates.

† A further $166,328 was received as royalties on CSIRO patents and was paid to the Department of Agriculture for credit to the Wool Research Trust Fund. The patent royalties included $156,919 for the self-twist spinning machine.

Capital Expenditure under CSIRO Control

The table which follows shows capital expenditure from funds made available directly to CSIRO. It includes expenditure on capital and developmental works and on items of equipment costing more than $15,000 each.

DIVISION OR UNIT	Treasury funds ($)	Contributory funds ($)	Total ($)
Head Office	16,397	—	16,397
Animal Health and Reproduction			
Animal Production Molecular and Cellular Biology Unit	53,671	111,727	165,398
Animal Health	82,204	18,704	100,908
Human Nutrition	35,797	—	35,797
Centre for Animal Research and Development—Indonesia	—	3,510,000	3,510,000
Plant Industry	43,830	4,041	47,871
Entomology and Wildlife			
Entomology	50,312	35,810	86,122
Wildlife Research	72,647	—	72,647
Horticulture and Irrigation			
Horticultural Research	11,682	2,947	14,629
Irrigation Research	32,854	—	32,854
Tropical Crops and Pastures	126,974	76,307	203,281
Land Resources			
Soils	49,453	—	49,453
Land Use Research	376	—	376
Land Resources Management	50,123	15,673	65,796
Processing of Agricultural Products			
Food Research	29,962	—	29,962
Wheat Research	26,919	—	26,919
Textile Industry	—	88,022	88,022
Textile Physics	21,861	71,072	92,933
Protein Chemistry	2,994	26,055	29,049
Fisheries and Oceanography			
Fisheries and Oceanography	259,764	235,000	494,764
Marine Biochemistry Unit	30,695	—	30,695
Chemical Research of Industrial Interest			
Applied Organic Chemistry	57,351	—	57,351
Chemical Physics	37,253	—	37,253
Chemical Technology	49,028	—	49,028
Minerals and Solar Energy Research			
Mineral Research Laboratory, Clayton	2,728	—	2,728
Mineral Research Laboratory, Port Melbourne	9,673	—	9,673
Mineral Research Laboratory, North Ryde	157,538	—	157,538
Physical Research of Industrial Interest			
National Measurement Laboratory	86,674	—	86,674
General Physical Research			
Radiophysics	62,939	—	62,939
Atmospheric Physics	95,517	—	95,517
General Industrial Research			
Building Research	65,218	—	65,218
Tribophysics	2,486	—	2,486
Applied Geomechanics	90,755	—	90,755
Mechanical Engineering	44,950	21,536	66,486
Research Services			
Computing Research	486,777	—	486,777
Western Australian Administration	1,326	—	1,326
Information and Publications			
Central Information, Library and Editorial Services	3,207	—	3,207
Miscellaneous	9,879	18,693	28,572
Central Administration—Indooroopilly	44,287	—	44,287
Total capital expenditure	**2,306,101**	**4,235,587**	**6,541,688**

AUDITOR-GENERAL'S OFFICE
Prudential Building, University Avenue,
Canberra City, A.C.T. 2601
17 August 1976

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

Dear Sir,

Commonwealth Scientific and Industrial Research Organization

In compliance with Section 30(2) of the Science and Industry Research Act 1949, financial statements of the Commonwealth Scientific and Industrial Research Organization for the year ended 30 June 1976 have been submitted for my report. These comprise—

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

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

I now report in accordance with section 30(2) of the Act that in my opinion—

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

Yours faithfully,

(Sgd) D. R. STEELE CRAIK

(D. R. STEELE CRAIK)
AUDITOR-GENERAL

Summary of Receipts and Payments

	Funds held 1 July 1975 ($)	Receipts ($)	Total funds available ($)	Payments ($)	Funds held 30 June 1976 ($)
Special Account					
Parliamentary Appropriation: Operational	—	101,670,000.00	101,670,000.00	101,669,754.62	245.38
	(—)*	(86,622,000.00)	(86,622,000.00)	(86,622,000.00)	—
Parliamentary Appropriation: Capital	264,047.17	2,268,000.00	2,532,047.17	2,306,100.80	225,946.37
	(116,457.81)	(2,480,000.00)	(2,596,457.81)	(2,332,410.64)	(264,047.17)
Revenue and Other Receipts	129,449.29	797,592.84	927,042.13	697,791.97	229,250.16
	(217,999.79)	(672,665.77)	(890,665.56)	(761,216.27)	(129,449.29)
Total: Special Account	393,496.46	104,735,592.84	105,129,089.30	104,673,647.39	455,441.91
	(334,457.60)	(89,774,665.77)	(90,109,123.37)	(89,715,626.91)	(393,496.46)
Specific Research Account	2,059,077.95	24,413,821.29	26,472,899.24	23,466,976.61	3,005,922.63†
	(1,830,292.46)	(19,137,255.18)	(20,967,547.64)	(18,908,469.69)	(2,059,077.95)
Other Trust Moneys‡	151,456.31	1,678,459.14	1,829,915.45	1,562,489.04	267,426.41
	(195,410.22)	(1,504,180.01)	(1,699,590.23)	(1,548,133.92)	(151,456.31)
Cafeteria Account§	1,965.90	47,611.91	49,577.81	43,675.00	5,902.81
	(6,569.11)	(52,149.76)	(58,718.87)	(56,752.97)	(1,965.90)
Total	**2,605,996.62**	**130,875,485.18**	**133,481,481.80**	**129,746,788.04**	**3,734,693.76**
	(2,366,729.39)	**(110,468,250.72)**	**(112,834,980.11)**	**(110,228,983.49)**	**(2,605,996.62)**

* Figures in brackets refer to 1974/75 financial year.
† Includes investments totalling $171,200.00.
‡ Moneys held temporarily on behalf of other organizations and individuals.
§ Operating receipts and expenses of CSIRO cafeteria at Melbourne.

J. R. Price (*Chairman*)

R. W. Viney (*Senior Assistant Secretary, Finance and Properties*)

Consolidated Statement of Payments

1974/75 ($)		1975/76 ($)
	Head Office (including Regional Administrative Offices)	
5,177,081	Salaries and allowances	5,962,401
342,777	Travelling and subsistence	277,461
428,430	Postage, telegrams and telephone	521,217
1,091,363	Incidental and other expenditure	1,390,325
7,039,651		8,151,404
	Research Programs	
	Agricultural research	
12,360,149	Animal health and reproduction	13,931,914
5,818,264	Plant industry	6,434,580
7,044,106	Entomology and wildlife	8,075,780
2,127,521	Horticulture and irrigation	2,483,717
4,435,091	Tropical crops and pastures	4,737,860
8,282,943	Land resources	9,195,449
—	Forest research	2,929,173
11,295,621	Processing of agricultural products	12,565,552
3,883,480	Fisheries and oceanography	4,713,880
5,605,148	Chemical research of industrial interest	6,322,960
7,707,711	Mineral and solar energy research	8,908,609
5,168,499	Physical research of industrial interest	5,810,400
5,985,105	General physical research	6,880,220
8,585,666	General industrial research	9,583,703
2,970,721	Research services	3,271,579
2,389,630	Information and publications	2,758,357
991,120	Miscellaneous	1,291,225
94,650,775		109,894,958
	Grants	
676,085	Research associations	771,526
362,599	Research studentships	428,048
1,889,400	Other grants and contributions	2,353,000
2,928,084		3,552,574
	Capital Works and Services	
1,876,600	Buildings, works, plant and developmental expenditure	4,664,677
1,595,979	Major items of laboratory equipment	1,323,772
453,007	Expansion of CSIRO computer network	443,239
80,000	Construction of research vessel	110,000
4,005,586		6,541,688
	Other Trust Moneys	
554,637	Remittance of revenue from investigations financed from Industry Trust Accounts	580,313
993,497	Other miscellaneous remittances	982,176
1,548,134		1,562,489

1974/75 ($)		1975/76 ($)
	Cafeteria Account	
56,753	Operating expenses of CSIRO cafeteria at Melbourne	43,675
56,753		43,675
110,228,983	**Total Expenditure**	**129,746,788**

J. R. Price (*Chairman*)

R. W. Viney (*Senior Assistant Secretary, Finance and Properties*)

Statement of Payments—Special Account*

1974/75 ($)		1975/76 ($)
	Head Office (including Regional Administrative Offices)	
5,172,882	Salaries and allowances	5,949,754
342,663	Travelling and subsistence	277,461
428,430	Postage, telegrams and telephone	521,217
1,079,122	Incidental and other expenditure	1,350,852
7,023,097		8,099,284
	Research Programs	
	Agricultural research	
7,506,551	Animal health and reproduction	8,365,783
5,209,799	Plant industry	5,783,298
5,488,689	Entomology and wildlife	6,218,394
2,014,697	Horticulture and irrigation	2,352,397
3,350,600	Tropical crops and pastures	3,878,298
7,329,307	Land resources	8,098,073
—	Forest research	2,903,215
4,771,949	Processing of agricultural products	5,400,477
3,671,198	Fisheries and oceanography	4,615,895
5,293,407	Chemical research of industrial interest	5,939,368
7,403,670	Mineral and solar energy research	8,521,854
5,168,499	Physical research of industrial interest	5,810,400
5,844,786	General physical research	6,661,027
8,209,144	General industrial research	9,131,305
2,970,632	Research services	3,271,293
2,387,696	Information and publications	2,758,357
811,411	Miscellaneous	1,006,255
77,432,035		90,715,689
	Grants	
676,085	Research associations	771,526
362,599	Research studentships	428,048
1,889,400	Other grants and contributions	2,353,000
2,928,084		3,552,574
	Capital Works and Services	
529,997	Buildings, works, plant and developmental expenditure	599,919
1,269,797	Major items of laboratory equipment	1,152,943
452,616	Expansion of CSIRO computer network	443,239
80,000	Construction of research vessel	110,000
2,332,410		2,306,101
89,715,626	**Total Expenditure**	**104,673,648**

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

J. R. Price (*Chairman*)

R. W. Viney (*Senior Assistant Secretary, Finance and Properties*)

Statement of Payments—Specific Research Account

1974/75 ($)		1975/76 ($)
	Head Office (including Regional Administrative Offices)	
4,199	Salaries and allowances	12,647
114	Travelling and subsistence	—
—	Postage, telegrams and telephone	—
12,241	Incidental and other expenditure	39,473
16,554		52,120
	Research Programs	
	Agricultural research	
4,853,598	Animal health and reproduction	5,566,131
608,465	Plant industry	651,282
1,555,417	Entomology and wildlife	1,857,386
112,824	Horticulture and irrigation	131,320
1,084,491	Tropical crops and pastures	859,562
953,636	Land resources	1,097,376
—	Forest research	25,958
6,523,672	Processing of agricultural products	7,165,075
212,282	Fisheries and oceanography	97,985
311,741	Chemical research of industrial interest	383,592
304,041	Mineral and solar energy research	386,755
—	Physical research of industrial interest	—
140,319	General physical research	219,193
376,522	General industrial research	452,398
89	Research services	286
1,934	Information and publications	—
179,709	Miscellaneous	284,970
17,218,740		19,179,269
	Capital Works and Services	
1,346,603	Buildings, works, plant and developmental expenditure	4,064,758
326,182	Major items of laboratory equipment	170,829
391	Expansion of CSIRO computer network	—
1,673,176		4,235,587
18,908,470	**Total Expenditure**	**23,466,976**

J. R. Price (*Chairman*)

R. W. Viney (*Senior Assistant Secretary, Finance and Properties*)

Research Activities

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

ANIMAL HEALTH

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

ANIMAL PRODUCTION

Physiology, endocrinology, nutrition and ecology of sheep and cattle in relation to reproductive performance and improvements in the efficiency of meat and wool production; efficient use of fertilizers and mineral supplements in animal enterprises; control of metabolic disorders in grazing ruminants; use of chemical methods for defleecing sheep. Genetics and its application to Australia's animal industries; genetics and the improvement of beef cattle, dairy cattle, sheep and poultry through breeding and selection.
Sydney, with a Genetics Laboratory at North Ryde, Sydney, the Pastoral Research Laboratory, Armidale, N.S.W., the Cattle Breeding Laboratory, Rockhampton, Qld, the Bloat Research Unit, Melbourne, the Beef Cattle Research Unit, Townsville, Qld, the Dairy Cattle Unit, Wollongbar, N.S.W., and research properties at Armidale and Badgery's Creek, N.S.W., and Rockhampton, Qld.

APPLIED GEOMECHANICS

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

APPLIED ORGANIC CHEMISTRY

Application of chemistry to problems of national and industrial importance with particular interest in biological organic chemistry, polymer science, and energy and environmental studies. Investigations into the application of organic chemistry to animal husbandry problems; chemical agents for improved primary product storage; chemical control of insects and ticks; chemical storage of solar energy; smoke pollution; water pollution by heavy metals; development of specialized polymers; surface science; useful chemicals from coal.
Melbourne.

ATMOSPHERIC PHYSICS

Physical and chemical atmospheric processes that underlie and control the weather and climate, and that are responsible for the distribution of airborne material including gases. Research into those aspects of the oceans that affect the atmosphere. Methods include field work, theoretical studies, laboratory and numerical models, and analyses of observations on a local, regional and global scale.
Melbourne.

BUILDING RESEARCH

Development of the built environment,

community planning and urban design; systems research; physical performance of buildings in relation to the well-being of occupants; building operations and economics; structural design and engineering; conversion of forest products for the production of wood-based building elements; design and improvement of building components and systems; development, processing and properties of building materials.
Melbourne.

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

CHEMICAL ENGINEERING
For research activities, see Minerals Research Laboratories.
Melbourne.

CHEMICAL TECHNOLOGY
Application of chemical technology and particularly polymer technology to developing ways whereby Australia's renewable and recycling resources can be more effectively utilized and protected. Investigations include fractionation of plants to produce fibre in conjunction with protein and other marketable products; studies of pulp and paper and the use of cellulose materials in packaging, writing, printing and building products; assessment of the technological potential of forest resources; technology of purifying and recycling water; energy storage; and recycling and bioenergetics.
Melbourne.

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

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

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

ENVIRONMENTAL MECHANICS
Transfer processes in the natural environment (physical interactions between soils, plants and the lowest layers of the atmosphere involving the

exchange of energy, water and carbon dioxide) and their effect on plant growth; mathematical and physical aspects of ecology.
Canberra.

FISHERIES AND OCEANOGRAPHY

Survey and appraisal of certain marine fishery resources including rock lobsters, prawns and pelagic fisheries of the south-eastern area of Australia; biology of the western rock lobster and prawn species of commercial importance; biological, chemical and physical oceanography of south-east Indian Ocean and south-west Pacific Ocean; studies on the dynamics of Australian estuarine ecosystems.
Sydney, with regional laboratories in Brisbane and Perth, and a field laboratory at Karumba, Qld.

FOOD RESEARCH

Properties, preservation, processing, packaging, storage and transport of foods in relation to quality at the consumer level; microbial physiology and methodology; membrane structure and biochemistry; identification and evaluation of flavours; plant physiology; polyunsaturated meat and dairy products; new protein and dairy foods; treatment and utilization of processing wastes.
Sydney, with the Meat Research Laboratory, Brisbane, Dairy Research Laboratory, Melbourne, Tasmanian Food Research Unit, Hobart.

FOREST RESEARCH

Studies, especially of a long-term nature, in fields such as resource assessment and management; forest production—taxonomy, genetics, ecology, nutrition, physiology and hydrology; tree pests and diseases; fire control; harvesting.
Canberra, with laboratories in Darwin, Hobart, Perth, Atherton, Qld, Traralgon, Vic., and Mt Gambier, S.A.

HORTICULTURAL RESEARCH

Introduction and adaptation of fruit crops to Australian environments; breeding of wine and drying grapes; management of fruit trees and grapevines including effects of nematodes, viruses and salinity; processing of dried grapes; physiology and biochemistry of horticultural plants; domestication of Australian native plants.
Adelaide, with a laboratory and field station at Merbein, Vic., and a laboratory at Hobart.

HUMAN NUTRITION

The study of nutritional processes directed towards an understanding of related human disorders. Epidemiological studies of human nutrition in the social environment. Biochemical and physiological investigations into protein metabolism and malnutrition; digestion and absorption of foodstuffs; efficiency of food utilization relevant to obesity. Aspects of inorganic nutrition, particularly trace element metabolism, and iodine deficiency in relation to brain development.
Adelaide.

IRRIGATION RESEARCH

Crop growth, management and quality of irrigated crops, especially vegetables and oil-seed crops; water quality and management in irrigation; environmental plant physiology, and biochemistry and engineering aspects of intensive crop production.
Griffith, N.S.W.

LAND RESOURCES MANAGEMENT

Development of the principles of land resources management for efficient productivity consistent with conservation; environmental implications of land use in pastoral, agricultural, forested and near-urban areas; development of methods of processing and communi-

cating data to assist land-use decision making.
Perth, with laboratories at Deniliquin, N.S.W., and Alice Springs, N.T., and field stations at Baker's Hill, W.A., and Deniliquin, N.S.W.

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

MATHEMATICS AND STATISTICS
Mathematical modelling and statistical analysis of data in the agricultural, biomathematical, environmental, physical and industrial fields. In addition to its consultative services to other CSIRO Divisions and outside bodies on mathematical and statistical problems, the Division conducts a sizeable amount of basic research.
Canberra, with officers stationed at Adelaide, Brisbane, Hobart, Melbourne, Perth, Sydney, Armidale, N.S.W., and Townsville, Qld.

MECHANICAL ENGINEERING
Utilization of recoverable energy resources; engineering associated with agricultural crop production and storage; human environmental engineering and noise control; underwater engineering; transportation engineering.
Melbourne.

MINERAL CHEMISTRY
For research activities, see Minerals Research Laboratories.
Melbourne.

MINERALOGY
For research activities, see Minerals Research Laboratories.
Perth, with laboratories in Canberra and Sydney.

MINERAL PHYSICS
For research activities, see Minerals Research Laboratories.
Sydney, with a laboratory in Melbourne.

MINERALS RESEARCH LABORATORIES
Field and laboratory work to help indicate where useful mineral deposits might occur in Australia; development of search and localization techniques designed to provide direct evidence for the existence of oil and mineral deposits; the exploitation of properties of rocks and minerals to improve the efficiency of their mining, concentration and handling; the adaptation, improvement and control of methods for processing and treating mineral and other resources; the reduction, and possible utilization of solid, liquid and gaseous wastes from recovery and use of minerals, together with a study of atmospheric pollutants in urban and industrial environments; the assessment and utilization of fossil fuels in Australia, including the conversion of coal into solid, liquid and gaseous fuels, and the development of alternative processes for treatment of minerals and other materials designed to reduce the demand on scarce energy resources.

CERES, the Controlled Environment Research Laboratory of the DIVISION OF PLANT INDUSTRY, is widely used by research workers from other CSIRO Divisions, State Departments of Agriculture and universities, as well as by a number of visiting research workers from overseas. Here, a visiting scientist from Bangladesh is checking sorghum plants used in a grain ripening experiment in one of the glasshouse growth cabinets in CERES. These cabinets control temperature to within half a degree and can also be used to regulate day length.

Photograph: Colin Totterdell

Melbourne. The Minerals Research Laboratories comprise the Divisions of Chemical Engineering, Mineral Chemistry, Mineralogy, Mineral Physics and Process Technology. (For locations see separate entries.)

NATIONAL MEASUREMENT LABORATORY

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

PLANT INDUSTRY

Research in the plant sciences as a basis for the development and utilization of crops and pastures better adapted to Australian conditions; taxonomy and ecology of Australian vegetation.
Canberra, with a cotton research unit at Narrabri, N.S.W., ecology units at Brisbane, Waste Point and Broken Hill, N.S.W., and experiment stations at Canberra and Burren Junction, N.S.W.

PROCESS TECHNOLOGY

For research activities, see Minerals Research Laboratories.
Sydney.

PROTEIN CHEMISTRY

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

RADIOPHYSICS

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

SOILS

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

TEXTILE INDUSTRY

Development of new and improved methods and machinery for processing wool; development of new and improved textile products from wool; relationships between fleece properties and processing; new uses for wool; environmental studies; cotton processing.
Geelong, Vic.

TEXTILE PHYSICS

Development of methods of testing wool as an aid to marketing and manufacturing; physical properties and behaviour of wool and its products; processing studies; surface properties of materials.
Sydney.

TRIBOPHYSICS

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

TROPICAL CROPS AND PASTURES

Development of efficient systems for beef production in northern Australia (excluding arid zones); research on

some tropical field crops; agronomic research integrated with work on introduction, selection and breeding of new pasture and crop varieties; studies on pasture and crop nutrition, genetics, physiology and biochemistry, and on legume nodulation and animal nutrition.
Brisbane, with laboratories at Townsville and Lawes, Qld, and field stations at Beerwah, Mundubbera, Samford and Woodstock, Qld, Katherine, N.T., and Kununurra, W.A.

WILDLIFE RESEARCH
Biology of birds and mammals, both native and introduced, in relation to pest control and conservation. Species investigated include those which are clearly pests such as the rabbit and wild pig, those which are exploited such as waterfowl and quail, and those which need to be conserved.
Canberra, with laboratories at Darwin and Perth.

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

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

AUSTRALIAN NUMERICAL METEOROLOGY RESEARCH CENTRE
Studies of the behaviour of the earth's atmosphere, with emphasis on numerical techniques, directed towards improvement in the accuracy and time scale of weather forecasting and in understanding the distribution and variations of climate on the earth.
Melbourne. The Centre is jointly sponsored by CSIRO and the Department of Science.

CENTRE FOR ANIMAL RESEARCH AND DEVELOPMENT
Research on the nutrition, genetics, reproduction, heat tolerance and resistance to disease of poultry, cattle, buffalo and goats with the objective of improving the efficiency of livestock production in Indonesia.
Bogor, West Java, Indonesia.

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

MOLECULAR AND CELLULAR BIOLOGY UNIT
Molecular evolution of influenza virus; DNA breakage and repair and its application to the development of new antibiotic systems; mechanisms of differentiation and the properties of differentiation factors.
Sydney.

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

WHEAT RESEARCH UNIT
Structure and biochemistry of the wheat grain and relationship to flour quality; investigations into rapid methods of grain sampling and testing, including protein determination and wheat variety identification.
Sydney.

Organization

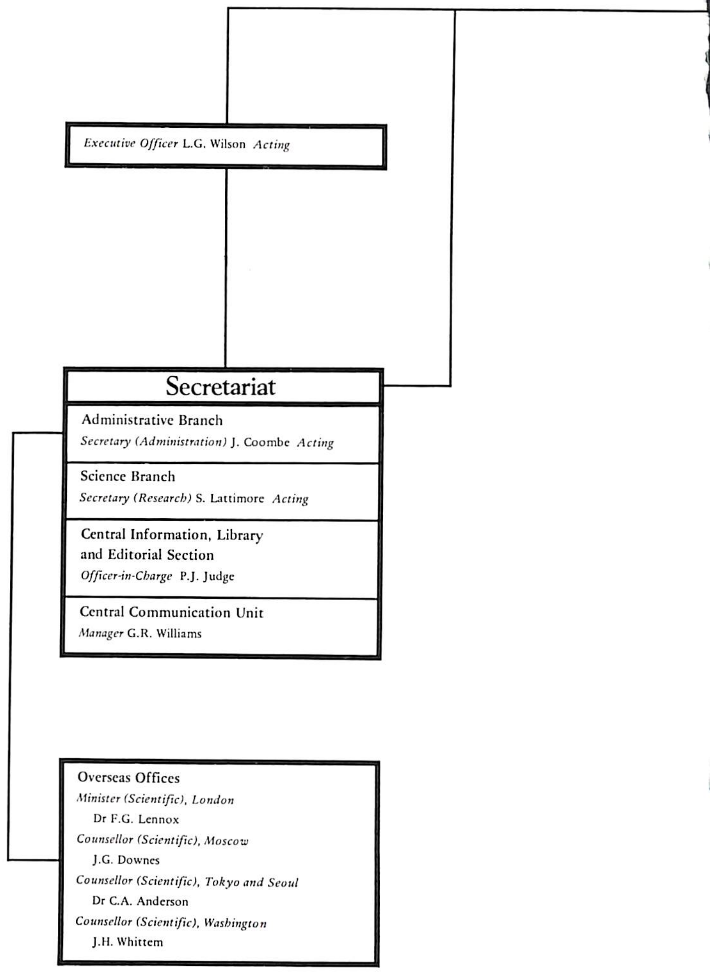
CSIRO has a total staff of some 7100 people located in more than 100 laboratories and field stations throughout Australia. About one-third of the staff are scientists.

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

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

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

The chart opposite shows the organizational structure of CSIRO as at 1 July 1976.



Executive

Chairman
Sir Robert Price

Members	*Part-time members*
V.D. Burgmann	Professor M.E. Holman
Dr A.E. Pierce	V.E. Jennings
Professor Emeritus, H.W. Worner	W.J. Vines
	Sir Frederick Wiltshire

Divisions and Chiefs

Animal Research Laboratories	
Animal Health	Dr A.K. Lascelles
Animal Production	Dr T.W. Scott
Applied Chemistry Laboratories	
Applied Organic Chemistry	Dr D.H. Solomon
Chemical Technology	Dr D.E. Weiss
Environmental Physics Research Laboratories	
Atmospheric Physics	Dr G.B. Tucker
Cloud Physics	J. Warner
Environmental Mechanics	Dr J.R. Philip
Land Resources Laboratories	
Land Resources Management	R.A. Perry
Land Use Research	Dr R.J. Millington
Soils	Dr A.E. Martin
Minerals Research Laboratories	
Chemical Engineering	Dr D.F. Kelsall
Mineral Chemistry	Dr D.F.A. Koch
Mineral Physics	Dr K.G. McCracken
Mineralogy	A.J. Gaskin
Process Technology	A.V. Bradshaw
Wool Research Laboratories	
Protein Chemistry	Dr W.G. Crewther
Textile Industry	Dr D.S. Taylor
Textile Physics	A.R. Haly *Acting*
Applied Geomechanics	Dr G.D. Aitchison
Building Research	Dr R.W.R. Muncey
Chemical Physics	Dr A.L.G. Rees
Computing Research	Dr G.N. Lance
Entomology	Dr D.F. Waterhouse
Fisheries and Oceanography	Dr K. Radway Allen
Food Research	M.V. Tracey
Forest Research	Dr M.F.C. Day
Horticultural Research	Dr J.V. Possingham
Human Nutrition	Dr B.S. Hetzel
Irrigation Research	E.R. Hoare
Mathematics and Statistics	Dr J.M. Gani
Mechanical Engineering	Dr B. Rawlings
Plant Industry	Dr L.T. Evans
Radiophysics	Dr J.P. Wild
Tribophysics	Dr J.R. Anderson
Tropical Crops and Pastures	Dr E.M. Hutton
Wildlife Research	Dr H.J. Frith
National Measurement Laboratory	F.J. Lehany *Director*

Units and Officers-in-Charge

Agro-industrial Research	G.A. Stewart
Marine Biochemistry	Dr G.F. Humphrey
Solar Energy Studies	R.N. Morse *Director*
Wheat Research	E.E. Bond
Australian Numerical Meteorology Research Centre	R.H. Clarke
Centre for Animal Research and Development	A.F. Gurnett-Smith
Molecular and Cellular Biology Unit	Dr G.W. Grigg *Acting*

Animal Research Laboratories Committee
Chairman Dr K.A. Ferguson

Applied Chemistry Laboratories Committee
Chairman Dr S.D. Hamann

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

Land Resources Laboratories Committee
Chairman Dr E.G. Hallsworth

Minerals Research Laboratories
Director I.E. Newnham

Wool Research Laboratories Committee
Chairman Dr D.S. Taylor

Advisory Council

Executive

Sir Robert Price, K.B.E., D.Phil., D.Sc., F.A.A. (*Chairman*)
V. D. Burgmann, B.Sc., B.E.
Professor M. E. Holman, M.Sc., D.Phil., D.Sc., F.A.A. (part-time)
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